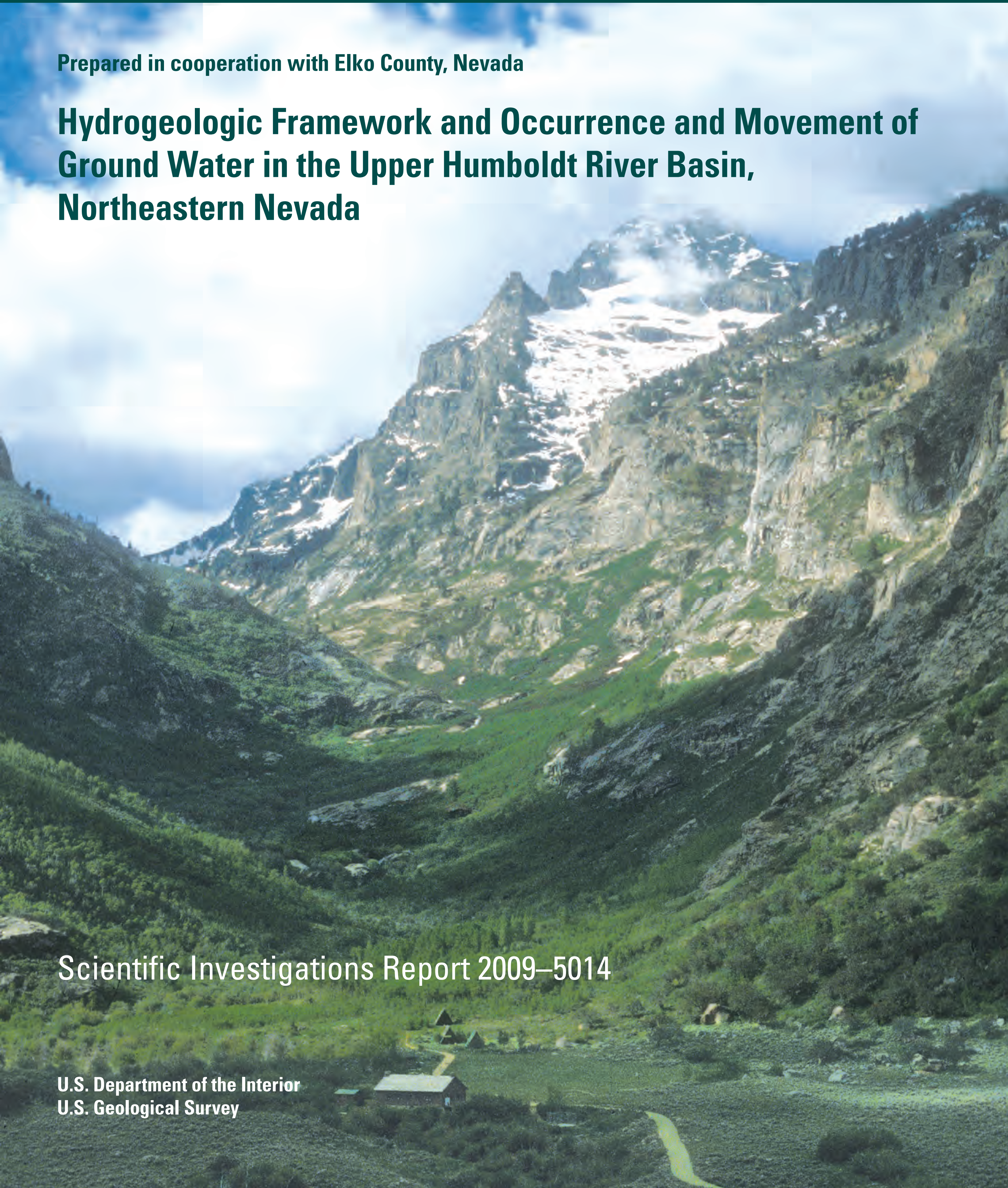
Prepared in cooperation with Elko County, Nevada

Hydrogeologic Framework and Occurrence and Movement of Ground Water in the Upper Humboldt River Basin, Northeastern Nevada



Scientific Investigations Report 2009–5014

U.S. Department of the Interior
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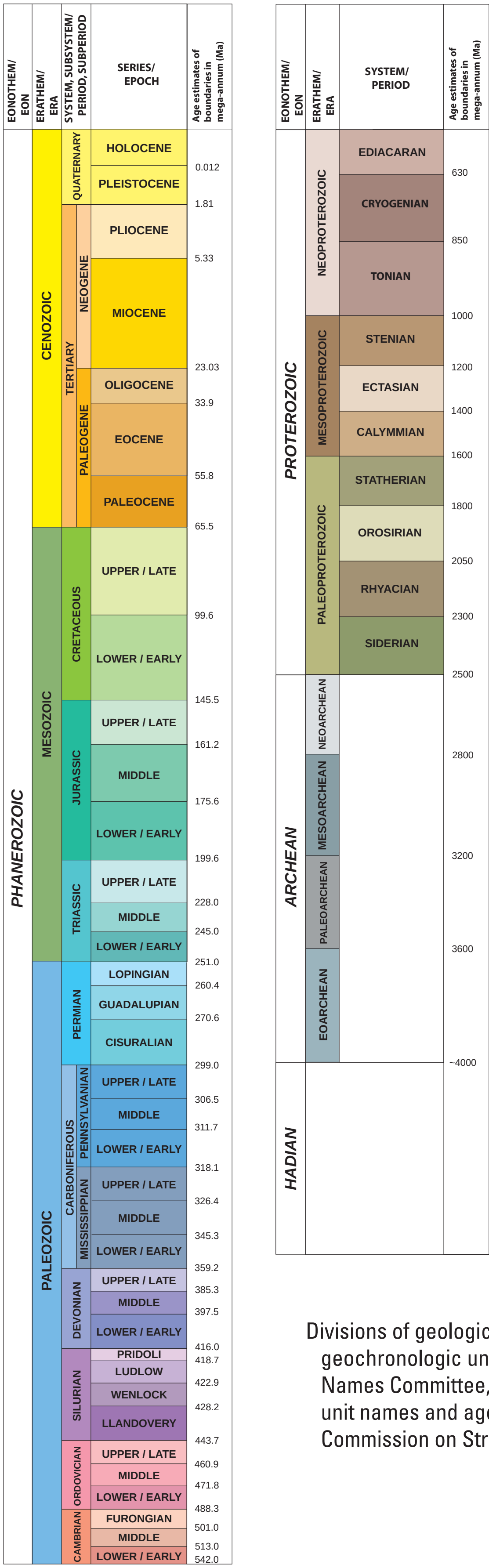
Photograph of Marys River looking south at the East Humboldt Range. (Photograph taken by Russell Plume, U.S. Geological Survey, Carson City, Nevada, April 1994.)

