Prepared in cooperation with
Eureka, Lander, and Nye Counties, Nevada and the
State of Nevada Department of Conservation and Natural Resources,
Division of Water Resources

Hydrogeologic Framework and Ground Water in Basin-Fill Deposits of the Diamond Valley Flow System, Central Nevada

Scientific Investigations Report 2006-5249

U.S. Department of the Interior
U.S. Geological Survey

Cover. View looking south from the north end of southern Monitor Valley. Top photo: cover of Rush, F.E. and Everett, D.E., 1964, Ground-water appraisal of Monitor, Antelope, and Kobeh Valleys, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources - Reconnaissance Report 30. Bottom photo: same view, 2006.

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U.S. Geological Survey
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Contents

Plate

[in pocket at back of report]

Figures

Tables

Conversion Factors and Vertical Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometers
	Volume	
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
gallons per minute (gpm)	0.06309	liter per second
	Rate	
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.0929	meter squared per day

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C = (°F-32)/1.8

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27). Altitude, as used in this report, refers to distance above the vertical datum.

Hydrogeologic Framework and Ground Water in Basin-Fill Deposits of the Diamond Valley Flow System, Central Nevada

By Mary L. Tumbusch and Russell W. Plume

Abstract

The Diamond Valley flow system, an area of about 3,120 square miles in central Nevada, consists of five hydrographic areas: Monitor, Antelope, Kobeh, and Diamond Valleys and Stevens Basin. Although these five areas are in a remote part of Nevada, local government officials and citizens are concerned that the water resources of the flow system eventually could be further developed for irrigation or mining purposes or potentially for municipal use outside the study area. In order to better understand the flow system, the U.S. Geological Survey in cooperation with Eureka, Lander, and Nye Counties and the Nevada Division of Water Resources, is conducting a multi-phase study of the flow system.

The principal aquifers of the Diamond Valley flow system are in basin-fill deposits that occupy structural basins comprised of carbonate rocks, siliciclastic sedimentary rocks, igneous intrusive rocks, and volcanic rocks. Carbonate rocks also function as aquifers, but their extent and interconnections with basin-fill aquifers are poorly understood.

Ground-water flow in southern Monitor Valley is from the valley margins toward the valley axis and then northward to a large area of discharge by evapotranspiration (ET) that is formed south of a group of unnamed hills near the center of the valley. Ground-water flow from northern Monitor Valley, Antelope Valley, and northern and western parts of Kobeh Valley converges to an area of ground-water discharge by ET in central and eastern Kobeh Valley. Prior to irrigation development in the 1960s, ground-water flow in Diamond Valley was from valley margins toward the valley axis and then northward to a large discharge area at the north end of the valley. Stevens Basin is a small upland basin with internal drainage and is not connected with other parts of the flow system.

After 40 years of irrigation pumping, a large area of ground-water decline has developed in southern Diamond Valley around the irrigated area. In this part of Diamond Valley, flow is from valley margins toward the irrigated area. In northern Diamond Valley, flow appears to remain generally northward to the large discharge area.

Subsurface flow through mountain ranges has been identified from Garden Valley (outside the study area) through the Sulphur Springs Range to Diamond Valley and from southeastern Antelope Valley through the Fish Creek Range to Little Smoky Valley (outside the study area). In both cases, the flow is probably through carbonate rocks.

Ground-water levels in the Diamond Valley flow system have changed during the past 40 years. These changes are the result of pumpage for irrigation, municipal, domestic, and mining uses, mostly in southern Diamond Valley, and annual and longer-term variations in precipitation in undeveloped parts of the study area. A large area of ground-water decline that underlies an area about 10 miles wide and 20 miles long has developed in the basin-fill aquifer of southern Diamond Valley. Water levels beneath the main part of the irrigated area have declined as much as 90 feet. In undeveloped parts of the study area, annual water-level fluctuations generally have been no more than a few feet.

Introduction

Background

The Diamond Valley regional flow system (Harrill and others, 1988) consists of five hydrographic areas[1] in Eureka, Lander, and Nye Counties, and a small part of southern Elko County, Nevada. The areas are Monitor, Antelope, Kobeh, and Diamond Valleys and Stevens Basin (fig. 1). Monitor Valley is divided into a southern part and a northern part. Southern Monitor Valley is internally drained and may only be minimally connected with northern Monitor Valley by ground-water flow. Northern Monitor, Antelope, Kobeh, and Diamond Valleys are connected by ephemeral streams and by subsurface ground-water flow through basin-fill aquifers and possibly through deeper carbonate-rock aquifers. Stevens Basin is a small upland basin with internal drainage. Diamond Valley is the terminus of the flow system and the water resources of the southern part of this basin have been developed for irrigation, mining, municipal, and domestic uses.

[1]Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960s for scientific and administrative purposes (Cardinalli and others, 1968, and Rush, 1968). The official hydrographic-area names, numbers, and geographic boundaries continue to be used in Geological Survey scientific reports and Division of Water Resources administrative activities.

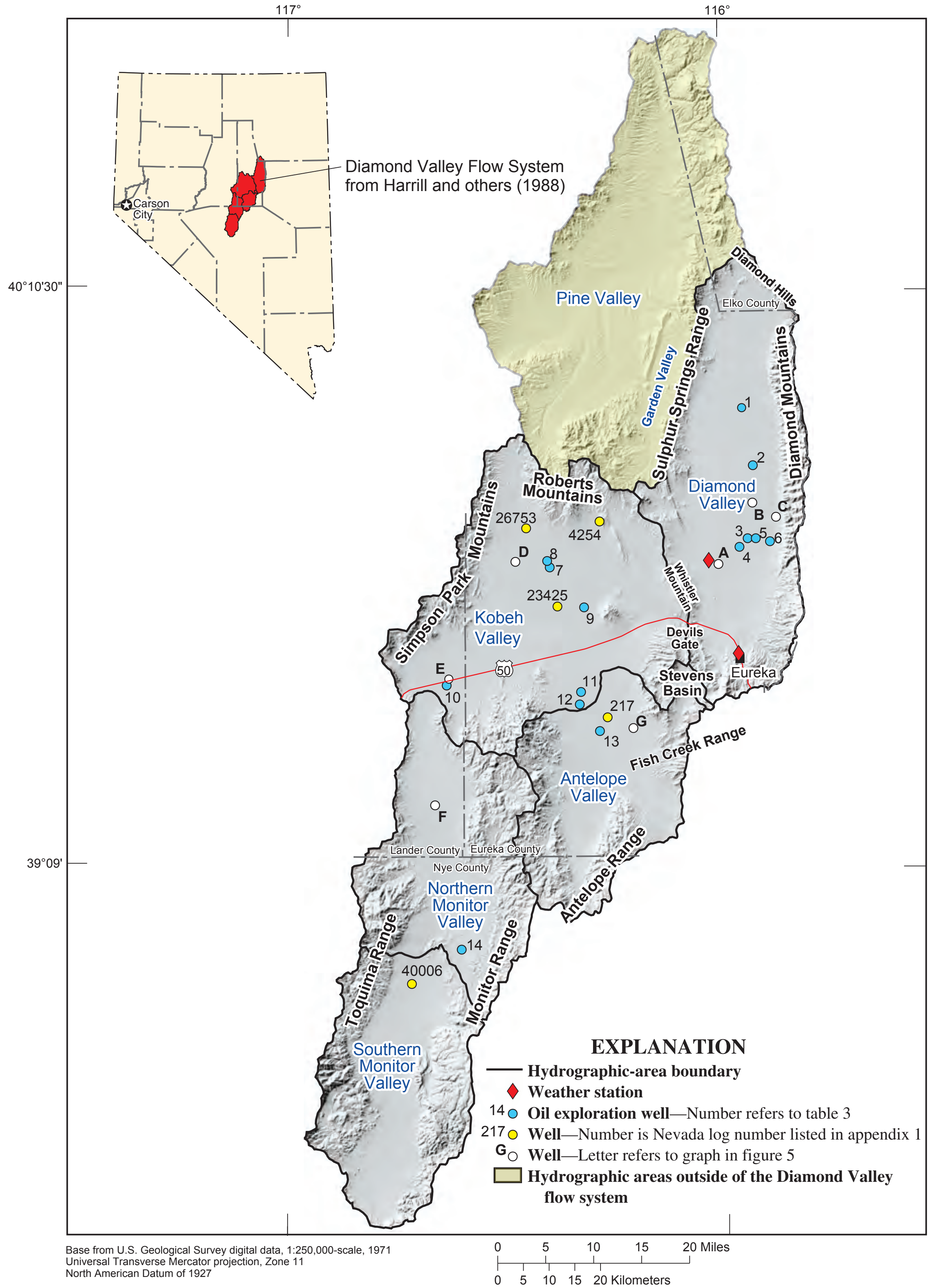


Figure 1. Locations of hydrographic areas, weather stations, and selected wells in the Diamond Valley flow system, central Nevada.

The ground-water resources of southern Antelope Valley and western Kobeh Valley also have been minimally developed for irrigation use. Except for scattered stock wells, the water resources for the rest of the study area are currently undeveloped.

Although the Diamond Valley flow system is in a remote part of Nevada, local government officials and citizens are concerned that the water resources of the flow system eventually could be further developed for irrigation or mining purposes or potentially for municipal use outside the study area. Specific concerns are that such development could affect present water uses, the flow of valley floor springs and wetlands that support wildlife habitat, and recreational uses. To better understand the flow system, the U.S. Geological Survey (USGS), in cooperation with Eureka, Lander and Nye Counties and the Nevada Division of Water Resources (NDWR), developed a multi-phase study of the Diamond Valley flow system. The overall objective of the study is to develop an understanding of the flow system that accounts for (1) the occurrence and movement of ground water in basin-fill and carbonate-rock aquifers and interactions between the two types of aquifers; (2) all natural inflow and outflow processes; (3) subsurface flow between basins and between aquifers; and (4) the effects of ground-water withdrawals on the different aquifers. Phase one of the study is documented in this report. The objectives of phase one are to (1) define the hydrogeologic framework of the flow system, (2) evaluate the occurrence and movement of ground water in and among the principal basin-fill aquifers of the flow system, and (3) quantify historical water-level changes in these aquifers. Subsequent phases will be designed to refine basin water budgets and evaluate interactions of basin-fill aquifers with underlying volcanic-rock and deeper carbonate-rock aquifers.

During the 1980s, the Diamond Valley flow system was defined as part of the Great Basin Regional Aquifer System Analysis (Harrill and others, 1988). Previous studies in the area have focused on Diamond Valley (Eakin, 1962; Harrill, 1968; and Arteaga and others, 1995) because of the extensive irrigation development. Monitor Valley, Antelope Valley, Kobeh Valley, and Stevens Basin have been studied only at the reconnaissance level (Rush and Everett, 1964).

Purpose and Scope

This report documents the findings of phase one of the Diamond Valley flow system study. The purposes of this report are to (1) define the hydrogeologic framework of the Diamond Valley flow system, (2) evaluate the occurrence and movement of ground water in and among the principal basin-fill aquifers of the flow system, and (3) quantify historical water-level changes in these aquifers. The extent of basin-fill aquifers is described based on the hydrogeologic map (plate 1). Limited information on basin-fill thickness and depths to carbonate rocks are based on records from 14 oil exploration wells that were drilled in different parts of the flow system. Depths to water measured in the spring and summer of 2005 and in previous years provide the basis for defining the occurrence and movement of ground water and water-level changes in basin-fill aquifers that have occurred since the 1960s. Little is known of ground-water interaction between other hydrogeologic units that may also function as aquifers. Phase two will be designed to develop a conceptualization of the Diamond Valley flow system that accounts for the geometry, hydraulic properties, and the interconnections of basin-fill and deeper aquifers.

Approach

The hydrogeologic map of the Diamond Valley flow system (plate 1) was compiled from the hydrogeologic map of Nevada (Maurer and others, 2004). Thickness of basin-fill deposits and depths to carbonate rocks were determined from the records of 14 oil exploration wells drilled in the study area. These records are part of an online database available at the Nevada Bureau of Mines and Geology website at <*http://www.nbmg.unr.edu/lists/oil/oil.htm*>.

Water levels in southern Diamond Valley are measured annually in the spring on a network of wells by the NDWR, Eureka County, and Barrick Gold Corporation. Water levels for wells in the rest of the study area were measured in the spring and summer of 2005 by the USGS. These measurements were used to develop a contour map of water-level altitudes used to assess directions of ground-water flow within and between basins. Comparison of water levels measured in 2005 with those measured in the past 40–50 years provided the basis for quantifying water-level changes.

Description of Study Area

The Diamond Valley flow system covers an area of about 3,120 mi^2 (table 1). U.S. Highway 50 passes east to west through the approximate center of the study area (fig. 1). The population of the study area is concentrated in southern Diamond Valley at the town of Eureka and the nearby agricultural area. The 2005 population of Eureka County was 1,900 (Eureka County web site, accessed August 1, 2006, at <*http://www.co.eureka.nv.us/*>).

Table 1. Hydrographic areas of the Diamond Valley flow system, central Nevada.

Name (fig. 1)	Number	Area[1] (square miles)	Area (acres)
Antelope Valley	151	450	288,000
Diamond Valley	153	750	480,000
Kobeh Valley	139	860	550,000
Monitor Valley-North	140A	530	339,000
Monitor Valley-South	140B	510	326,000
Stevens Basin	152	20	12,800
Totals (rounded)		3,120	2,000,000

[1] From Rush (1968).

The study area is located in central Nevada and is part of the Great Basin physiographic province. The study area is characterized by north to south trending mountains separated by basins of various size and shapes (plate 1). Monitor, Antelope, and Diamond Valleys are elongate, whereas Kobeh Valley and Stevens Basin are roughly equidimensional. The study area is bounded on the west by the Toquima Range and Simpson Park Mountains, on the north by the Roberts Mountains, the Sulphur Springs Range, and the Diamond Hills, and on the east by the Diamond Mountains, Fish Creek Range, Antelope Range, and the Monitor Range. The highest points of several of these mountain ranges exceed altitudes of 10,000 ft.

The five hydrographic areas of the Diamond Valley flow system range in size from about 20 mi^2 in Stevens Basin to about 1,040 mi^2 in Monitor Valley (table 1). Monitor Valley is oriented north-south and is about 65 mi long and up to 20 mi wide. The valley is divided into north and south parts of nearly equal area by a group of hills that extend across the valley. Because of these hills, southern Monitor Valley is topographically closed and internal drainage is to the playa at the north end of the basin. In addition, the hills impede northward ground-water flow to northern Monitor Valley. Drainage in northern Monitor Valley is northward to Kobeh Valley. The lowlands of Monitor Valley range from about 6,300 ft at the northern end to more than 7,000 ft at the southern end. The valley is bounded on the west by the Toquima Range and on the east by the Monitor Range.

Antelope Valley also is oriented from north to south and it is about 25 mi long and 20 mi wide. It is bounded on the east by the Antelope and Fish Creek Ranges and on the west by the Monitor Range. The lowlands of Antelope Valley range in altitude from 6,075 ft in the north to more than 6,800 ft at the south end of the valley. Surficial drainage of Antelope Valley is northward to Kobeh Valley.

Kobeh Valley is about 35 mi wide in both an east to west direction and in a north to south direction. It is bounded on the north by the Roberts Mountains, on the west by the Simpson Park Mountains, on the east by Whistler Mountain, and on the south by the northern boundaries of the Monitor Range and Monitor and Antelope Valleys. The lowlands of Kobeh Valley range from about 6,400 ft on the west side of the valley to about 6,000 ft on the east side at Devils Gate, which is a gap where eastward surficial drainage in the valley enters Diamond Valley (fig. 1).

Diamond Valley is elongated from north to south and is about 50 mi long and 15 mi at its widest. The valley is bounded on the west by the Sulphur Springs Range and Whistler Mountain, on the north by the Diamond Hills, on the east by the Diamond Mountains, and on the south by the Fish Creek Range. The lowlands of Diamond Valley range in altitude from about 5,770 ft at the large discharging playa at the north end of the valley to 6,200 ft at the south end. Surficial drainage in Diamond Valley is from the margins of the valley to its axis and then northward to the playa.

Stevens Basin is a small (18 mi^2) high-altitude basin in the northern part of the Fish Creek Range. The altitude of the lowlands of this basin is about 7,350 ft. Surficial drainage of Stevens Basin is from adjacent mountains to the lowlands.

The climate of the study area can be characterized as mid-latitude steppe in basin lowlands and as subhumid continental in the mountains (Houghton and others, 1975, p. 3). The mid-latitude steppe zone is semiarid, with warm to hot summers and cold winters (Houghton and others, 1975, p. 69). The subhumid continental zone has cool to mild summers and cold winters with annual precipitation occurring mostly as snow (Houghton and others, 1975, p. 71). Most precipitation in the study area comes from winter storms. Although summer thunderstorms can produce large amounts of precipitation as rain in a short time, their effects usually are localized and do not contribute significantly to total annual precipitation.

Figure 2 shows average annual precipitation compared with annual precipitation for weather stations at Eureka and Austin for 1971–2000 and at Diamond Valley for 1979–2000. The Eureka and Diamond Valley stations are in the eastern part of the study area (fig. 1), and the Austin station is about 15 mi west of the study area. For 1971-2000, average annual precipitation at the Eureka and Austin stations is about 12 in. and 14.5 in., respectively. Annual precipitation at the two stations ranged from 7 in. in 1985 to 23 in. in 1983 at Eureka and from 6 in. in 1986 and 1997 to 22 in. in 1983 at Austin. Data collection at the Diamond Valley station did not begin until 1979, so its period of record through 2000 is 22 years. Average annual precipitation at Diamond Valley is 10 in. and annual totals have ranged from 5 in. in 1981 and 1985 to more than 15 in. in 1983 and 1995 (fig. 2). The values of average annual precipitation and the annual totals shown in figure 2 and discussed above should be considered minimum values because days of missing record are common for each of the stations. The source of this precipitation data is the Western Regional Climate Center (2006).

Well Designations

Four different designations are used for identifying wells in this report: USGS standard site identification, USGS local well number, American Petroleum Institute number, and Nevada log number. The USGS standard site identification consists of 15 digits and is based on the grid system of latitude and longitude. The first six digits denote degrees, minutes, and seconds of latitude; the next seven digits denote degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify sites within a 1-second grid. For example, the site identification for the first well listed in appendix 2 is 392636116365601. The number refers to 39°26'36" latitude, 116°36'56" longitude, and it is the first site recorded in that 1-second grid (U.S. Geological Survey, 1989). This number is retained as a permanent identifier even if a more precise location is determined later.

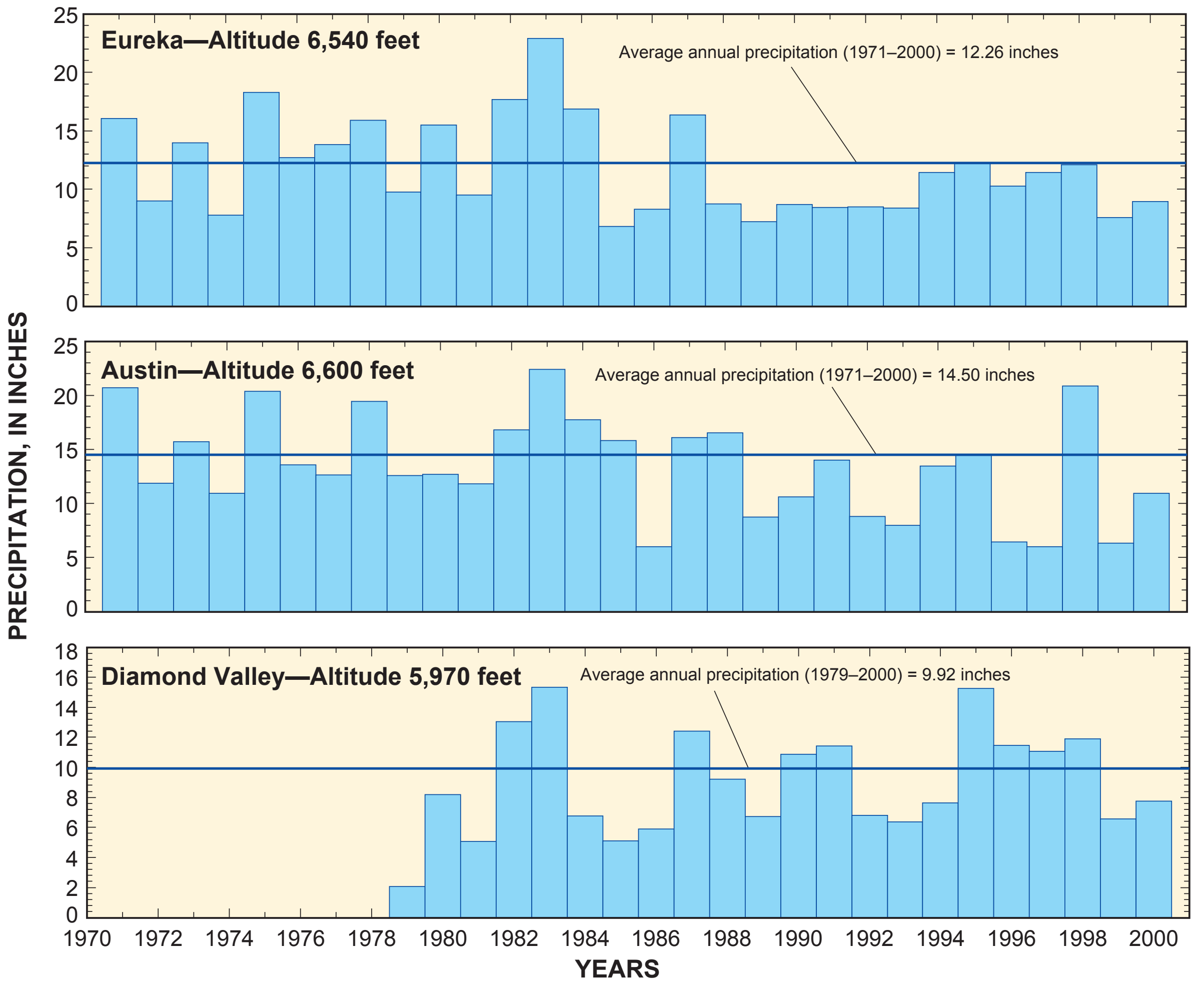


Figure 2. Annual precipitation at weather stations at Eureka and Austin, Nevada, 1971–2000, and at Diamond Valley, 1979–2000. Data source is Western Regional Climate Center.

The USGS local well number is based on an index of hydrographic areas for Nevada (Rush, 1968) and on the rectangular subdivision of the public lands referenced to the Mount Diablo baseline and meridian. Each number consists of four units separated by spaces. The first unit is the hydrographic area number (table 1). The second unit is township preceded by an N to indicate location north of the baseline. The third unit is range preceded by an E to indicate location east of the meridian. The fourth unit consists of section number and letters designating quarter section, quarter-quarter section, and so on (A, B, C, and D indicate northeast, northwest, southwest, and southeast quarter, respectively). For example, the local well number for the first well listed in appendix 2 is 139 N18 E48 07ACDD. This well is in Kobeh Valley (139) and is the first site recorded in the southeast quarter, of the southeast quarter, of the southwest quarter, of the northeast quarter of section 7, Township 18 North, Range 48 East, Mount Diablo baseline and meridian.

The American Petroleum Institute (API) number which consists of three groups of digits separated by dashes are used to identify oil exploration wells. Data from oil exploration wells are used in this report to help describe thicknesses of and depths to different hydrogeologic units. The API number for one of the wells referred to in this report is 27-011-05206. The first two digits denote state (Nevada is 27). The second three digits denote county (Eureka County, 011; Lander County, 015; and Nye County, 023). The last five digits are assigned sequentially to wells as they are permitted and drilled in each county.

The Nevada log number is assigned by NDWR after the well is completed and the log is filed with NDWR. The Nevada log number is used to describe drillers' logs for water wells in the study area that are used in this report to define the lithology of basin-fill deposits (appendix 1).

Acknowledgments

This study was a result of discussions between the USGS and the Eureka County Commissioners. The authors acknowledge their cooperation and the cooperation of Lander and Nye Counties and NDWR. The authors also appreciate the friendly attitudes of the residents of Eureka, Lander, and Nye Counties. Many private landowners, including ranchers and individual

residents, granted access to their wells, and in public meetings provided historical background for the study area. Most of the water levels in Diamond Valley were measured by NDWR, Eureka County, and Barrick Gold Corporation.

Geologic Setting

Hydrogeologic Units

The hydrogeologic map of the study area (plate 1) was modified from the hydrogeologic map of Nevada (Maurer and others, 2004), which was compiled from the geologic map of Nevada (Stewart and Carlson, 1978). The geologic map of Nevada was compiled from numerous reports on the geology of various parts of Nevada including the geologic reports for Eureka, Lander, and northern Nye Counties (Roberts and others, 1967; Stewart and McKee, 1977; and Kleinhampl and Ziony, 1985).

Geologic units, ranging from Paleozoic[2] carbonate rocks, quartzites, shales, sandstones, and conglomerates that comprise mountain ranges and structural basins to Tertiary and Quaternary basin-fill deposits occur in the study area. These rocks and deposits were grouped into 12 hydrogeologic units for the Nevada hydrogeologic map (Maurer and others, 2004), and were grouped into five units for this report (table 2 and plate 1). The grouping of hydrogeologic units generally is based on lithology, which affects the permeability and water-bearing properties of the units. The five main hydrogeologic units that either store and transmit ground water or impede its flow are, in order of decreasing age (1) carbonate rocks consisting of limestones and dolomites of Middle Cambrian to Devonian age and of Pennsylvanian age; (2) siliciclastic sedimentary rocks consisting of shales, siltstones, sandstones, and conglomerates of Upper Cambrian to Cretaceous age; (3) igneous intrusive rocks of Jurassic, Cretaceous and Tertiary

[2] Paleozoic and other geologic names such as Quaternary or Mesozoic, denote ranges of geologic age. The geologic-time scale on page 38 of this report gives ages in millions of years for these terms.

Table 2. Lithology, thickness, extent, and water-bearing characteristics of hydrogeologic units in Monitor, Kobeh, Antelope, and Diamond Valleys and Stevens Basin, central Nevada.

Geologic age	Rock or stratigraphic unit	Lithology	Thickness and locality	Water-bearing characteristics
		Basin-fill deposits		
Quaternary and Tertiary	Deposits of alluvial fans, basin flats, and northern Diamond Valley and southern Monitor Valley playas	Unconsolidated and unsorted deposits of silt, sand, gravel, cobbles, and boulders on alluvial fans. Interbedded clay, silt, sand, and gravel in basin lowlands. Mostly silt and clay with discontinuous lenses of sand and gravel beneath playas.	Ranges from tens of feet near basin margins to 1,110–7,500 feet in Diamond Valley, 800–4,200 feet in Kobeh Valley, 1,500–1,900 feet in Antelope Valley, and 1,000 feet or more in Monitor Valley.	Comprise shallow water-table aquifers and deeper confined aquifers.
		Volcanic rocks		
Tertiary	Volcanic rocks	Ash-flow and air-fall tuffs of rhyolitic composition. Lava flows and shallow intrusives of rhyolitic and andesitic composition. Basaltic lava flows.	Greatest thicknesses probably preserved in basins beneath and interbedded with older basin-fill deposits. As much as 6,300 feet in the subsurface of Diamond Valley, 500–3,200 feet in Kobeh Valley, 3,400–4,800 feet in Antelope Valley, and 2,200 feet in Monitor Valley.	Mostly impede ground-water flow because tuffs weather to clay and because of interbedded fine-grained lake deposits. Presence of perennial streams in watersheds underlain by these rocks also indicates low permeability.
		Igneous intrusive rocks		
Tertiary, Cretaceous, and Jurassic	Granitic rocks. Mafic intrusive rocks.	Mostly quartz monzonite, granodiorite, and basalt.	Extend to great depths and can be much more extensive than indicated by outcrop area.	Impedes the movement of ground water.
		Siliciclastic sedimentary rocks		
Cretaceous	Newark Canyon Formation	Shale, sandstone, and conglomerate	1,400 feet in southern Diamond Mountains	Generally impedes movement of ground water. Presence of perennial streams in watersheds underlain by these rocks also indicates low permeability.
Permian	Garden Valley Formation Carbon Ridge Formation	Shale, sandstone, sandy limestone, and conglomerate	4,200-4,800 feet in southern Diamond Mountains	
Mississippian	Diamond Peak Formation Chainman Shale	Shale, sandstone, and conglomerate	7,500 feet in the Diamond Mountains	

age; (4) volcanic rocks of Tertiary age; and (5) basin-fill deposits of Tertiary and Quaternary age. Basin-fill deposits and carbonate rocks can have high permeability and transmit ground water, whereas the other rocks generally have low permeability and impede the flow of ground water. The lithology and water-bearing properties of each unit are discussed below and are summarized in table 2.

Carbonate Rocks

The study area was along the continental margin of western North America from the late Precambrian through early Mesozoic (Stewart, 1980, p. 14–60). During parts of this time span, carbonate rocks accumulated in a continental shelf marine environment as limestone reefs and associated deposits from Middle Cambrian through Devonian and during the Pennsylvanian. The total stratigraphic thickness of the carbonate-rock section in the Eureka area is about 14,500 ft (Roberts and others, 1967, p. 7). The interruption of carbonate-rock deposition from Devonian to Pennsylvanian is discussed in the next section of this report.

Carbonate rocks are exposed to differing extents in all of the mountain ranges of the study area (plate 1), and information from oil exploration well logs shows that they comprise part of the bedrock beneath each of the intervening basins (fig. 1 and table 3). These carbonate rocks are, by far, the most commonly exposed hydrogeologic unit in the Diamond Mountains and in the Sulphur Springs, Fish Creek, and Antelope Ranges. Carbonate rocks are less extensively exposed in the Monitor and Toquima Ranges and in the Simpson Park and Roberts Mountains because they are overlain by siliciclastic sedimentary and volcanic rocks.