Photograph of late Eocene basin-fill deposits exposed at a gravel pit along State Route 226 about 1.3 miles west of State Route 225 (Mountain City Highway). The sediments exposed here are fairly typical of Tertiary age sediments that underlie basins of the study area (Alan Wallace, U.S. Geological Survey, written and oral commun., 2008). (Photograph taken by Russell Plume, U.S. Geological Survey, Carson City, Nevada, June 2007.)



Divisions of geologic time - major chronostratigraphic and geochronologic units (U.S. Geological Survey Geologic Names Committee, 2007). Reflects accepted and ratified unit names and age estimates from the International Commission on Stratigraphy.

Cover: Photograph of Right Fork Lamoille Canyon looking south. (Photograph taken by Russell Plume, U.S. Geological Survey, Carson City, Nevada, June 1981.)

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Datums

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 Occurrence and Movement of Ground Water in the Upper Humboldt River Basin, Northeastern Nevada

By Russell W. Plume

Abstract

The upper Humboldt River basin encompasses 4,364 square miles in northeastern Nevada, and it comprises the headwaters area of the Humboldt River. Nearly all flow of the river originates in this area. The upper Humboldt River basin consists of several structural basins, in places greater than 5,000 feet deep, in which basin-fill deposits of Tertiary and Quaternary age and volcanic rocks of Tertiary age have accumulated. The bedrock of each structural basin and adjacent mountains is composed of carbonate and clastic sedimentary rocks of Paleozoic age and crystalline rocks of Paleozoic, Mesozoic and Cenozoic age. The permeability of bedrock generally is very low except for carbonate rocks, which can be very permeable where circulating ground water has widened fractures through geologic time.

The principal aquifers in the upper Humboldt River basin occur within the water-bearing strata of the extensive older basin-fill deposits and the thinner, younger basin-fill deposits that underlie stream flood plains. Ground water in these aquifers moves from recharge areas along mountain fronts to discharge areas along stream flood plains, the largest of which is the Humboldt River flood plain. The river gains flow from ground-water seepage to its channel from a few miles west of Wells, Nevada, to the west boundary of the study area.

Water levels in the upper Humboldt River basin fluctuate annually in response to the spring snowmelt and to the distribution of streamflow diverted for irrigation of crops and meadows. Water levels also have responded to extended periods (several years) of above or below average precipitation. As a result of infiltration from the South Fork Reservoir during the past 20 years, ground-water levels in basin-fill deposits have risen over an area as much as one mile beyond the reservoir and possibly even farther away in Paleozoic bedrock.

Introduction

Background

The Humboldt River basin is the largest river basin that is entirely within the State of Nevada. Numerous diversions reduce flow in the river, and the diverted surface water is used almost exclusively for irrigation of crops and meadows, especially in the middle and lower reaches. Even though the upper Humboldt River basin encompasses only about 25 percent of the entire river basin (fig. 1), the upper Humboldt River basin is the source of almost all of the total flow of the river.

Elko County officials and citizens are concerned about growing demand for water within the county and increasing external demands that are occurring statewide. Because flow of the Humboldt River and its tributaries is fully appropriated, any additional water needed to support growth in the upper Humboldt River basin presumably would come from ground water. However, ground water and streamflow can be intimately connected in lowland areas where ground-water discharge to the stream channel sustains flow (baseflow) during low runoff periods. Decisions to further develop the ground-water resources of the upper Humboldt River basin will need to consider the potential effects of such development on streamflow. County and State water-resource managers need information that will enable them to make informed decisions regarding future use of the ground-water resources of the upper Humboldt River basin. To address these needs and concerns, the U.S. Geological Survey (USGS), in cooperation with Elko County, evaluated the water resources of the upper Humboldt River basin in northeastern Nevada during Federal fiscal years 2007–08 (fig. 1).