Carbonate rocks are dense with very low primary porosity and permeability. During geologic time, however, these carbonate rocks have been extensively faulted and as a result can have significant secondary porosity and permeability that developed through the process of solution widening of fractures by ground water. A compilation of the results of 23 aquifer tests made in carbonate rocks in other parts of the Great Basin shows that estimated hydraulic conductivity ranges from 0.0005 to 900 ft/d (Plume, 1996, p. 13). The mean and median

Table 2. Lithology, thickness, extent, and water-bearing characteristics of hydrogeologic units in Monitor, Kobeh, Antelope, and Diamond Valleys and Stevens Basin, central Nevada—Continued.

Geologic age	Rock or stratigraphic unit	Lithology	Thickness and locality	Water-bearing characteristics
Siliciclastic sedimentary rocks—Continued				
Mississippian	Diamond Peak Formation Chainman Shale	Shale, sandstone, and conglomerate	7,500 feet in the Diamond Mountains	Generally impedes movement of ground water. Presence of perennial streams in watersheds underlain by these rocks also indicates low permeability.
Devonian to Ordovician	Slaven Chert Clipper Canyon Group Willow Canyon Formation Pinecone Formation Valmy Formation Vinini Formation Palmetto Formation	Shales, siltstones, sandstones, quartzites, cherts, and marine volcanic rocks	At least 3,300 feet in the Toquima Range	
Carbonate rocks				
Pennsylvanian	Ely Limestone Joana Limestone Pilot Shale Devils Gate Limestone Nevada Formation Rabbit Hill Limestone	Thick intervals of limestone and dolomite interrupted by thinner intervals of shale, quartzite, and conglomerate. Increasing clastic content in western parts of study area.	More than 22,000 feet in southern Diamond Mountains thinning to 3,000 feet or less in northern Toquima Range	Comprise carbonate-rock aquifers generally beneath basin-fill aquifers. High permeability due to solution widening of fracture zones. Absence of perennial streams in watersheds even partly underlain by these rocks indicates high permeability.
Devonian to Cambrian	Lone Mountain Dolomite Roberts Mountains Formation Hanson Creek Formation Eureka Quartzite Pogonip Group Windfall Formation Dunderberg Shale Hamburg Dolomite Secret Canyon Shale Geddes Limestone Eldorado Dolomite Pioche Shale Prospect Mountain Quartzite			

Table 3. Hydrogeologic units penetrated by 14 oil exploration wells in Diamond, Kobeh, Antelope, and Monitor Valleys, central Nevada.

Data from Nevada Bureau of Mines and Geology: <*http://www.nbmg.unr.edu/lists/oil/oil.htm*>.

Well number (fig. 1)	American Petroleum Institute Number	Altitude (feet)	Total depth (feet)	Depth (feet)	Unit	Thickness (feet)	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)
					Diamond Valley			
1	27-011-05206	5,780	8,900	0	Basin-fill deposits	1,070	395711	1155724
				1,070	Volcanic rocks	6,285		
				7,355	Carbonate rocks			
2	27-011-05056	5,800	8,042	0	Basin-fill deposits	7,500	395102	1155557
				7,500	Carbonate rocks			
3	27-011-05204	5,881	10,600	0	Basin-fill deposits	1,070	394316	1155648
				1,070	Volcanic rocks	6,285		
				7,355	Carbonate rocks			
4	27-011-05224	5,880	6,552	0	Basin-fill deposits	2,248	394222	1155756
				2,248	Volcanic rocks	2,132		
				4,380	Clastic sedimentary rocks	1,830		
				6,210	Carbonate rocks			
5	27-011-05251	5,893	8,600	0	Basin-fill deposits	4,242	394314	1155542
				4,242	Volcanic rocks	530		
				4,773	Carbonate rocks			
6	27-011-05287	5,900	4,055	0	Basin-fill deposits	3,850	394256	1155342
				3,850	Carbonate rocks			
					Kobeh Valley			
7	27-011-05225	6,210	7,834	0	Basin-fill deposits	7,197	394021	1162409
				7,197	Carbonate rocks			
8	27-011-05242	6,263	6,462	0	Basin-fill deposits	830	394102	1162430
				830	Volcanic rocks	880		
				1,714	Clastic sedimentary rocks	1,036		
				2,750	Carbonate rocks			
9	27-011-05243	6,132	5,201	0	Basin-fill deposits	1,400	393605	1161928
				1,400	Carbonate rocks			
10	27-015-05006	6,267	5,050	0	Basin-fill deposits	390	392748	1163826
				390	Volcanic rocks	3,206		
				3,596	Clastic sedimentary rocks			
11	27-011-05247	6,270	8,031	0	Basin-fill deposits	1,820	392701	1161956
				1,820	Volcanic rocks	4,804		
				6,624	Carbonate rocks			
12	27-011-05286	6,316	5,940	0	Basin-fill deposits	1,535	392542	1162008
				1,535	Volcanic rocks	4,325		
				5,860	Carbonate rocks			
					Antelope Valley			
13	27-011-05284	6,283	5,660	0	Basin-fill deposits	1,860	392251	1161726
				1,860	Volcanic rocks	3,402		
				5,262	Clastic sedimentary rocks			
					Monitor Valley			
14	27-023-05355	7,021	4,679	0	Basin-fill deposits	1,010	385939	1163630
				1,010	Volcanic rocks	2,188		
				3,198	Carbonate rocks			

values for the tests were 0.8 and 80 ft/d, respectively (Plume, 1996, p. 13). These ranges in values illustrate the importance of faulting and fracturing in the development of secondary porosity and permeability in carbonate rocks. The lowest values represent dense, unfractured rock and the highest values represent zones of solution widened fractures.

A qualitative indicator of the relatively high permeability of carbonate rocks is the absence of perennial streams in watersheds where these rocks are the predominant hydrogeologic unit. Perennial streams occur in the Monitor and Toquima Ranges and the southern Diamond Mountains and where units other than carbonate rocks predominate. Exceptions to this are the perennial streams in the Roberts Mountains where carbonate rocks occur. Mafic dikes have intruded the carbonate rocks in this area and probably reduced their permeability. The presence and probable hydrologic effects of mafic dikes are discussed in a subsequent section of this report.

Siliciclastic Sedimentary Rocks

Siliciclastic sedimentary rocks in the study area span four separate age ranges—Cambrian through Devonian, Mississippian, Permian, and Cretaceous. Rocks of the first three age ranges are of marine origin and those of the Cretaceous age are of continental origin.

Shale, siliceous shale, chert, quartzite, siltstone, and minor amounts of limestone and andesitic volcanic rocks of Cambrian through Devonian age (Roberts and others, 1967, p. 30-34) were deposited in a deep water, marine environment adjacent to the continental shelf of western North America where carbonate rocks were being deposited at about the same time. From the Late Devonian to Early Mississippian time, the siliciclastic sedimentary rocks were thrust eastward as much as 90 mi over the carbonate rocks along a low-angle fault named the Roberts Mountains thrust (Stewart, 1980, p. 36). This tectonic event is named the Antler orogeny (Stewart, 1980, p. 36). The easternmost extent of Cambrian through Devonian siliciclastic sedimentary rocks is in eastern Eureka County (Stewart, 1980, p. 38). These rocks are found in the southern Sulphur Springs Range and the Roberts Mountains in addition to the Simpson Park Mountains, and the Toquima and Monitor Ranges (plate 1).

The Antler orogeny not only emplaced siliciclastic sedimentary rocks over carbonate rocks of equivalent age, it also produced a highland offshore of western North America. Erosion of this highland resulted in deposition of more siliciclastic sedimentary rocks in a basin between the highland and the margin of western North America during Mississippian time (Stewart, 1980, p. 41). Siliciclastic sedimentary rocks of this age consist of shale, siltstone, sandstone, and conglomerate and are found only in the Diamond Mountains and southernmost Sulphur Spring Range (plate 1; Roberts and others, 1967, p. 8). Thus, deposition of siliciclastic sedimentary rocks during the Mississippian interrupted deposition of carbonate rocks along the North American continental margin. As noted in the preceding section, deposition of carbonate rocks did not resume until the Pennsylvanian.

The youngest siliciclastic sedimentary rocks in the study area are of Permian and Cretaceous age. These rocks consist of shale, sandstone, sandy limestone, and conglomerate and are exposed only in the southern Diamond Mountains.

Siliciclastic sedimentary rocks of all four age ranges generally have low permeability and impede the movement of ground water because they either consist of fine-grained shales or, if coarser grained, have been cemented, which reduces interconnected porosity. At the Nevada Test Site area of south-central Nevada, siliciclastic sedimentary rocks of Mississippian age have been found to have negligible permeability (Winograd and Thordarson, 1975, p. 43 and Sweetkind and others, 2004, p. 63). In north-central Nevada, siliciclastic sedimentary rocks of Ordovician to Devonian age usually have low permeability, although permeability may be greater along faults (Maurer and others, 1996, p. 11).

Igneous Intrusive Rocks

Two types of igneous intrusive rocks are found in the study area—granitic rocks and mafic dikes. Granitic rocks range in age from Jurassic to Tertiary and are exposed in the southern and central Toquima Range, central Simpson Park Mountains, at Whistler Mountain on the southwest side of Diamond Valley, and in the southern Fish Creek Range (plate 1). The extent of the outcrop area of these rocks generally does not indicate the full areal extent of the intrusive body in the subsurface. These rocks typically have low effective porosity and where faulted develop fine-grained gouge (pulverized rock along the fault zone). As a result, granitic rocks almost always impede ground-water flow.

Mafic intrusive rocks, composed of heavy dark-colored minerals, are exposed in the Roberts Mountains as what has been described as a “spectacular dike swarm” (Zoback and others, 1994, p. 375). These dikes are of basaltic composition and have intruded fractures in carbonate rocks in the mountains along a north-northwest trending zone about 6 mi long and and as wide as 3–4 mi. The average width of individual dikes is less than 10 ft although some are as wide as 50 ft. Lengths range from a few hundred feet to 1–2 mi (Zoback and others, 1994, p. 376). The hydrologic effect of the dikes is that they have reduced the fracture porosity and permeability of the carbonate rocks. The general trend of the dike swarm and aeromagnetic data discussed in a subsequent section of this report indicate that the zone of dikes extends farther southeast across Kobeh Valley to the northern end of the Fish Creek Range (plate 1). Although similar dikes are not exposed in carbonate rocks at Lone Mountain or the Fish Creek Range, they probably are present at shallow depths (Zoback and others, 1994, p. 375). Thus, the dikes may be a major barrier to ground-water flow in these areas of carbonate rocks.

Volcanic Rocks

Volcanic rocks are found in or near every mountain range in the Diamond Valley flow system. The occurrence of these volcanic rocks ranges from scattered outcrops in the northern Diamond Mountains to extensive outcrops in the Toquima and Monitor Ranges. At various locations the volcanic rocks overlie all of the older hydrogeologic units.

Volcanic rocks in the study area are of Oligocene and Miocene age (Stewart and McKee, 1977, p. 51; Kleinhampl and Ziony, 1985, p. 116-120; McKee, 1986). Lava flows and shallow intrusives of dacitic and andesitic composition are overlain by rhyolitic ash-flow tuffs in the southern Simpson Park Mountains and northern Toquima Range (Stewart and Mckee, 1977, p. 35 and 39-41). Farther south and east in the Toquima, Monitor, and Antelope Ranges, volcanic rocks consist of tuffaceous sedimentary rocks and bodies of rhyolite, overlain by lava flows of andesitic composition, that are in turn overlain by extensive ash-flow and air-fall tuffs (Kleinhampl and Ziony, 1985, p. 116–121 and 124–128). Volcanic rocks in the Roberts Mountains consist of rhyolitic lava flows, ash-flow tuffs, and shallow intrusives of Oligocene age that are, in places, overlain by basaltic lava flows of Miocene age (McKee, 1986). The feeders for these basalt flows occur as a swarm of shallow mafic dikes (McKee, 1986; Zoback and others, 1994, p. 374-376).

Volcanic rocks also underlie basin-fill deposits in each of the basins of the study area at differing depths. Thicknesses of volcanic rocks penetrated by oil exploration wells (table 3) are about 500–6,300 ft in Diamond Valley; 900–3,200 ft in Kobeh Valley; 3,400–4,800 ft in Antelope Valley; and 2,200 ft in Monitor Valley (table 3).

The only known aquifer test of volcanic rocks was done in southern Monitor Valley at a well drilled in 1967 as part of a program for the U.S. Atomic Energy Commission (Dinwiddie, 1968, p. 7-14). The hole penetrated alluvium from land surface to 1,104 ft; welded tuff from 1,104 to 1,361 ft; bedded tuff from 1,361 to 1,471 ft; and rhyolite from 1,471 to 4,343 ft. A zone of water production was identified during drilling in rhyolite at depths from 1,687 to 1,850 ft. During testing of this interval, the well was allowed to flow at a rate of 8 gpm for an unspecified time and the buildup of pressure was recorded. Maximum pressure buildup occurred almost instantaneously, which indicates relatively high permeability (Dinwiddie, 1968, p. 10). Three deeper intervals in the rhyolite at 3,536–3,734 ft; 3,772–3,970 ft; and 4,144–4,343 ft also were tested. Test results indicated that these three intervals had low permeability (Dinwiddie, 1968, p. 14). Volcanic rocks probably have low permeability over much of the study area. Evidence includes several watersheds containing perennial streams in the Monitor and Toquima Ranges. Perennial streams are found in these watersheds because the volcanic rocks that underlie them are poorly permeable.

Basin-Fill Deposits

Basin-fill deposits consist of heterogeneous mixtures of fine-, medium-, and coarse-grained materials eroded from mountain ranges and deposited in adjacent basins. Previous geologic mapping by Stewart and McKee (1977; plate 1) identified two types of Quaternary basin fill in northern Monitor Valley and western Kobeh Valley: (1) alluvial-fan deposits and (2) valley alluvium. In central and eastern Kobeh Valley, northern Antelope Valley, and Diamond Valley, Roberts and others (1967, plate 3) identified three types of Quaternary alluvial deposits: (1) older alluvium, mostly as alluvial fans along basin margins; (2) younger alluvium in basin lowlands; and (3) playa deposits. The first two units of Quaternary alluvium identified by Roberts and others (1967, plate 3) correspond with those identified by Stewart and McKee (1977, plate 1). In southern Monitor Valley, Kleinhampl and Ziony (1985, plate A1A) only identify a single unit of alluvium, lumping deposits of alluvial fans, basin lowlands, and playas together. This inconsistency in the mapping of the different types of Quaternary alluvium from basin to basin in Nevada was recognized by Stewart (1980, p. 95).

Only a single unit of basin fill is discussed in this report (plate 1) because of the inconsistencies in the mapping and identification of different types of basin-fill deposits discussed above. This hydrogeologic unit includes deposits of alluvial fans, basin lowlands, stream deposits, and the playas at the north end of southern Monitor Valley and at the north end of Diamond Valley. The unit also includes Tertiary sedimentary deposits that underlie Quaternary deposits at uncertain depths in each basin. Tertiary sedimentary deposits are exposed over small areas in the southern Toquima and northern Monitor Ranges (plate 1), indicating that the deposits accumulated in broad basins, and then were uplifted by faulting as the present distribution of basins and mountains developed. For this reason, Tertiary sedimentary deposits are believed to underlie younger deposits of Quaternary alluvium in each basin of the study area at uncertain depths.

The only detailed study of the lithology and hydrologic properties of basin-fill deposits in the study area was by Harrill (1968, p. 12–16 and fig. 3). He used well drillers' logs to estimate the distribution of sand, gravel, and finer-grained material such as silt and clay for the upper 100 ft of saturated material (Harrill, 1968, p. 12–16). Harrill (1968, fig. 3) also developed a map showing the permeability distribution of these deposits. The zone of lowest permeability is along the south, southeast, and west valley margins and in the north-central part of southern Diamond Valley. A zone of high permeability occupies an area that corresponds with the south-central part of the valley. Finally, an arcuate zone of moderate permeability occupies the southern part of the valley between the zone of high permeability and the zone of low permeability along the valley margins. The large zone of low permeability corresponds with basin-fill deposits that have only 20–40 percent sand and gravel. The distribution of these relatively fine-grained deposits (Harrill, 1968, fig. 2) suggests that they also underlie northern parts of the valley.

Thickness of basin-fill deposits ranges from a few tens of feet near basin margins to thousands of feet in the deepest parts of the basins of the Diamond Valley flow system. Six oil exploration wells have been drilled in Diamond Valley—two in the northern part and four in the southern part (fig. 1). The two northern wells are near the axis of the valley where the thickness of basin-fill deposits is 1,070 and 7,500 ft, respectively (table 3). The four southern wells are in the central and eastern parts of the valley where the thickness of the basin-fill deposits ranges from 1,070 to 4,250 ft.

Six oil exploration wells were drilled in Kobeh Valley—three in the central part of the basin, two in the southern part, and the sixth in the southwestern part (fig. 1). At the three wells in the central part of Kobeh Valley, basin-fill deposits range from 830 to 7,200 ft in thickness. At the southwestern well the deposits are 390-ft thick (table 3).

One oil exploration well has been drilled in the northern part of Antelope Valley where the basin-fill deposits are 1,860 ft in thickness (table 3). A single oil exploration well was drilled in Monitor Valley between the eastern margin of the valley and the group of hills that separate the northern and southern parts of the valley. The thickness of basin-fill deposits at this well is 1,010 ft (table 3).

Determining the areal distribution of sand, gravel, and clay in Monitor, Antelope, and Kobeh Valleys was beyond the scope of this study, but is being planned as part of phase two. However, logs for five wells illustrate differences in sorting and lithology of basin-fill deposits of alluvial fans and lowlands (fig. 1; appendix 1). Two of the wells penetrate deposits of alluvial fans in northern parts of Kobeh Valley (fig. 1). Deposits penetrated by these wells consist of differing mixtures of boulders, gravel, sand, and clay (Nevada log numbers 4254 and 26753; fig. 1 and appendix 1). Individual beds of a single lithology such as sand or clay are rare, indicating that the deposits mostly are unsorted mixtures of material eroded from the nearby mountains. The other three wells are in the lowlands of Kobeh, Antelope, and Monitor Valleys (fig. 1). Deposits penetrated by the Kobeh Valley well consist of sand and gravel beds from depths of 0 to 35 ft and 190 to 225 ft and mostly clay from 35 to 190 ft and 225 to 232 ft (Nevada log number 23425; fig. 1 and appendix 1). Deposits penetrated by the Antelope Valley well consist of alternating beds of sand and clay from depths of 0 to 80 ft, clay and sandy clay from 80 to 235 ft, and clay from 235 to 480 ft (Nevada log number 217; fig. 1 and appendix 1). The third lowland well is located along the western margin of the playa in southern Monitor Valley (Nevada log number 40006; fig. 1 and appendix 1). This well penetrated brown and black clay from 0 to 22 ft, sand from 22 to 35 ft, brown clay from 35 to 58 ft, sand from 58 to 73 ft, brown clay from 73 to 85 ft, gravel from 86 to 96 ft, and black clay from 96 to 100 ft. The deposits penetrated by the three lowland wells indicate alternating periods of lacustrine deposition (clays deposited in shallow lakes) and fluvial deposition (sands and gravels deposited by streams).

The hydraulic properties of basin-fill deposits range more than two orders of magnitude due to variations in grain size and sorting. Hydraulic properties include transmissivity and hydraulic conductivity. Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient (Lohman, 1972, p. 13). Hydraulic conductivity is the volume of water that will move in a unit time under a unit hydraulic gradient through a unit area of the aquifer (Lohman, 1972, p. 4). Estimates of the transmissivity of basin-fill deposits in the study area range from 6,700 to 13,000 ft^2/d in Monitor Valley, and 3,600 to 33,000 ft^2/d in Diamond Valley (Rush and Everett, 1964, p. 16; Harrill, 1968, p. 15). In other basins of central and eastern Nevada, the estimated hydraulic conductivity of basin-fill deposits ranged from less than 1 ft/d to more than 100 ft/d (Plume, 1996, p.16–17).

Structural Features

Faults can function as conduits for the movement of ground water or they can impede its movement where they juxtapose hydrogeologic units of differing permeability or because of gouge. In north-central Nevada near large gold mines along the Carlin Trend, faults impede the movement of ground water where carbonate rocks are juxtaposed against volcanic and siliciclastic sedimentary rocks (Plume, 2005, p. 6–7). In this area, the effects of faults are evident because of the differences in water levels on opposite sides of the fault. After more than 15 years of large-scale pumpage for mine dewatering, water-level differences across these faults are more than 1,000 ft (Plume, 2005, p. 6). Pumping at a mine in southern Diamond Valley has also resulted in large differences in water levels across faults (Jon Hutchings, Eureka County, written commun., 2006). In many cases, however, the effects of faults may not be known until large-scale pumping stresses are applied to an aquifer.

Another structural feature in northern and central Nevada that probably affects ground-water flow is the northern Nevada rift. On the aeromagnetic map of Nevada this feature is expressed as a linear, northwest-southeast trending anomaly that extends from the Nevada-Oregon border into central Nevada (Zeitz and others, 1978). The source rocks for the northern Nevada rift are igneous intrusive, mafic dikes that occupy a zone in the earth's crust several miles wide (Zoback and others, 1994, p. 371). When first described, the rift was thought to extend southeastward to the Eureka area; however, subsequent work shows that it extends to southeastern Nevada (Zoback and others, 1994, p. 372). In the Roberts Mountains on the north side of Kobeh Valley, a zone of dikes 3–4 mi wide over a northwest to southeast distance of about 6 mi intruded Paleozoic carbonate rock (Zoback and others, 1994, 374–376). Based on analysis of aeromagnetic data, the northern Nevada rift appears to underlie most of eastern Kobeh Valley, northern Antelope Valley, and the northern Fish Creek Range (plate 1 and Plume, 1996, plate 5). Although mafic dikes are not exposed in Paleozoic carbonate rocks of Lone Mountain or the northern Fish Creek Range, the dikes are believed to be present at shallow depths (Zoback and others, 1994, p. 375). The hydrologic effect of the northern Nevada rift almost certainly is that ground-water flow in carbonate rocks is impeded. Thus, any eastward ground-water flow from western Kobeh Valley or northern flow from southern Antelope Valley probably is forced upward into overlying volcanic rocks and basin-fill deposits upon encountering the dikes.

Ground Water in Basin-Fill Deposits

Ground water in basin-fill deposits of the Diamond Valley flow system occurs as extensive, shallow water-table aquifers or deeper confined aquifers. Ground water also occurs in carbonate rocks and volcanic rocks, although, to a poorly understood extent. The shallow water-table aquifer is connected between basins by subsurface flow and is separated from deeper confined aquifers by clay beds described in a previous section of this report. Depths to water range from less than 10 ft in the lowlands of southern Monitor, Kobeh, Antelope, and northern Diamond Valleys to more than 200 ft on alluvial fans near basin margins. Water levels measured in 2005 are used in this report to describe the occurrence and movement of shallow ground water. Some of the wells that were measured may penetrate a confined aquifer in addition to the shallow water table. Thus, water levels measured may represent a composite ground-water altitude rather than the water table.

Flowing (artesian) wells and valley-floor springs both indicate one or more confined aquifers at some depth below the shallow water-table aquifer. When water at these sites is warm or hot, deep circulation of ground water is indicated, and the discharge probably is coming from carbonate-rock or volcanic-rock aquifers below basin-fill aquifers (hot is defined as greater than 98°F <*http://www.nbmg.unr.edu/geothermal/gtmap.pdf*>). Springs and flowing wells are common along the west side of northern Diamond Valley, central Kobeh and Antelope Valleys, and the southernmost part of northern Monitor Valley at a large hot spring named Dianas Punch Bowl. Water temperatures from springs in Diamond Valley range from 48° to 94°F (Harrill, 1968, p. 40) and is about 140°F at Dianas Punch Bowl in Monitor Valley (Rush and Everett, 1964, p. 23).

Occurrence and Movement

Plate 1 is a map of hydrogeologic units and the altitudes of shallow ground water in basin-fill aquifers and is based on water levels measured in wells in spring and summer of 2005. Water-level altitude contours shown on the map define the shape of the shallow ground-water surface. In addition to the contour lines, general directions of ground-water flow (arrows) are shown on plate 1.

Contoured water-level altitudes in the study area range from 6,900 ft in southern Monitor Valley to less than 5,800 ft at the northern end of Diamond Valley. In southern Monitor Valley, water-level altitude contours and flow arrows indicate that ground-water flow is from basin margins toward the basin axis and then northward. However, the group of hills composed of volcanic rocks that separate the southern and northern parts of Monitor Valley (plate 1) appear to function as a partial barrier to ground-water flow. As a result, in wet years water levels in the aquifer rise to or near land surface forming a shallow lake. In dry years, the lakebed is a dry alkali flat. In both cases an extensive area of phreatophytes, which are plants that have roots that reach the water table, surrounds the area. The combined area of the lake and surrounding phreatophytes has been estimated to exceed 30,000 acres (Rush and Everett, 1964, table 5). This is a large area of evapotranspiration (ET), which is the predominant ground-water discharge process in the study area. The term incorporates the process of evaporation from open water and shallow ground water and transpiration of ground water by phreatophytes.

Rush and Everett (1964, p. 16) estimated subsurface flow to northern Monitor Valley through the older alluvium to be about 2,000 acre-ft/yr. This estimate was based on an estimated transmissivity of 6,700 ft^2/d, an approximate ground-water gradient of 0.004 and width of flow through the alluvium of about 2 mi. Ground-water flow in northern Monitor Valley is from basin margins and northward along the basin axis to Kobeh Valley (plate 1). An area of about 6,000 acres of ground-water discharge by ET occupies the lowlands of the southern part of northern Monitor Valley for a distance of about 10 mi (Rush and Everett, 1964, plate 1). A portion of this ground-water discharge may come from the shallow basin-fill aquifer. A portion of the discharge also may originate as upwelling from thermal springs, including Dianas Punch Bowl, which comes from the deep bedrock aquifer. Subsurface flow from northern Monitor Valley to Kobeh Valley is an estimated 6,000 acre-ft/yr (Rush and Everett, 1964, p. 16).

In most of Antelope Valley, ground-water flow is from basin margins to the basin axis and northward to Kobeh Valley. An area of about 13,000 acres of ground-water discharge by ET also occupies the lowlands of Antelope Valley, for a distance of about 7–10 mi (Rush and Everett, 1964, plate 1). The source of this discharge is shallow ground water and thermal spring discharge from deep bedrock aquifers. This ET area does not extend northward to the ET area in central and eastern Kobeh Valley. Rush and Everett (1964, p. 16) state that east-trending faults cut the alluvium of northern Antelope Valley and impede the northward movement of ground water forcing it to land surface. However, these faults are not shown on their ground-water map (Rush and Everett, 1964, plate 1) and no such faults have been mapped in the area. Alternate explanations for this ET area include (1) a northward thinning of the basin-fill aquifer cross section, (2) a northward change in aquifer lithology from sand and gravel to greater proportions of clay, and (3) ground water forced upward from carbonate rocks as a result of mafic dikes associated with the northern Nevada rift.

Water levels at four wells in southeastern Antelope Valley indicate that ground-water flows eastward through carbonate rocks of the southern Fish Creek Range (plate 1). This area generally coincides with a topographic low between the southern Fish Creek Range and northern Antelope Range where faulting may promote the eastward movement of ground water. Fish Creek Springs, thought to be a discharge area for regional ground-water flow (Rush and Everett, 1966, p. 23 and 25; Prudic and others, 1995, p. 88), are east of the study area in Little Smoky Valley. Subsurface flow from southeastern Antelope Valley may be a ground-water source for these springs.

Ground-water flow in Kobeh Valley is generally southward from the Roberts Mountains and eastward from the Simpson Park Mountains (plate 1). This ground-water flow and that from Monitor and Antelope Valleys converges in central and eastern Kobeh Valley. The result is an area of ground-water discharge by ET of about 29,000 acres (Rush and Everett, 1964, table 5). Ground water rises to or near land surface in this part of Kobeh Valley because the aquifer cross section is not large enough to accommodate flow converging from such a large area. Mafic intrusive dikes associated with the northern Nevada rift may also contribute to the presence of shallow ground water. The dikes probably impede ground-water flow in deep carbonate rocks forcing the water to rise into the overlying basin-fill aquifers.

Subsurface flow from Kobeh Valley to Diamond Valley occurs in basin-fill deposits at Devils Gate at a rate of about 40 acre-ft/yr (Harrill, 1968, p. 23). Previous studies concluded that no subsurface flow enters Diamond Valley through carbonate rocks at Devils Gate (Rush and Everett, 1964, p. 16, and Harrill, 1968, p. 23); however, such flow is considered possible because carbonate rocks exposed in the canyon walls at Devils Gate have numerous solution-widened fractures.

Prior to irrigation development in the 1960s, ground-water flow in southern Diamond Valley was from valley margins toward the valley axis and then northward to the large discharge area in the northern part of the valley (fig. 3; Harrill, 1968). Ground-water flow in northern Diamond Valley was northward from the southern part of the valley and radial from the Diamond Mountains, Diamond Hills, and Sulphur Springs Range to the discharge area. This discharge area consists of a shallow lake in wet years and an alkali flat in dry years, both surrounded by an extensive stand of phreatophytes. The total discharge area was about 106,000 acres in the 1960s (Harrill, 1968, p. 29). During the last 40 years, water levels have declined over a large area in southern Diamond Valley beneath the irrigated area. The decline has created a divide between northward flow to the discharge area and southward flow to the pumped area. The cumulative volume of ground water pumped for irrigation use in southern Diamond Valley was more than 1.2 million acre-ft as of 1990 (Arteaga and others, 1995, p. 5).