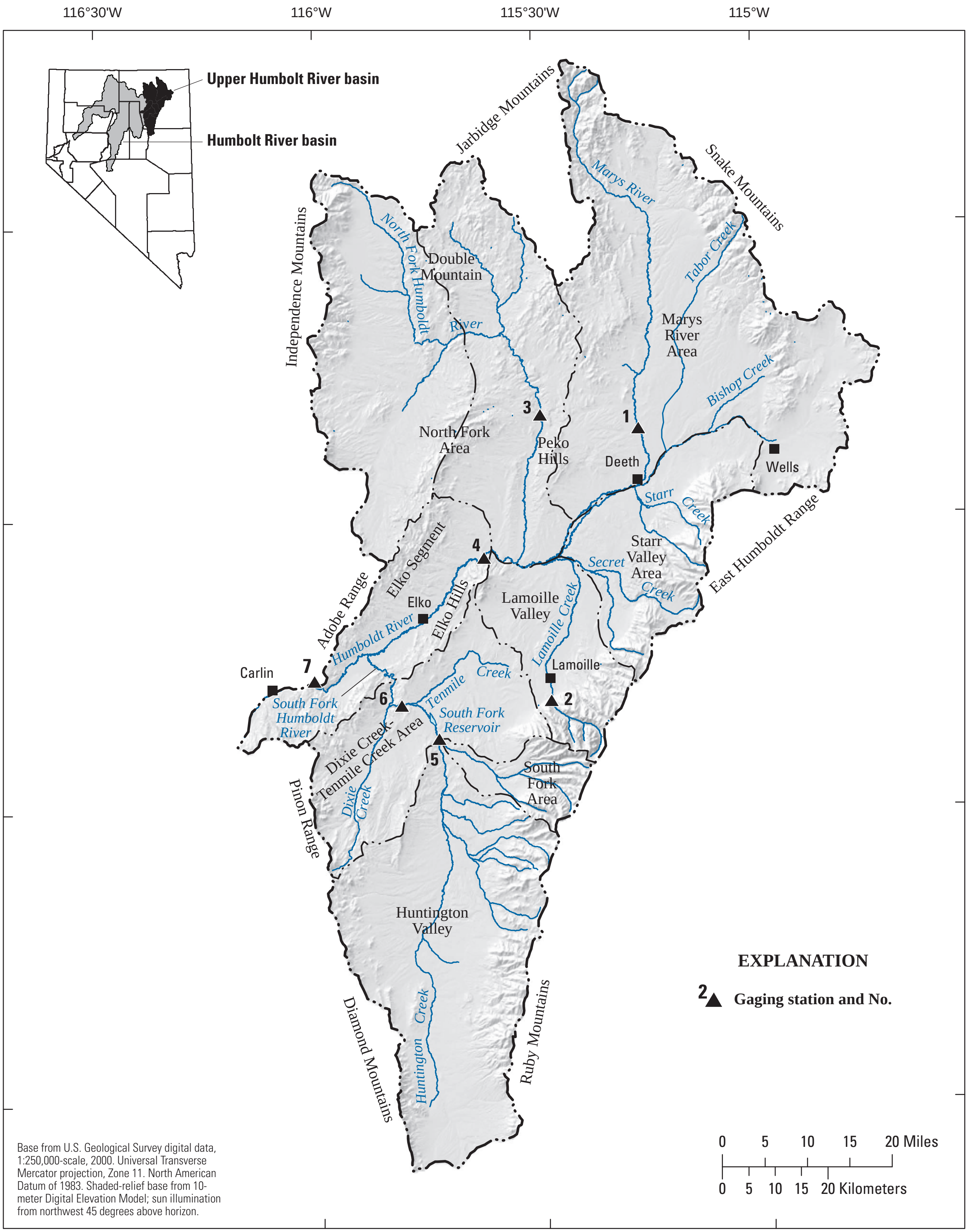

Figure 1. Selected features of the upper Humboldt River basin and location of streamflow-gaging stations, northeastern Nevada.

Purpose and Scope

This report presents the Upper Humboldt River basin phase one results. The objective of this report is to provide hydrologic information that improves the understanding of the water resources of the upper Humboldt River basin; specifically the delineation of the hydrogeologic framework and descriptions of the occurrence and movement of ground water in and between the eight hydrographic areas that make up the basin. The hydrogeologic framework of the study area comprises the extent, both areally and at depth, of rocks and deposits that store and transmit ground water (aquifers) and rocks and deposits that impede the movement of ground water (confining or semiconfining units). Delineation of the hydrogeologic framework of the upper Humboldt River basin is based on geologic and hydrogeologic studies completed during the past 60–70 years. The discussion of the occurrence and movement of ground water is based on water levels that were measured during the spring and summer of 2007 in about 160 wells.

Description of Study Area

The upper Humboldt River basin covers an area of 4,364 mi^2 in northeastern Nevada, and consists of eight hydrographic areas—Marys River Area, Starr Valley Area, North Fork Area, Lamoille Valley, South Fork Area, Huntington Valley, Dixie Creek–Tenmile Creek Area, and Elko Segment (fig. 1, table 1). These eight areas encompass the headwaters of the Humboldt River, which is the source of nearly all of the total flow of the river in years of average flow. From west to east, gaged tributaries of the upper Humboldt River are South Fork Humboldt River, North Fork Humboldt River, Lamoille Creek, and Marys River. Other tributaries include Secret, Starr, Tabor, and Bishop Creeks. Altitudes of land surface in the study area range from 4,900 to 5,900 ft along the flood plain of the Humboldt River to greater than 11,000 ft in the highest parts of the Ruby Mountains. Each of the hydrographic areas is described briefly below.

The Marys River Area covers 1,073 mi^2 and is drained by Marys River and its tributaries on the north and west and by Bishop and Tabor Creeks on the east (fig. 1). The area is bounded by the Snake Mountains to the east, the Jarbidge Mountains to the north, the Peko Hills to the west, and by the Humboldt River to the south.

The Starr Valley Area covers 332 mi^2 and is drained by Starr and Secret Creeks (fig. 1). The area consists of a northwest sloping pediment bounded by the East Humboldt Range to the east and the Humboldt River to the northwest.

The North Fork Area covers 1,110 mi^2 and consists of an upper and lower basin, both of which are drained by the North Fork Humboldt River and its numerous tributaries (fig. 1).

Table 1. Hydrographic areas of the upper Humboldt River basin, northeastern Nevada.

[See fig. 1 for locations of hydrographic areas. **Hydrographic area:** Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960s (Cardinalli and others, 1968; Rush, 1968). These areas have been the basic units for assembling hydrologic data and for regulating water use in the State since 1968. The official hydrographic area names, numbers, and geographic boundaries continue to be used in U.S. Geological Survey scientific reports and Nevada Division of Water Resources administrative activities. **Area (square miles):** From Rush (1968)]

Hydrographic area			
Name	Number	Area (square miles)	Area (acres)
Marys River Area	42	1,073	686,720
Starr Valley Area	43	332	212,480
North Fork Area	44	1,110	710,400
Lamoille Valley	45	257	164,480
South Fork Area	46	99	63,360
Huntington Valley	47	787	503,680
Dixie Creek–Tenmile Creek Area	48	392	250,880
Elko Segment	49	314	200,960
Totals (rounded)		4,364	2,793,000

The upper basin is bounded by the Independence Mountains to the west, the south end of the Jarbidge Mountains to the northeast, and the north end of the Adobe Range to the southeast. The lower basin is bounded by the Adobe Range and Peko Hills to the west and east, respectively, the south end of the Jarbidge Mountains to the north, and the Humboldt River to the south.

Lamoille Valley covers an area of 257 mi^2 and is drained by Lamoille Creek and its tributaries (fig. 1). The area consists of Lamoille Canyon in the Ruby Mountains and a northwest sloping pediment bounded to the southeast by the mountains, to the northwest by the Humboldt River, and by low topographic divides between the Starr Valley Area to the east and the Dixie Creek–Tenmile Creek Area to the west.

The South Fork Area covers 99 mi^2 and is drained by the South Fork Humboldt River and its numerous tributaries (fig. 1). The area is bounded by topographic divides between the Dixie Creek–Tenmile Creek Area to the north and Huntington Valley to the south. The two divides converge to the northwest and join at the confluence of the South Fork Humboldt River and Huntington Creek. The Ruby Mountains form the high altitude uplands of the area.

Huntington Valley covers 787 mi^2 and is drained by Huntington Creek and by several tributaries that originate in the northeast part of the area. The area is bounded by the Ruby Mountains to the east, by the Diamond Mountains and Pinon Range to the west, by low topographic divides to the south and north.

The Dixie Creek–Tenmile Creek Area covers 392 mi^2 and is drained by the South Fork Humboldt River and its two main tributaries in the area—Dixie and Tenmile Creeks (fig. 1). Since December 1987, flow has been regulated by the South Fork Reservoir, which has a maximum altitude of 5,231.4 ft. The Dixie Creek–Tenmile Creek Area is bounded by the South Fork Area and Huntington Valley to the south, Lamoille Valley to the east, the Pinon Range to the west, and by a group of unnamed hills to the north that extend from the Elko Hills to the north end of the Pinon Range.

The Elko Segment covers 314 mi^2 and consists of the Humboldt River flood plain and adjacent uplands (fig. 1). The area is bounded by the Adobe Range to the north and the Elko Hills and north end of the Pinon Range to the south.

Streamflow is an important component of the water resources of the upper Humboldt River basin. Although a detailed discussion of the streamflow characteristics of the study area is beyond the scope of this report, a short summary, with examples, will help to emphasize the importance of streamflow and its interactions with ground water. See Eakin and Lamke (1966) and Prudic and others (2006) for more details on streamflow characteristics of the Humboldt River.

The streamflow characteristics of the upper Humboldt River and its tributaries are summarized by the flow-duration curves in figure 2, which show the frequency, as percent of time, that a given stream discharge per square mile of drainage area was equaled or exceeded during the period of record for water years 1992–2007. The term “water year” means a 12-month period beginning on October 1 and ending the following September 30. The curves in figure 2 represent streamflow conditions of the Humboldt River at the Elko and Carlin gaging stations and at Marys River, Lamoille Creek, and South Fork Humboldt River above Tenmile Creek (see fig. 1 and table 2 for station locations and descriptions). All curves tend to flatten at their upper ends, indicating that high flows are dominated by snowmelt runoff (Searcy, 1959, p. 22).