Table 4 provides a summary of estimates of ground-water inflow and outflow and ground water in storage in the upper 100 ft of the basin-fill aquifer in each of the five basins of the Diamond Valley flow system determined in previous studies (Eakin, 1962, p. 21 and 26; Rush and Everett, 1964, p. 25 and 29; Harrill, 1968, p. 34 and 37). It is believed that these water budgets and storage estimates have not changed for Monitor, Kobeh, and Antelope Valleys and Stevens Basin because these areas remain, for the most part, undeveloped. The disparity between the two inflow and outflow estimates for Diamond Valley result from differences in calculation methods. First, Harrill's estimate of inflow was based on a precipitation distribution that increased from the southern part of Diamond Valley to the northern part (Harrill, 1968, p. 23); whereas, Eakin (1962, p. 19–21) used a single precipitation distribution. Second, Harrill (1968, p. 25–26) estimated subsurface inflow from Garden Valley (outside of the study area) through the Sulphur Springs Range to be 9,000 acre-ft/yr. Eakin (1962) recognized that such flow might be occurring but did not estimate its magnitude. Garden Valley is in the southeastern part of the Pine Valley hydrographic area (fig. 1), which is part of the Humboldt flow system as described by Harrill and others (1988). Finally, Harrill's estimates of outflow by ET include transpiration by phreatophytes and evaporation from the playa (Harrill, 1968, p. 28). Eakin's (1962, p. 22) estimates did not include evaporation from the playa.

Historical Water-Level Changes

Water levels in the Diamond Valley flow system have changed over time as a result of withdrawals for irrigation, municipal, domestic, and mining uses and as a result of annual and long-term variations in precipitation. Most withdrawals have been for irrigation in southern Diamond Valley where the irrigated area expanded from 3,200 acres in 1961 to 22,200 acres in 1990 (Arteaga and others, 1995, p. 5). Harrill (1968, p. 49) estimated total pumpage to be 12,000 acre-ft in 1965 and 50,000 acre-ft for 1950–65. Between 1972 and 1990, annual pumpage of ground water for irrigation increased from 23,000 to 64,000 acre-ft (Arteaga and others, 1995, p. 1) in Diamond Valley. Two irrigation wells were pumped in Monitor and Kobeh Valleys in 1963 (Rush and Everett, 1964, p. 32) but were not in use in 2005. Two areas in western Kobeh Valley (about 880 acres) and southern Antelope Valley (250 acres) were being irrigated when water levels were measured for this study in 2005. Except for scattered stock wells, the ground-water resources of Monitor, Antelope, Kobeh, and northern Diamond Valleys are largely undeveloped.

In 1961, about 85 irrigation wells had been drilled in Diamond Valley and by 1965 more than 200 irrigation wells had been drilled in the valley (Harrill, 1968, p. 6). In 1990, there were 291 irrigation wells, of which 158 were being used, and water levels had declined more than 50 ft in developed areas of southern Diamond Valley (Arteaga and others, 1995, p. 1). In 2005, 87 wells were measured in Diamond Valley. Water-level declines from the 1960s to 2005 in southern Diamond Valley ranged from 26 to 90 ft at 67 wells (fig. 4). The large area of water-level decline that has developed in the basin-fill aquifer of southern Diamond Valley underlies an area of about 10 mi wide and 20 mi long (plate 1). Figure 5A

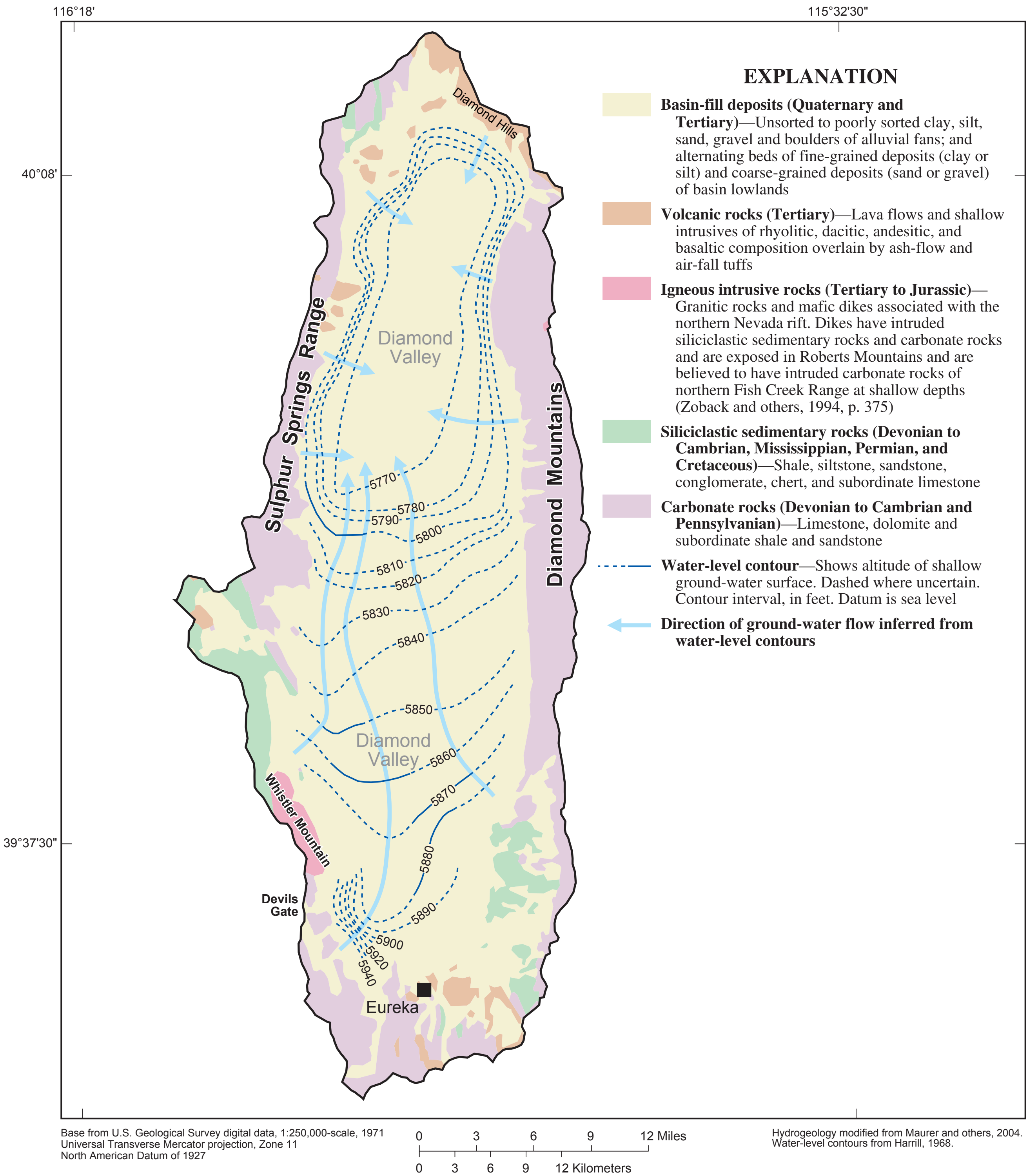


Figure 3. Hydrogeology and ground-water levels in Diamond Valley, central Nevada, 1950.

Table 4. Summary, from previous studies, of estimated ground-water inflow, ground-water outflow, and ground water in storage in the upper 100 feet of aquifer, 1962–68, in Antelope, Diamond, Kobeh, and Monitor Valleys, and Stevens Basin, central Nevada.

Hydrographic area	Inflow	Outflow	Ground water in storage
	in acre-feet		
Antelope Valley[1]	4,100	4,200	1,000,000
Diamond Valley	16,000[2] 30,000[3]	23,000[2] 30,000[3]	1,500,000[2] 2,800,000[3]
Kobeh Valley[1]	17,000	15,000	2,700,000
Monitor Valley-North[1]	8,300	8,000	1,000,000
Monitor Valley-South[1]	15,000	11,200	1,000,000
Stevens Basin[1]	200	200	50,000

[1] Rush and Everett (1964).

[2] Eakin (1962).

[3] Harrill (1968).

shows the hydrograph for well 153 N21 E53 21BBDD. The water level at this well was 52 ft below land surface in 1961 and 142 ft in 2005. Water levels have declined more than 40 ft in the northeastern part of this area (fig. 5B, C), and less than 10 ft in the northernmost parts of township 23 north (appendix 2). The water level at well 153 N22 E54 27CAB, fig. 5C was 5 ft below land surface in 1949 and 79 ft below land surface in 2004. Since 1990, the average water-level decline in wells measured in southern Diamond Valley was 12 ft. Water-level changes in undeveloped parts of northern Diamond Valley have been less than 5 ft in the past 30–40 years.

Long-term water-level records are available for only a few wells in Kobeh, Monitor, and Antelope Valleys (fig. 5D–G). At well 139 N21 E49 16CCBB (fig. 5D) in central Kobeh Valley, the depth to water ranged from 35 to 46 ft below land surface from 1953 to 2005. Annual water-level fluctuations at this well generally have been 2–4 ft, although a rise of 9 ft measured in 1985 was the result of above average precipitation in 1982–84 (fig. 2). Water-levels in well 139 N21 E47 36BBBA ranged from 48 to 56 ft below land surface from 1964 to 2005 (fig. 5E). The record for this well does not show a response to wet years in 1982–84; however, water levels were not measured at this well between 1985 and 2005. Three water levels measured in 1964, 1985, and 2005 at a well in southern Monitor Valley range from depths of 58–62 ft (fig. 5F). The water-level records at all three of these wells may be typical of other parts of the study area where depths to water did not exceed about 60 ft. At greater depths, fluctuations are presumed to be less because water levels do not respond as readily to short-term variations in precipitation. For instance, depths to water at well 151 N18 E51 34DCCB (fig. 5G) in northern Antelope Valley were 94–98 ft below land surface from 1964 to 2005 and annual fluctuations were less than 1 ft.

Phase Two

The findings of this study have raised some issues and questions that could be addressed as part of a second phase of the water-resource appraisal of Monitor, Antelope, Kobeh, and Diamond Valleys and Stevens Basin:

- What is the relative importance of mafic dikes, thinning alluvium, and Whistler granitics on upwelling of ground water in eastern Kobeh Valley?
- Does drawdown from Diamond Valley pumping propagate through Devils Gate carbonates?
- Is there a connection between southern Antelope Valley and the Fish Creek Basin through the Fish Creek Range?
- What controls the northward propagation of water-level declines from southern Diamond Valley to northern Diamond Valley?
- Is underflow from Garden Valley a major contributor of recharge to northern Diamond Valley?
- Do the Diamond Mountain carbonates play a role in the regional hydrology?
- How much water is discharged from playas and phreatophytes? Has this number changed since pre-pumping?
- Can we better define alluvial aquifer volumes?

Summary

The Diamond Valley flow system, an area of about 3,120 mi^2 in central Nevada, consists of five hydrographic areas: Monitor, Antelope, Kobeh, and Diamond Valleys and Stevens Basin. Although these five areas are in a remote part of Nevada, local government officials and citizens are concerned that the water resources of the flow system eventually could be further developed for irrigation or mining purposes or potentially for municipal use outside the study area. In order to better understand the flow system, the USGS, in cooperation with Eureka, Lander, and Nye Counties and the Nevada Division of Water Resources, is conducting a multi-phase study of the flow system. The overall objective of the study is to develop an understanding of the flow system that accounts for (1) the occurrence and movement of ground water in basin-fill and carbonate-rock aquifers and interactions between the two types of aquifers; (2) all natural inflow and outflow processes; (3) subsurface flow between basins and between aquifers; and (4) the effects of ground-water withdrawals on the different aquifers. This report describes the results of phase one, the objectives of which are to (1) define the hydrogeologic framework of the flow system, (2)

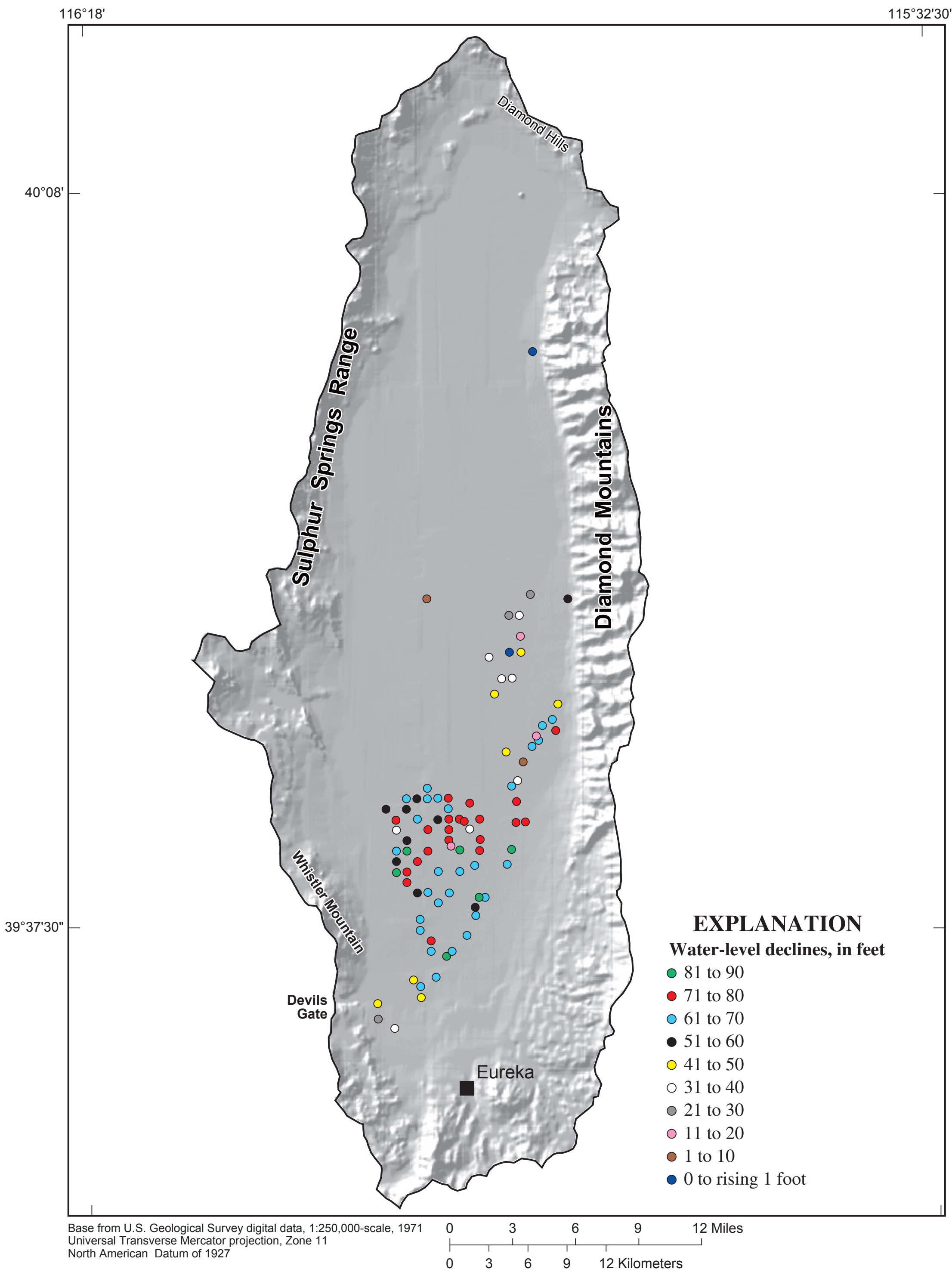


Figure 4. Locations of wells and water-level declines in Diamond Valley, central Nevada.