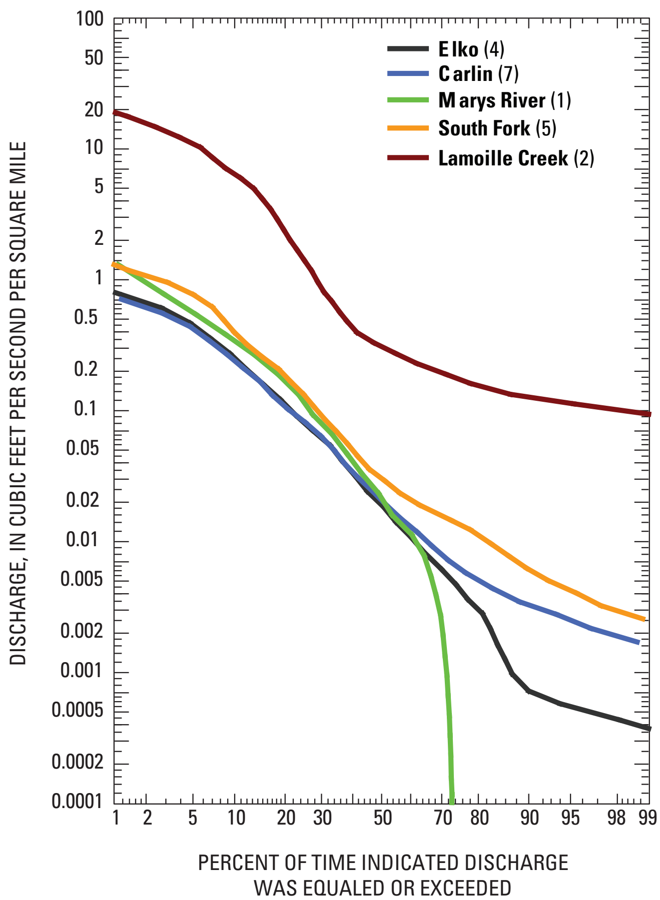

Figure 2. Flow-duration curves for water years 1992–2007 at the Humboldt River near Elko and Carlin, Marys River below Twin Buttes, Lamoille Creek near Lamoille, and South Fork Humboldt River above Tenmile Creek gaging stations, northeastern Nevada. Numbers in parentheses refer to streamflow-gaging stations in figure 1 and table 2.

Table 2. Streamflow-gaging stations in the upper Humboldt River basin, northeastern Nevada.

[Streamflow-gaging station numbers are shown in figure 1. USGS site identification No.: This unique number can be used to access streamflow data for a streamflow-gaging station at http://waterdata.usgs.gov/nv/nwis/current/?type=flow]

Streamflow-gaging station and No.	USGS site identification No.	Name
1	10315600	Marys River below Twin Buttes near Deeth
2	10316500	Lamoille Creek near Lamoille
3	10317500	North Fork Humboldt River at Devils Gate near Halleck
4	10318500	Humboldt River near Elko
5	10319900	South Fork Humboldt River above Tenmile Creek near Elko
6	10320000	South Fork Humboldt River above Dixie Creek near Elko
7	10321000	Humboldt River near Carlin

At their lower ends, the curves for the Elko, Carlin, Lamoille Creek, and South Fork stations also flatten, which indicates that late summer and autumn baseflow of each stream is sustained by ground-water discharge to the stream channel (Searcy, 1959, p. 22). In contrast, the curve for the Marys River station steepens at its lower end indicating the stream at this site has no baseflow and goes dry every summer and autumn.

The curves also indicate that the runoff yield (discharge per square mile of drainage area) of Lamoille Creek is much greater than that of the other four stations. The reason for this is that the entire watershed above the Lamoille Creek station is at high altitude and is underlain by low permeability crystalline rocks. In contrast, the watersheds above the other four stations include large areas of low altitude and they are underlain by rocks of varying permeability.

Curves for the Elko and Carlin stations indicate similar flow characteristics at high to medium flows. At low flows, however, the curves diverge and flow at Carlin is an order of magnitude greater. Two reasons for this are that: (1) regulated flow of the South Fork Humboldt River provides a perennial source of discharge to the mainstem of the river between Elko and Carlin, and (2) flow in the Humboldt River increases downstream of the Elko gaging station due to ground-water discharge.

On October 19, 1992, after several years of below average precipitation, USGS measured the flow of the Humboldt River and its main tributaries and diversions at 35 sites from the Elko to Imlay gaging stations (Emett and others, 1994, p. 475). Three sites were measured that day in the vicinity of Elko—Humboldt River near Elko, Humboldt River near Carlin (sites 4 and 7, fig. 1) and South Fork Humboldt River near Elko at its confluence with the mainstem Humboldt River. The timing of these measurements was such that daily minimum temperatures had been low enough to have minimized the effects of evapotranspiration, but not low enough to cause formation of ice and consequent reduction of streamflow. The three measurements together (Carlin station minus Elko station minus South Fork Station) indicate that the Elko to Carlin reach of the Humboldt River was gaining about 9.1 ft^3/s or about 6,600 acre-ft/yr, as ground-water discharge to the river channel. This might be a minimum value of ground-water discharge to the river channel because several years of drought preceded the time of the measurements.

Geologic Setting

The upper Humboldt River basin consists of several deep structural basins in which basin-fill deposits of Tertiary and Quaternary[1] age and volcanic rocks of Tertiary age have accumulated. The bedrock of each basin and adjacent mountains are composed of carbonate and clastic sedimentary rocks of Paleozoic age, and crystalline rocks of Cambrian, Jurassic, and Tertiary age. Numerous geologic studies have been conducted in the area since about the 1930s in efforts to identify and characterize the different rocks and deposits that underlie the study area and to map their distribution.

[1] This term, and others such as Tertiary or Paleozoic, denotes ranges of geologic age. The geologic time scale on the inside front cover of this report gives ages in millions of years for these terms.

Hydrogeologic Units

The numerous rock units and sedimentary deposits identified in previous studies were grouped into hydrogeologic units by Maurer and others (2004). These hydrogeologic units were regrouped into six hydrogeologic units in this report (pl. 1, table 3**).** The units, in order of decreasing age, are: (1) carbonate rocks and interbedded clastic sedimentary rocks of Cambrian to Permian age; (2) clastic sedimentary rocks of Ordovician to Devonian age; (3) crystalline rocks consisting of granitic intrusive and metamorphic rocks of Cambrian, Jurassic, and Tertiary age; (4) volcanic rocks of Tertiary age; (5) older basin-fill deposits of Tertiary age that comprise most of the alluvial fill in each basin; and (6) younger basin-fill deposits of Quaternary age that consist mostly of deposits along stream flood plains. 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 (Maurer and others, 2004). The lithology and water-bearing characteristics of each unit are discussed below and summarized in table 3.