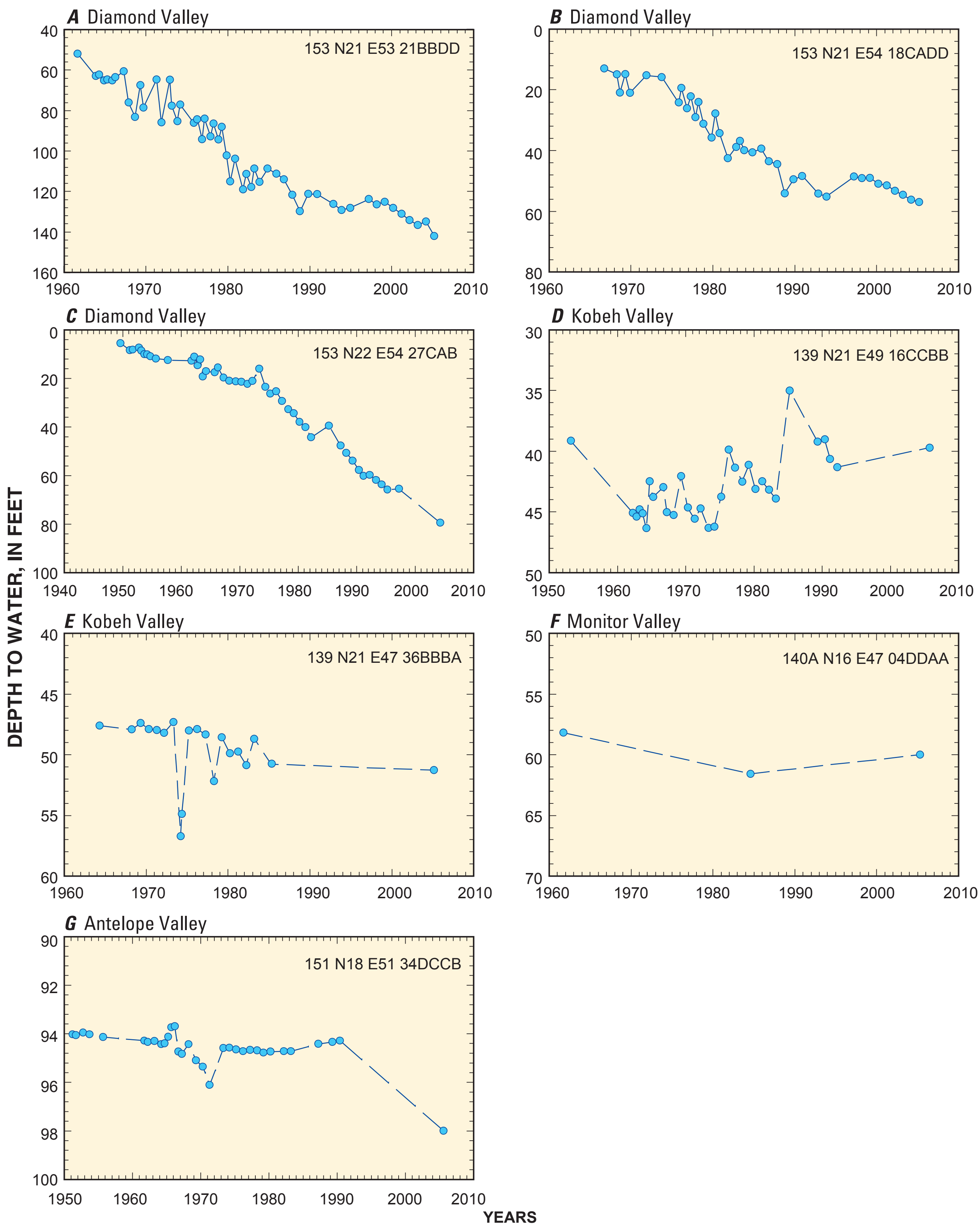


Figure 5. Depth to water at wells in (***A, B, C***) Diamond Valley, (***D, E***) Kobeh Valley, (***F***) Monitor Valley, and (***G***) Antelope Valley.

evaluate the occurrence and movement of ground water in and among the principal basin-fill aquifers of the flow system, and (3) quantify historical water-level changes in these aquifers.

The five main hydrogeologic units that either store and transmit ground water or impede its flow are (1) carbonate rocks consisting of limestones and dolomites of Middle Cambrian to Devonian age and of Pennsylvanian age; (2) siliciclastic sedimentary rocks consisting of shales, siltstones, sandstones, and conglomerates of Cretaceous age to Upper Cambrian; (3) igneous intrusive rocks of Jurassic, Cretaceous and Tertiary age; (4) volcanic rocks of early Tertiary age, and (5) basin-fill deposits of Tertiary and Quaternary age. The first four units make-up mountain ranges and the deep structural basins in which basin-fill deposits have accumulated. Basin-fill deposits comprise the most extensive aquifers in the study area. Carbonate rocks also function as aquifers, but their extent and interconnections with basin-fill aquifers are poorly understood. The other three hydrogeologic units generally impede the movement of ground water.

Ground-water flow in southern Monitor Valley is from the valley margins toward the valley axis and then northward to a large area of discharge by ET south of a group of hills consisting of volcanic rocks. The hills impede the northward movement of ground water forming the large discharge area. Ground-water flow in northern Monitor and Antelope Valleys is from valley margins toward the valley axis and then northward to Kobeh Valley. Ground-water flow in Kobeh Valley is eastward from the Simpson Park Mountains and southward from the Roberts Mountains. All of this ground-water flow converges in an area of central and eastern Kobeh Valley and northern Antelope Valley. The result is another large area of ground-water discharge by ET. Subsurface flow from Kobeh Valley to Diamond Valley occurs in basin-fill deposits at Devils Gate.

Prior to irrigation development in the 1960s, ground-water flow in Diamond Valley was from valley margins toward the valley axis and then northward to a large discharge area at the north end of the valley. During the last 40 years, however, ground-water levels in southern Diamond Valley have declined as much as 90 ft as a result of pumping for irrigation. In this part of Diamond Valley, flow is from the valley margins toward the irrigated area. In northern Diamond Valley, flow is still northward to the large discharge area.

Subsurface flow through mountain ranges is indicated in two parts of the study area. Subsurface inflow from Garden Valley (outside the study area) through the Sulphur Springs Range to Diamond Valley was identified in previous studies. Potential subsurface outflow from southeastern Antelope Valley through the Fish Creek Range to Little Smoky Valley (outside the study area) was identified as part of this study. In both cases, the flow is thought to be through carbonate rocks.

Water levels in the Diamond Valley flow system have changed over time as a result of pumpage for irrigation, municipal, domestic, and mining uses and as a result of annual and long-term variations in precipitation. Most pumpage has been for irrigation in southern Diamond Valley where the irrigated area expanded from 3,200 acres in 1961 to 22,200 acres in 1990. Except for scattered stock wells, the ground-water resources of Monitor, Antelope, Kobeh, and northern Diamond Valleys are largely undeveloped.

Measured water levels in the basin-fill aquifer of southern Diamond Valley have declined over an area about 10 mi wide and 20 mi long since the 1960s when pumping began. Declines have been as much as 90 ft in the southern part of the area, and have been less than 10 ft in northernmost parts of the area.

Long-term records indicate that depths to water at two wells in central Kobeh Valley ranged from 35 to 46 ft and 48 to 56 ft below land surface, respectively. Annual water-level fluctuations at both wells generally have been no more than a few feet. The water-level records at these wells may be typical of other parts of the study area where depths to water do not exceed 60 ft. At greater depths, water-level fluctuations are expected to be less. For instance, depths to water at a well in northern Antelope Valley from 1964 to 2005 were 94–98 ft below land surface and annual fluctuations were less than 1 ft.

References Cited

Arteaga, F.E., Smith, J.L., and Harrill, J.R., 1995, Irrigated croplands, estimated pumpage, and water-level changes in Diamond Valley, Eureka and Elko Counties, Nevada, through 1990: U.S. Geological Survey Open-File Report 95–107, 68 p.

Cardinalli, J.L., Roach, L.M., Rush, F.E., and Vasey, B.J., 1968, State of Nevada hydrographic areas: Nevada Division of Water Resources map, scale 1:500,000.

Dinwiddie, G.A., 1968, Hydraulic testing of wells in central Nevada: U.S. Geological Survey Technical Letter Central Nevada-20, 110 p.

Eakin, T.E., 1962, Ground-water appraisal of Diamond Valley, Eureka and Elko Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources - Reconnaissance Series Report 6, 60 p.

Harrill, J.R., 1968, Hydrologic response to irrigation pumping in Diamond Valley, Eureka and Elko Counties, Nevada, 1950-65: Nevada Department of Conservation and Natural Resources, Water Resources Bulletin 35, 85 p.

Harrill, J.R., Gates, J.S., and Thomas, J.M., 1988, Major ground-water flow systems in the Great Basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey Hydrologic-Investigations Atlas HA–694–C.

Houghton, J.G., Sakamoto, C.M., and Gifford, R.O., 1975, Nevada’s weather and climate: Nevada Bureau of Mines and Geology Special Publication 2, 78 p.

Kleinhampl, F.J., and Ziony, J.I., 1985, Geology of northern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 99A, 172 p., scale 1:250,000.

Lohman, S.W., 1972, Definitions of selected ground-water terms, revisions and conceptual refinements: U.S. Geological Survey Water-Supply Paper 1988, 21 p.

Maurer, D.K., Plume, R.W., Thomas, J.M., and Johnson, A.K., 1996, Water resources and effects of changes in ground-water use along the Carlin Trend, north-central Nevada: U.S. Geological Survey Water-Resources Investigations Report 96–4134, 146 p.

Maurer, D.K., Lopes, T.J., Medina, R.L., and Smith, J.L., 2004, Hydrogeology and hydrologic landscape regions of Nevada: U.S. Geological Survey Scientific Investigations Report 2004–5131, 36 p.

McKee, E.H., 1986, Geologic map of the Roberts Wilderness Study Area, Eureka County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF–1844, 1 sheet, scale1:48,000.

Plume, R.W., 1996, Hydrogeologic framework of the Great Basin Region of Nevada, Utah, and adjacent states: U.S. Geological Survey Professional Paper 1409–B, 64 p.

Plume, R.W., 2005, Changes in ground-water levels in the Carlin Trend area, north-central Nevada, 1989–2003: U.S. Geological Survey Scientific Investigations Report 2005–5075, 14 p.

Prudic, D.E., Harrill, J.R., and Burbey, T.J., 1995, Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah, and adjacent states: U.S. Geological Survey Professional Paper 1409-D, 102 p.

Roberts, R.J., Montgomery, K.M., and Lehner, R.E., 1967, Geology and mineral resources of Eureka County, Nevada: Nevada Bureau of Mines and Geology Bulletin 64, 152 p.

Rush, F.E., 1968, Index of hydrographic areas: Nevada Division of Water Resources Information Report 6, 38p.

Rush, F.E., and Everett, D.E., 1964, Ground-water appraisal of Monitor, Antelope, and Kobeh Valleys, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources - Reconnaissance Report 30, 45 p.

Rush, F.E., 1966, Water-resources appraisal of Little Fish Lake, Hot Creek, and Little Smoky Valleys, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources - Reconnaissance Report 38, 38 p.

Stewart, J.H., 1980, Geology of Nevada, a discussion to accompany the geologic map of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Stewart, J.H., and Carlson, J.E., 1978, Geologic Map of Nevada: U.S. Geological Survey Map, scale 1:500,000.

Stewart, J.H., and McKee, E.H., 1977, Geology and mineral deposits of Lander County, Nevada, Geology: Nevada Bureau of Mines and Geology Bulletin 88, pt. I, 59 p.

Sweetkind, D.S., Belcher, W.R., Faunt, C.C., and Potter, C.J., 2004, Geology and Hydrogeology, *in* Belcher, W.R., ed., 2004, Death Valley regional ground-water flow system, Nevada and California—Hydrogeologic framework and transient ground-water flow model: U.S. Geological Survey Scientific Investigations Report 2004–5205, p. 21-98.

U.S. Geological Survey National GAP Analysis Program. 2005. Southwest Regional GAP Analysis Project—Land Cover Descriptions. RS/GIS Laboratory, College of Natural Resources, Utah State University.

U.S. Geological Survey, 1989, National Water Information System User's Manual, vol. 2, chap. 4, Ground-water site inventory system: U.S. Geological Survey Open-File Report 89–587, 294 p.

Winograd, I.J., and Thordarson, William, 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712–C, 126 p.

Zietz, I., Gilbert, F.P., and Kirby, J.R., 1978, Aeromagnetic map of Nevada—Color coded intensities: U.S. Geological Survey Geophysical Investigations Map GP–922, scale 1:1,000,000.

Zoback, M.L., McKee, E.H., Blakely, R.J., and Thompson, G.A., 1994, The northern Nevada rift—Regional tectonomagmatic relations and middle Miocene stress direction: Geological Society of America Bulletin, v. 106, no. 3, p. 371–382.

Appendixes

Appendix 1. Selected drillers' logs for wells in Monitor, Kobeh, and Antelope Valleys, central Nevada.

Material	From (feet)	To (feet)	Thickness (feet)
Nevada log number 40006			
Clay	0	7	7
Black clay	7	20	13
Brown clay	20	22	2
Sand	22	35	13
Brown clay	35	58	23
Sand	58	73	15
Brown clay	73	85	12
Large gravel	85	96	11
Black clay	96	100	4
Nevada log number 23425			
Top soil	0	2	2
Large gravel	2	16	14
Gravel	16	35	19
Clay	35	90	55
Gravelly clay	90	120	30
Clay	120	190	70
Sand	190	225	35
Clay	225	232	7
Nevada log number 26753			
Silty sand gravel and clay	0	47	47
Gravel with silt and clay	47	176	131
Sand and gravel	178	188	10
Gravel and minor clay	188	210	22
Silty clay with gravel	210	223	13
Silty, sandy gravels	223	353	130
Gravel	353	390	37
Sandy silt	390	403	13
Silty sand and gravel	403	488	85
Silty sand and gravel	488	560	72
Nevada log number 4254			
Gravel and clay	0	23	23
Gravel and boulders	23	31	8
Gravel and clay	31	142	111
Gravel and sand	142	152	10
Gravel and clay	152	187	35
Gravel and sand	187	237	50
Yellow clay	237	241	4
Rocks, gravel and sand	241	350	109

Appendix 1. Selected drillers' logs for wells in Monitor, Kobeh, and Antelope Valleys, central Nevada—Continued.