Carbonate and Clastic Sedimentary Rocks

Carbonate and clastic sedimentary rocks consist of: (1) carbonate rocks (limestones and dolomites) with interbedded shales and sandstones of Cambrian through Devonian age, (2) mostly shales and sandstones of Mississippian and Pennsylvanian age, and (3) interbedded carbonate rocks, sandstones, and shales of Pennsylvanian and Permian age (pl. 1, table 3). The thickness of this sequence of rocks is at least 20,000 ft in the southern Ruby Mountains, 10,000 ft in the Pinon Range and Snake Mountains, and 4,000 ft in the Independence Mountains (Coats, 1987, p. 13–47). Parts of the unit that consist of carbonate rocks of Cambrian to Devonian age are exposed extensively in the southern Ruby Mountains, southern Pinon Range, and to a limited extent in western parts of the Snake Mountains and northeastern parts of the Independence Mountains (Coats, 1987, pl. 1). Clastic sedimentary rocks, such as sandstone and shale of the Diamond Peak Formation and Chainman Shale, are exposed extensively in the Pinon Range, Adobe Range, and Peko Hills where they overlie the older carbonate rocks (Coats, 1987, pl. 1).

Table 3. Lithology, thickness, extent, and water-bearing characteristics of hydrogeologic units in the upper Humboldt River basin, northeastern Nevada.

[**Abbreviations**: ft, foot; Fm, formation]

Hydrogeologic unit	Geologic age	Rock or stratigraphic unit	Lithology	Thickness and extent	Water-bearing characteristics
Younger basin-fill deposits	Quaternary	Alluvium and glacial moraines	Sorted and interbedded clay, sand, and gravel along stream flood plains. Poorly sorted to unsorted clay, silt, sand, gravel, and boulders of alluvial fans and moraines.	Deposits of flood plains probably do not exceed a few tens of feet in thickness. Moraines and deposits of alluvial fans probably range from hundreds to more than 1,000 ft thick.	Together with older basin-fill deposits, comprise shallow water-table aquifers and deeper confined aquifers. Permeability highly variable depending on lithology.
Older basin-fill deposits	Quaternary and Tertiary	Older alluvium of stream terraces (Coats, 1987, p. 70), sedimentary deposits of the Miocene and Pliocene Elko Basin (Wallace and others, 2008, p. 59–62), and limestone, conglomerate, sandstone, shale, and tuff of Oligocene to Paleocene age (Coats, 1987, p. 51–62).	Poorly consolidated deposits of fluvial and lacustrine origin. Includes deposits of alluvial fans, stream flood plains, and shallow lakes. Deposits commonly are tuffaceous and are extensively interbedded with volcanic rocks.	Total thickness including interbedded volcanic rocks ranges from less than 500 ft mostly along basin margins to more than 5,000 ft in a deep and narrow structural basin that extends from southern Huntington Valley to northern Marys River Area (fig. 3).	Together with younger basin-fill deposits, comprise shallow water-table aquifers and deeper confined aquifers. Permeability highly variable depending on lithology.
Volcanic rocks	Tertiary	Volcanic rocks	Ash-flow and air-fall tuffs, lava flows, and domes. Compositions include basalt, andesite, dacite, latite, and rhyolite (Coats, 1987, pl. 1 and p. 51–67).	Extensively interbedded with older basin-fill deposits. See above for composite thickness.	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.
Crystalline rocks	Cambrian and Jurassic	Metamorphic rocks	Metamorphic rocks include marble, schist, and gneiss. They are metamorphosed carbonate and clastic sedimentary rocks of Paleozoic age in the central and northern Ruby Mountains and Elko Hills.	Thickness of metamorphic rocks probably similar to nearby unmetamorphosed carbonate and clastic sedimentary rocks of Paleozoic age. Granitic rocks extend to great depths and can be much more extensive than indicated by outcrop area.	Impedes the movement of ground water.
	Tertiary and Jurassic	Granitic intrusive rocks	Granite and granodiorite in the central Ruby Mountains and alaskite in the southern Independence Mountains.		
Clastic sedimentary rocks	Devonian to Ordovician	Woodruff Fm Valmy Fm Vinini Fm	Shale, siltstone, sandstone, quartzite, chert, and marine volcanic rocks. Structurally overlie along the Roberts Mountains thrust various units of carbonate rocks.	Thickness about 2,000 ft in the Snake Mountains, 9,000 ft in northern Independence Mountains, 4,700 ft in the Pinyon Range, and 4,000–10,000 ft in the Ruby Mountains (Coats, 1987, p. 10–13 and 29–34).	Generally impedes movement of ground water. Presence of perennial streams in watersheds underlain by these rocks also indicates low permeability.

Table 3. Lithology, thickness, extent, and water-bearing characteristics of hydrogeologic units in the upper Humboldt River basin, northeastern Nevada.—Continued

[**Abbreviations**: ft, foot; Fm, formation]

Hydrogeologic unit	Geologic age	Rock or stratigraphic unit	Lithology	Thickness and extent	Water-bearing characteristics
Carbonate and clastic sedimentary rocks	Permian, Pennsylvanian and Mississippian	Edna Mountain Fm Schoonover Fm Diamond Peak Fm Chainman Shale Webb Fm	Shale, sandstone, sandy limestone, conglomerate, and chert. Depositionally overlie various units of carbonate rocks	Thickness at least 20,000 ft in the Ruby Mountains, 10,000 ft in the Pinyon Range and Snake Mountains, and about 4,000 ft in the Independence Mountains. An oil well penetrated 4,500 ft of carbonate rocks from the Devils Gate Limestone to the Hanson Creek Formation at the north end of the Pinon Range (Coats, 1987, p. 13–47).	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.
	Permian to Cambrian	Phosphoria Fm Strathearn Fm Moleen Fm Tomera Fm Ely Limestone Joana Limestone Pilot Shale Devils Gate Limestone Nevada Formation Lone Mountain Dolomite Roberts Mountains Fm Hanson Creek Fm Eureka Quartzite Pogonip Group Windfall Fm Dunderberg Shale Hamburg Dolomite Secret Canyon Shale Geddes Limestone Eldorado Dolomite Pioche Shale Prospect Mountain Quartzite	Intervals of limestone and dolomite interrupted by thinner intervals of shale, quartzite, and conglomerate. All units rarely present in a single mountain range. Underlie entire study area, but are concealed over large parts of mountain ranges by various units of clastic sedimentary rocks.		

The permeability of the combined unit of carbonate and clastic sedimentary rocks undoubtedly varies over a wide range because of the differing lithologies present. The permeability of clastic parts of the unit probably is relatively low. In contrast, carbonate rocks can be very permeable where circulating ground water has widened fractures through geologic time. Hydraulic conductivity ranges from 0.0005 to 900 ft/d based on estimates from 23 carbonate rock aquifer tests conducted throughout the Great Basin (Plume, 1996, p. 13). Additionally, the hydraulic conductivity of the carbonate rocks ranged from 0.1 to greater than 150 ft/d at two large gold mines (west of the study area) in the vicinity of Carlin (Maurer and others, 1996, p. 9–11). Lowest values reflect hydraulic properties of dense, unfractured rock and highest values reflect hydraulic properties of fracture zones that have been widened by dissolution. This range of values illustrates the importance of faulting and fracturing in the development of secondary porosity and permeability in carbonate rocks. A qualitative indication of the high permeability of carbonate rocks in the study area is the absence of perennial streams in watersheds of the southern Ruby Mountains (fig. 1), which are underlain almost entirely by carbonate rocks (pl. 1; Coats, 1987, pl. 1). In other parts of the study area, perennial mountain streams are common.

Clastic Sedimentary Rocks

Shale, siliceous shale, chert, quartzite, siltstone, and minor amounts of limestone and andesitic volcanic rocks of Ordovician through Devonian age were deposited in a deep-water marine environment adjacent to the continental shelf of Western North America, offshore from where carbonate rocks were being synchronously deposited. During Late Devonian to Early Mississippian time, the clastic 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 known as the Antler orogeny (Stewart, 1980, p. 36). Along the Roberts Mountains thrust in the study area, these clastic sedimentary rocks overlie carbonate and clastic rocks of equivalent age (Coats, 1987, p. 80–81). This hydrogeologic unit is exposed extensively in the Snake and Independence Mountains and to a lesser extent in the Adobe and Pinon Ranges and Diamond and Ruby Mountains (pl. 1).

The permeability of clastic sedimentary rocks of Ordovician to Devonian age varies widely depending on the degree to which the unit has been affected by faulting. At two large gold mines in the area of Carlin just west of the study area, the hydraulic conductivity of this unit was found to range from 0.001 to 0.5 ft/d in unfractured rock to as much as 100 ft/d along faults (Maurer and others, 1996, p. 9–11).

Crystalline Rocks

Two types of crystalline rocks are found in the study area—metamorphic rocks and granitic rocks (pl. 1). Metamorphic rocks occur in the central and northern Ruby Mountains and East Humboldt Range. They formed as a result of the metamorphism (re-crystallization due to heat and pressure) of carbonate and clastic sedimentary rocks of Cambrian to Devonian age during part of the Paleozoic and again in the Mesozoic (Coats, 1987, p. 77–79). Textures and compositions include metaquartzite, calcite marble, gneiss, and schist. The thickness of metamorphic rocks may be as much as 20,000 ft, which is similar to that of unmetamorphosed carbonate rocks in southern parts of the Ruby Mountains.

Granitic rocks occur in the central Ruby Mountains, Elko Hills, southern Independence Mountains, and Pinon Range (pl. 1). Compositions include granite of Jurassic age and granodiorite of Tertiary age in the Ruby Mountains and alaskite of Tertiary age in the southern Independence Mountains and Pinon Range (Coats, 1987, pl. 1, p. 73–77). These rocks extend to great depth, and their distribution at depth can be much greater than that indicated by outcrop area.

The low permeability of crystalline rocks can be inferred from the presence of numerous perennial streams in the central and northern Ruby Mountains and East Humboldt Range. Every watershed in these parts of the mountain ranges has a stream that is perennial at least to the mountain front.

Volcanic Rocks and Sedimentary Basin-Fill Deposits

A thick sequence of alternating sedimentary deposits and volcanic rocks accumulated in structural basins of the study area from Eocene time to Holocene time (Coats, 1987, p. 50–71). The sequence consists of three hydrogeologic units listed in table 3 and shown on plate 1—volcanic rocks, older basin-fill deposits, and younger basin-fill deposits. Herein, the three units are discussed together because they are complexly interbedded. The composite thickness[2] of the three units ranges from 1,000 ft to more than 5,000 ft in a deep narrow structural basin that extends from southern Huntington Valley to the southern Marys River Area paralleling the Ruby Mountains and East Humboldt Range (fig. 3). Thicknesses also range from 1,000 ft to more than 5,000 ft in northern parts of the Marys River and North Fork Areas and in part of the Elko Segment. Sixteen oil exploration wells drilled since 1951 penetrated differing thicknesses of basin-fill deposits and volcanic rocks overlying older bedrock (fig. 3; table 4) as follows:

- 6,475 and 3,310 ft at wells 1 and 6 in the Marys River Area;
- 4,230 and 410 ft at wells 2 and 5 in the North Fork Area;
- 3,150 and 3,070 ft at wells 9 and 11 in Lamoille Valley;
- 1,900 and 5,490 ft at wells 8 and 10 in the Elko Segment; and
- 9,538, 8,170, and 3,700 ft at wells 14, 15, and 16 in Huntington Valley.