Material	From (feet)	To (feet)	Thickness (feet)
Nevada log number 217			
Soil	0	8	8
Sand	8	55	47
Clay	55	57	2
Sand	57	80	23
Hard pan	80	123	43
Sandy clay	123	170	47
Clay	170	200	30
Red clay	200	225	25
Sandy clay	225	235	10
White clay	235	250	15
Hard white ls	250	300	50
White clay	300	380	80
Hard chalk	380	400	20
Clay	400	410	10
Sandy clay	410	420	10
Hard pan	420	440	20
White clay	440	460	20
Clay	460	480	20
Ls	480	690	210

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record.

Water-level date: --, indicates exact date is unknown.

Water level below land surface: NA, not available.

Water-level change: Negative water-level change indicates decline; positive indicates rise.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
		Kobeh Valley				
1	392636116365601	139 N18 E48 07ACDD	6,371	04/14/64 04/20/05	154 154	0
2		139 N18 E48 09CBBB	6,450	05/25/05	172	
3	392754116213201	139 N18 E50 05DACA	6,320	11/01/80 10/31/91 04/07/05	160 150 160	-0
4	392703116380401	139 N18H E47 01ABDA	6,310	11/2/1991 04/04/05	84 86	-2
5	393155116411801	139 N19 E47 09ADDC	6,359	04/06/05	146	
6		139 N19 E47 15CBBB	6,300	04/06/05	94	
7		139 N19 E47 15DBCC	6,275	04/06/05	71	
8		139 N19 E47 21DADD	6,273	04/06/05	64	
9		139 N19 E47 22BBBB	6,282	04/06/05	76	
10		139 N19 E47 22CDBB	6,265	04/06/05	65	
11		139 N19 E47 23AACC	6,252	04/06/05	49	
12		139 N19 E47 23BDBB	6,257	04/06/05	54	
13	392849116405701	139 N19 E47 28ACCC	6,282	02/01/81 04/06/05	64 67	-3
14	392821116425401	139 N19 E47 31AADC	6,308	07/31/84 04/04/05	92 95	-2
15	392800116380001	139 N19 E47 36BBBA	6,257	04/19/58 04/14/64 03/19/68 03/25/85 04/05/05	56 48 48 51 51	5
16	393155116310301	139 N19 E48 12ABCC	6,181	04/06/05	8	
17		139 N19 E48 22BDAA	6,242	04/06/05	53	
18		139 N19 E48 34BCCB	6,325	05/10/05	133	
19		139 N19 E49 04CCDC	6,165	04/07/05	12	
20		139 N19 E49 08BDDD	6,163	05/25/05	2	
21		139 N19 E49 18CABD	6,199	04/07/05	27	
22	393058116244501	139 N19 E49 24BBCA	6,259	10/31/91 04/07/05	105 102	3
23		139 N19 E49 29CCCA	6,350	04/07/05	165	
24		139 N19 E50 30DBCB	6,268	05/10/05	127	
25		139 N19 E51 27ACBC	6,344	04/07/05	280	
26		139 N20 E48 10CABA	6,239	04/06/05	52	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
27		139 N20 E49 23CACB	6,138	04/05/05	10	
28		139 N20 E49 24ACAB	6,113	04/05/05	6	
29		139 N20 E49 27CBBC	6,139	04/05/05	1	
30		139 N20 E51 05CBCC	6,140	09/12/05	11	
31		139 N20 E52 17BBDD	6,015	04/05/05	12	
32	393546116092301	139 N20 E52 17BDDA	6,020	11/18/53	18	
				04/05/05	17	
33	393544116084801	139 N20 E52 17DBAB	6,035	04/05/05	32	
34		139 N20 E52 18ABDB	6,006	04/05/05	4	
35		139 N20 E52 18BBBB	6,009	04/05/05	6	
36		139 N20 E52 21DBDA	6,000	04/05/05	7	
37		139 N21 E48 15AAAA	6,488	07/27/05	6	
38		139 N21 E48 35DBAC	6,208	04/06/05	27	
39	394059116282901	139 N21 E49 16CCBB	6,230	01/15/48	41	1
				09/13/49	41	
				03/18/92	41	
				09/12/05	40	
40		139 N21 E49 25BBDA	6,185	04/06/94	13	2
				03/29/95	12	
				04/06/05	11	
41		139 N21 E50 17BACC	6,222	04/06/05	59	
42	394036116183401	139 N21 E50 23AABD	6,221	11/01/91	34	-2
				08/12/02	35	
				04/06/05	36	
43		139 N21 E51 01 CCCA	6,282	06/12/05	204	
44		139 N21 E51 24DDCA	6,150	04/05/05	81	
45		139 N21 E51 36DCDB	6,079	04/05/05	39	
46	393808116105801	139 N21 E51 36DCDC	6,080	09/30/82	40	3
				08/12/02	38	
				04/05/05	37	
47		139 N21 E51H 07BBDD	6,272	04/05/05	204	
48		139 N22 E50 31CCAC	6,404	04/06/05	234	
49		139 N22 E51 30BABB	6,470	04/05/05	149	
			Monitor Valley			
50	390438116394301	140 A N14 E47 03DBBB	6,740	11/03/91	80	-1
				07/26/05	81	
51	390150116403801	140 A N14 E47 21DDDB	6,800	11/03/91	77	-2
				07/26/05	79	
52	390608116364901	140 A N15 E48 30CADA	6,692	01/01/59	10	3
				07/25/05	5	
				09/14/05	7	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
53	391503116401001	140 A N16 E47 04DDAA	6,434	09/21/61	58	-2
				07/31/84	62	
				04/18/05	60	
54		140 A N16 E47 35ABAC	6,514	06/10/05	99	
55	391058116385501	140 A N16 E47 35CBAB	6,533	11/02/91	116	-2
				06/10/05	118	
56	391948116415401	140 A N17 E47 08ACAD	6,382	04/14/64	77	0
				04/18/05	77	
57		140 A N17 E48 18CBCB	6,680	07/25/05	193	
58	392445116414800	140 A N18 E47 08DBCB	6,317	04/04/05	92	
59	392654116421401	140 N18H E47 08BBDC	6,298	08/12/02	84	-1
				04/04/05	85	
60		140 B N09 47E 07DDCB	7,091	07/26/05	168	
61		140 B N10 E46 12ACAA	6,889	07/26/05	3	
62	384005116480101	140 B N10 E46 34AACD	7,015	11/04/91	101	-1
				06/11/05	102	
63		140 B N11 E46 04ADCC	6,845	07/26/05	15	
64	384736116481801	140 B N11E46 16BDDB	6,923	11/03/91	54	1
				06/11/05	52	
65		140 B N11 E46 36ABBA	6,868	09/15/05	4	
66		140 B N12 E46 13CCBC	6,815	12/11/81	15	1
				06/11/05	14	
67	385819116462301	140 B N12 E46 15ADDA	6,939	11/03/91	139	-0
				06/11/05	139	
68		140 B N12 E47 07AACB	6,788	07/26/05	2	
69	385306116412001	140 B N12 E47 09DCAB	6,896	11/01/81	94	25
				11/03/91	93	
				07/26/05	69	
Antelope Valley						
70	391114116185101	151 N15 E50 02CCBD	6,460	11/01/80	123	0
				01/01/81	123	
				10/30/91	121	
				07/25/05	123	
71		151 N16 E50 8DDCD	6,500	04/25/05	177	
72	391330116184101	151 N16 E50 26CDCA	6,395	05/25/05	62	
73	391342116194401	151 N16 E50 27CADC	6,438	10/30/91	107	-1
				05/25/05	108	
74	391626116155901	151 N16 E51 07DAAD	6,321	06/01/63	26	-1
				04/19/05	27	
75	391855116191501	151 N17 E50 26BCCC	6,400	10/30/91	126	
				04/07/05	132	
76	391935116144901	151 N17 E51 20DD	6,340	11/01/80	96	1
				03/01/81	95	
				07/27/05	95	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
77		151 N17 E51 22BBBD	6,339	09/13/05	90	
78	391835116163701	151 N17 E51 27C	6,410	09/--/42	157	-3
				07/20/49	161	
				05/24/05	160	
79	392137116094901	151 N17 E52 07CA	6,560	08/26/42	318	1
				05/24/05	317	
80		151 N18 E49 02DBAA	6,610	06/11/05	63	
81		151 N18 E51 10BADB	6,230	04/16/64	177	21
				09/13/05	156	
82	392529116133901	151 N18 E51 22BCCD	6,235	04/14/64	59	-1
				05/11/05	60	
83		151 N18 E51 31BCDD	6,200	04/25/05	6	
84	392310116125001	151 N18 E51 34DCCB	6,330	07/20/49	94	-4
				09/19/50	94	
				07/27/05	98	
85	392847116143901	151 N19 E51 33CBBD	6,197	11/01/80	82	-30
				01/01/81	83	
				08/13/02	106	
				04/20/05	112	
Diamond Valley						
86	393731115570301	153 N20 E53 01BDDA	5,952	11/01/61	82	-72
				03/01/65	86	
				03/15/04	151	
				09/30/05	154	
87	393705115574201	153 N20 E53 02DDDD	5,967	09/01/63	102	-66
				11/01/63	99	
				03/15/04	167	
				03/10/05	168	
88	393743116002101	153 N20 E53 04ACDD	5,924	09/13/61	57	-70
				11/01/61	55	
				03/15/04	124	
				03/10/05	127	
89	393714116000301	153 N20 E53 04DDBB	5,931	11/01/61	57	-69
				11/01/63	59	
				03/15/04	123	
				03/10/05	126	
90	393645115592801	153 N20 E53 10BADD	5,942	04/05/66	67	-65
				10/01/73	98	
				03/19/02	144	
				03/15/04	132	
91	393623115593301	153 N20 E53 10CACC	5,942	04/05/66	73	-71
				10/01/73	96	
				03/10/05	141	
				09/12/05	144	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
92	393613115585101	153 N20 E53 10DDD	5,956	08/09/61	79	-89
				11/01/63	85	
				03/17/03	162	
				03/15/04	168	
93	393623115582401	153 N20 E53 11CDBB	5,955	04/05/66	91	-66
				10/01/73	102	
				03/15/04	150	
				03/10/05	157	
94	393519115592401	153 N20 E53 15CDDD	5,996	11/01/65	122	-60
				04/05/66	122	
				03/19/02	185	
				03/17/03	183	
95		153 N20 E53 17DCAA	5,947	09/13/05	146	
96		153 N20 E53 20CBCD	5,960	09/13/05	165	
97		153 N20 E53 21BBAC	5,965	03/--/76	117	-49
				11/--/76	123	
				03/15/04	175	
				03/09/05	166	
98	393505116003501	153 N20 E53 21BDDD	5,968	04/04/66	98	-68
				11/03/75	120	
				03/15/04	163	
				03/10/05	166	
99	393440116001901	153 N20 E53 21CDDC	5,976	04/04/66	124	-51
				10/01/73	121	
				03/15/04	171	
				03/10/05	175	
100		153 N20 E53 24DBBD	6,077	09/12/05	268	
101	393413116023001	153 N20 E53 30ABCC	5,985	12/06/60	55	-48
				11/--/63	66	
				03/15/04	90	
				03/09/05	103	
102		153 N20 E53 30CAAB	6,005	09/13/05	102	
103		153 N20 E53 30CABB	6,005	09/13/05	106	
104	393343116023001	153 N20 E53 30DCCC	6,029	04/26/66	94	-29
				10/01/73	134	
				03/15/04	122	
				03/09/05	123	
105		153 N20 E53 32AAAB	6,010	09/13/05	214	
106	393332116015001	153 N20 E53 32BBBA	6,024	04/04/66	88	-34
				10/08/66	98	
				04/04/01	117	
				03/19/02	122	
107	393327116013601	153 N20 E53 32BDCC	6,052	04/04/66	113	-37
				10/01/73	138	
				03/09/05	144	
				09/13/05	150	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
108	393310116013901	153 N20 E53 32CCAA	6,061	04/04/66	124	-34
				10/01/73	149	
				11/27/95	155	
				04/04/01	158	
109	394248115572701	153 N21 E53 01BCAA	5,884	04/06/66	37	-58
				11/01/80	63	
				03/29/01	92	
				03/21/02	95	
110	394232115572701	153 N21 E53 01CDCC	5,889	02/03/61	33	-78
				04/--/65	38	
				03/17/04	108	
				03/16/05	111	
111	394232115584201	153 N21 E53 02CCAA	5,886	05/01/61	35	-72
				11/--/1963	38	
				03/17/04	105	
				03/16/05	107	
112	394310115594702	153 N21 E53 03BBDD2	5,883	10/19/67	39	-62
				08/26/68	45	
				03/17/04	99	
				03/16/05	101	
113	394230115594401	153 N21 E53 03CDBB	5,887	11/--/61	38	-69
				03/--/66	40	
				03/17/04	105	
				03/16/05	107	
114	394238115593301	153 N21 E53 03DDBB	5,884	11/--/61	38	-69
				11/--/63	40	
				03/17/04	105	
				03/16/05	107	
115	394258116000401	153 N21 E53 04 ADDD	5,883	05/03/61	36	-60
				11/--/63	37	
				03/20/00	100	
				03/29/01	96	
116	394228116004601	153 N21 E53 04CDBB	5,882	01/01/60	38	-66
				04/06/66	38	
				03/17/04	105	
				03/16/05	104	
117	394233116000401	153 N21 E53 04DDBB	5,881	07/21/63	42	-63
				11/--/63	40	
				03/17/04	102	
				03/16/05	105	
118	394243116030601	153 N21 E53 06CDBB	5,880	11/03/75	57	-40
				03/01/76	52	
				03/20/03	95	
				03/17/04	97	
119	394220116020001	153 N21 E53 08BACC	5,892	11/08/76	61	-58
				03/05/77	64	
				03/17/04	115	
				03/15/05	119	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
120	394145116013401	153 N21 E53N 08DCAA	5,892	11/--/61	42	-79
				11/--/63	58	
				03/17/04	117	
				03/15/05	121	
121	394219116005401	153 N21 E53 09BBDD	5,892	07/20/64	55	-55
				11/--/64	39	
				03/17/04	107	
				03/15/05	110	
122	394149116003201	153 N21 E53 09DBDD	5,892	04/06/66	44	-70
				10/01/73	48	
				03/17/04	112	
				03/15/05	114	
123	394147115592501	153 N21 E53 10DCAA	5,894	11/03/75	58	-44
				03/01/76	54	
				03/04/99	98	
				03/20/00	102	
124	394151115591301	153 N21 E53 10DCAA	5,894	03/30/01	116	-3
				03/21/02	112	
				03/17/04	117	
				03/15/05	119	
125	394218115584401	153 N21 E53 11BCAA	5,891	11/06/60	36	-65
				11/--/63	42	
				03/04/99	95	
				03/29/01	101	
126	394149115584301	153 N21 E53 11CDBB	5,893	09/30/60	36	-82
				11/--/63	43	
				03/17/04	115	
				03/15/05	118	
127	394147115581001	153 N21 E53 11DACC	5,893	04/06/66	43	-73
				11/14/77	35	
				03/20/03	113	
				03/17/04	115	
128	394144115574801	153 N21 E53 12CCBC	5,893	05/12/61	44	-75
				11/--/63	47	
				03/19/03	115	
				03/17/04	119	
129	394145115571701	153 N21 E53 12DCAA	5,888	04/06/66	39	-72
				10/01/73	73	
				03/17/04	110	
				03/15/05	111	
130	394118115574601	153 N21 E53 13BACC	5,894	11/--/61	42	-38
				11/--/64	50	
				03/20/00	93	
				03/19/03	80	
131	394053115574101	153 N21 E53 13DACC	5,897	04/06/66	44	-76
				11/--/76	67	
				03/17/04	118	
				03/15/05	120	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
132	394116115584801	153 N21 E53 14BACC	5,896	04/06/66	45	-76
				11/--/75	63	
				03/17/04	119	
				03/15/05	121	
133	394056115585001	153 N21 E53 14CACC	5,899	04/06/66	48	-79
				10/01/73	65	
				03/17/04	124	
				03/11/05	127	
134	394118115595501	153 N21 E53 15BACC	5,897	11/--/61	111	-10
				11/--/64	116	
				03/17/04	118	
				03/11/05	121	
135	394101116005701	153 N21 E53 16CCAA	5,911	10/01/73	75	-62
				11/03/75	69	
				03/17/04	134	
				03/15/05	137	
136	394129116013001	153 N21 E53 17ABD	5,901	06/27/81	90	-35
				03/29/83	89	
				03/29/01	119	
				03/19/03	125	
137		153 N21 E53 18CDBB	5,924	09/14/05	118	
138	394037116102101	153 N21 E53 20AACC	5,926	03/--/61	71	-71
				09/13/61	72	
				03/16/04	134	
				03/11/05	142	
139	394007116012801	153 N21 E53 20 DDBB	5,935	10/01/73	108	-54
				11/03/75	105	
				03/16/04	159	
				03/15/05	162	
140	394033116005201	153 N21 E53 21BBDD	5,916	08/31/61	52	-90
				11/--/63	63	
				03/16/04	135	
				03/15/05	142	
141	394004116002101	153 N21 E53 21DCAA	5,910	04/06/66	58	-80
				10/01/73	75	
				03/16/04	136	
				03/11/05	138	
142	394032115594401	153 N21 E53 22BDBB	5,904	05/12/63	51	-75
				11/--/63	52	
				03/28/01	122	
				03/20/02	126	
143	394036115580101	153 N21 E53 23AACC	5,904	09/18/60	44	-84
				11/--/63	52	
				03/16/04	126	
				03/11/05	128	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
144		153 N21 E53 23BABA	5,903	11/16/93	114	-11
				12/08/94	111	
				03/16/04	123	
				03/11/05	125	
145	394025115571701	153 N21 E53 24ADBB	5,903	04/06/66	47	-76
				03/26/97	104	
				03/16/04	121	
				03/15/05	123	
146	393956115571101	153 N21 E53 24CDDD	5,919	06/20/64	62	-72
				04/06/66	62	
				03/16/04	132	
				03/11/05	134	
147	393942115580401	153 N21 E53 26AACC	5,909	09/13/61	48	-70
				04/--/64	53	
				03/19/03	122	
				03/16/04	118	
148	393940115591701	153 N21 E53 27ACAA	5,908	04/06/66	55	-71
				10/01/73	77	
				03/18/04	123	
				03/15/05	126	
149	393942116005401	153 N21 E53 28BBDD	5,938	11/01/65	91	-72
				03/16/04	161	
				03/15/05	163	
150	393915116011001	153 N21 E53 28CCAA	5,940	04/06/66	86	-73
				10/01/73	104	
				03/16/04	157	
				03/11/05	159	
151	393942116013601	153 N21 E53 29ADBB	5,940	04/06/66	87	-81
				10/24/89	143	
				03/20/02	158	
				03/16/04	168	
152	393838116002401	153 N21 E53 33AACC	5,920	03/--/64	60	-61
				11/--/64	56	
				03/16/04	119	
				03/11/05	121	
153	393849116000201	153 N21 E53 34BCAA	5,918	07/10/61	60	-68
				04/--/64	48	
				03/19/02	122	
				03/15/04	128	
154	393816115591701	153 N21 E53 34DDBB	5,919	04/05/66	58	-67
				10/01/73	72	
				03/15/04	122	
				03/10/05	125	
155	393842115584201	153 N21 E53 35BDBB	5,917	04/05/66	59	-62
				11/09/83	112	
				03/15/04	123	
				03/11/05	121	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
156	393850115570101	153 N21 E53 36ACDC	5,941	08/29/60	62	-85
				11/--/63	71	
				03/15/04	144	
				03/10/05	147	
157	393844115570601	153 N21 E53 36ADDD	5,946	04/05/66	79	-72
				11/10/83	113	
				03/15/04	143	
				03/10/05	151	
158	393810115571501	153 N21 E53 36CDDD	5,943	11/01/63	90	-57
				03/15/04	144	
				03/10/05	147	
159		153 N21H E53 36CBCB	5,883	09/14/05	93	
160	394312115551601	153 N21 E54 05BDBB	5,874	11/--/64	26	-70
				04/07/66	23	
				03/18/04	92	
				03/16/05	96	
161	394232115545701	153 N21 E54 5DCCC	5,878	04/07/66	24	-79
				10/01/73	47	
				03/18/04	100	
				03/16/05	103	
162	394141115552601	153 N21 E54 8CDDD	5,891	08/29/64	37	-77
				11/--/65	34	
				03/18/04	113	
				03/16/05	114	
163	394141115543801	153 N21 E54 8DDDD	5,896	04/07/66	46	-83
				12/03/85	NA	
				03/18/04	125	
				03/16/05	129	
164	394037115551401	153 N21 E54 20BACC	5,922	04/07/66	68	-79
				08/27/68	88	
				03/18/04	150	
				03/15/05	147	
165	393958115552701	153 N21 E54 20CCCC	5,931	04/07/66	83	-68
				11/03/75	96	
				03/18/04	148	
				03/15/05	151	
166		153 N21 E54 20DCCC	5,943	09/12/05	214	
167	394327115545301	153 N21H E54 32DCCC	5,873	11/07/83	58	-34
				11/01/84	60	
				03/18/04	89	
				03/15/05	91	
168	394717116044901	153 N22 E52 14ABDA	5,858	09/14/05	67	
169		153 N22 E52 16CCCB	6,117	09/14/05	32	
170		153 N22 E52 17DDAC	6,137	09/14/05	25	
171		153 N22 E52 17DDCA	6,150	09/14/05	30	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
172		153 N22 E52 36BBDB	5,820	09/14/05	28	
173	394839115550801	153 N22 E54 5CDBB	5,836	04/07/66	4	-41
				10/01/73	12	
				03/24/04	43	
				03/09/05	45	
174	394833115542001	153 N22 E54 5DDBB	5,835	04/07/66	4	-41
				11/03/75	13	
				03/21/03	42	
				03/24/04	44	
175	394835115561801	153 N22 E54 6CCCC	5,838	04/07/66	8	-39
				10/01/73	15	
				03/24/04	44	
				03/16/05	47	
176	394743115554302	153 N22 E54 7DDCD	5,845	06/29/60	14	-32
				11/--/63	13	
				03/24/04	48	
				03/16/05	46	
177	394743115550601	153 N22 E54 8CDCD	5,841	10/16/63	12	-38
				11/--/63	13	
				03/24/04	50	
				03/16/05	50	
178	394703115560401	153 N22 E54 18CADD	5,847	09/23/66	13	-44
				04/--/68	15	
				03/24/04	56	
				03/16/05	57	
179	394558115525801	153 N22 E54 22CCDD	5,857	03/15/62	8	-68
				11/--/65	15	
				03/24/04	73	
				03/16/05	76	
180	394520115524001	153 N22 E54 27CAB	5,866	8/11/49	5	-74
				3/15/51	8	
				3/24/97	65	
				4/13/04	79	
181	394542115533001	153 N22 E54 28AACC	5,857	11/10/58	8	-66
				11/--/61	14	
				03/24/04	76	
				03/16/05	74	
182		153 N22 E54 28CADD	5,861	11/20/92	68	-11
				11/22/93	67	
				03/24/04	80	
				03/16/05	79	
183	394507115534101	153 N22 E54 28DCCC	5,860	05/30/61	13	-66
				11/--/63	18	
				03/24/04	81	
				03/16/05	79	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

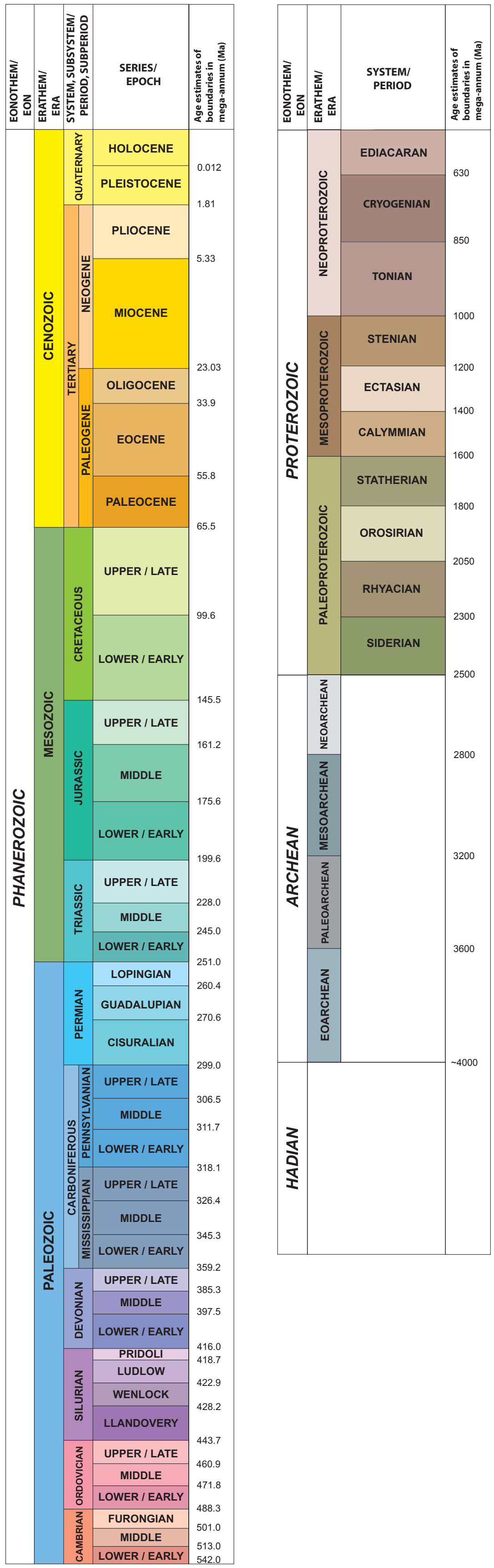
Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
184	394439115552901	153 N22 E54 32BCCC	5,864	11/03/75	31	-49
				03/05/77	32	
				03/18/04	78	
				03/16/05	80	
185		153 N22 E54 32DDCC	5,873	03/26/97	70	-13
				03/17/98	78	
				03/18/04	80	
				03/16/05	83	
186	394452115540801	153 N22 E54 33BBDD	5,851	05/01/61	60	-22
				11/--/64	18	
				03/18/04	79	
				03/16/05	82	
187	395255116051101	153 N23 E52 11ADAB	5,801	11/19/65	0	-8
				09/14/05	8	
188	395147116043901	153 N23 E52 13CDDD	5,800	03/28/97	10	-3
				04/04/01	12	
				09/14/05	13	
189	395100115593001	153 N23 E53 27BBBD	5,817	11/18/66	13	-3
				03/20/68	13	
				04/13/04	15	
				09/14/05	16	
190	395020116030001	153 N23 E53 29CCBD	5,820	04/28/73	14	-5
				05/13/74	14	
				04/13/04	16	
				09/14/05	19	
191	395220115561001	153 N23 E54 18DB	5,800	11/18/66	16	-2
				03/20/68	17	
				03/24/97	18	
				04/13/04	18	
192	395106115540601	153 N23 E54 20DDDD	5,820	04/07/66	0	-24
				03/10/82	12	
				03/21/03	22	
				03/24/04	24	
193	395044115524001	153 N23 E54 27ADBA	5,835	04/07/66	13	-51
				03/27/97	55	
				03/21/03	62	
				03/24/04	64	
194	395019115543801	153 N23 E54 29CDDD	5,820	11/--/64	6	-32
				11/--/65	4	
				03/24/04	37	
				03/16/05	38	
195	394927115543601	153 N23 E54 30DDDD	5,827	04/07/66	2	-32
				08/28/68	7	
				03/24/04	33	
				03/16/05	34	

Appendix 2. Selected well and water-level data for Kobeh, Monitor, Antelope, and Diamond Valleys for period of record—Continued.

Well number	U.S. Geological Survey standard identification[1]	Local well number[2]	Altitude of land surface (feet)	Water level		
				Date	Below land surface (feet)	Change (feet)
196	394927115543601	153 N23 E54 32DCCC	5,831	06/05/64	15	-16
				04/--/66	2	
				03/08/99	31	
				03/21/00	31	
197	395444116040301	153 N24 E52 36CCCA	5,806	09/14/05	16	
198	395914116023301	153 N24 E53 6BDAB		03/28/97	8	-1
				04/04/01	9	
199		153 N25 E54 28BCBC	5,810	03/27/97	12	0
				03/17/98	12	
				03/29/02	12	
				07/28/05	12	

[1]The U.S. Geological Survey site identification number consists of 15 digits and is based on the grid system of latitude and longitude. The first six digits denote degrees, minutes, and seconds of latitude; the next seven digits denote degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify sites within a 1-second grid. For example, the site identification for the first well listed in this appendix is 392636116365601. The number refers to 39°26'36" latitude, 116°36'56" longitude, and it is the first site recorded in that 1-second grid. This number is retained as a permanent identifier even if a more precise location is determined later.

[2]The Nevada local well number is based on an index of hydrographic areas for Nevada (Rush, 1968) and on the rectangular subdivision of the public lands referenced to Mount Diablo base line and meridian. Each number consists of four units separated by spaces. The first unit is the hydrographic area number. The second unit is township preceded by an N to indicate location north of the base line. The third unit is range preceded by an E to indicate location east of the meridian. The fourth unit consists of section number and letters designating quarter section, quarter-quarter section, and so on (A, B, C, and D indicate northeast, northwest, southwest, and southeast quarter, respectively). For example, the Nevada local well number for the first well listed in this appendix is 139 N18 E48 07ACDD. This well is in Kobeh Valley (139) and is the first site recorded in the southeast quarter, southeast quarter, southwest quarter, northeast quarter of section 7, Township 18 North, Range 48 East, Mount Diablo baseline and meridian.



Geologic time scale.

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