Well 13 in Huntington Valley penetrated 11,926 ft of basin-fill deposits and never encountered pre-Tertiary bedrock. Logs for several of the wells also illustrate the complex interbedding of older and younger basin-fill deposits with volcanic rocks. Well 2 penetrated 1,690 ft of older basin fill, 1,110 ft of volcanic rocks, and another 1,430 ft of older basin fill. Well 10 penetrated 3,420 ft of older basin fill, 900 ft of volcanic rocks, and another 1,170 ft of older basin fill. Well 11 penetrated 909 ft of younger basin fill, 243 ft of older basin fill, 1,243 ft of volcanic rocks, and another 684 ft of older basin fill.

The oldest basin-fill deposits and volcanic rocks in the study area, consisting of basal conglomerate overlain by a sequence of welded tuffs, deposits of the Elko Formation (claystone, siltstone, shale, limestone, and tuff), and rhyolitic lava flows and domes, are of Eocene and earliest Oligicene age and are almost entirely north of the Humboldt River (Coats, 1987, p. 51–58). All of the basin-fill deposits are tuffaceous to differing extents. The total thickness exceeds 3,000 ft; however, these rocks and deposits apparently do not constitute a continuous blanket over northern parts of the study area. According to Henry (2008), these deposits accumulated in and along at least three deep and wide eastward draining valleys during Eocene time. The valleys were separated by uplands from which any air-fall tuffs were eroded and re-deposited in the valleys.

From late Eocene to middle Miocene, the upper Humboldt River basin probably was an area undergoing erosion since deposits and volcanic rocks of this age span are absent. About 15–14 Ma (millions of years before present), during the middle Miocene, the Elko basin began to form as low-angle and high-angle faulting began along the west sides of the Ruby Mountains, East Humboldt Range, and Snake Mountains (Wallace and others, 2008, p. 58–61).

[2] Combined basin fill and volcanic rock thicknesses discussed above and shown in figure 3 are from a depth to pre-Tertiary basement grid developed for northern Nevada. The depths shown should be considered estimates that do not always agree with depths recorded for oil wells in table 4. (D.A. Ponce, U.S. Geological Survey, written and oral commun., 2007). The process of developing the grid and its uncertainties are described by Ponce (2004, p. 71–74 and figs. 6–3 and 6–9).

Table 4. Hydrogeologic units penetrated by oil exploration wells in the upper Humboldt River basin, northeastern Nevada.

[See pl. 1 and fig. 3 for well locations. Data obtained in 2007 from Nevada Bureau of Mines and Geology at http://www.nbmg.unr.edu/lists/oil/oil.htm. American Petroleum Institute (**API**) No.**:** Oil exploration wells are identified by their API number, which consists of three groups of digits separated by dashes. The API number for the first well in this table is 27-007-05010. The first two digits denote state (Nevada is 27). The second three digits denote county (Elko County is 007). The last five digits are assigned sequentially to wells as they are permitted and drilled]

Well No.	Nevada permit No.	API No.	Altitude of land surface (feet)	Total depth (feet)	Depth of unit top (feet)	Hydrogeologic units penetrated	Thickness (feet)
1	16	27-007-05010	5,973	6,612	0	Basin-fill deposits	1,600
					1,600	Volcanic rocks	4,875
					6,475	Carbonate rocks	
2	178	27-007-05208	6,050	7,106	0	Older basin-fill deposits	1,690
					1,690	Volcanic rocks	1,110
					2,800	Older basin-fill deposits	1,430
					4,230	Paleozoic rocks	
3	552	27-007-05245	6,619	8,843	0	Mississippian clastic rocks	3,600
					3,600	Devonian carbonate rocks	
4	404	27-007-05233	6,076	10,000	0	Volcanic rocks	1,850
					1,850	Older basin-fill deposits	200
					2,050	Vinini Formation	4,400
					6,450	Chainman Shale	
5	377	27-007-05232	6,034	12,573	0	Younger basin-fill deposits	84
					84	Volcanic rocks	88
					172	Older basin-fill deposits	238
					410	Mississippian clastic rocks	5,538
					5,948	Carbonate rocks	
6	12	27-007-05006	5,505	5,465	0	Younger basin-fill deposits	370
					370	Older basin-fill deposits	2,940
					3,310	Mississippian clastic rocks	
7	729	27-007-05253	6,174	10,415	0	Volcanic rocks	1,230
					1,230	Mississippian clastic rocks	7,579
					8,809	Carbonate rocks	
8	428	27-007-05234	5,910	8,865	0	Younger basin-fill deposits	115
					115	Volcanic rocks	845
					960	Older basin-fill deposits	940
					1,900	Mississippian clastic rocks	4,040
					5,940	Carbonate rocks	
9	0	27-007-05004	5,250	4,125	0	Older basin-fill deposits	3,150
					3,150	Carbonate rocks	500
					3,650	Mississippian clastic rocks	
10	182	27-007-05209	5,182	5,670	0	Older basin-fill deposits	3,420
					3,420	Volcanic rocks	900
					4,320	Older basin-fill deposits	1,170
					5,490	Paleozoic rocks	
11	24	27-007-05003	5,308	7,349	0	Younger basin-fill deposits	909
					909	Older basin-fill deposits	243
					1,152	Volcanic rocks	1,234
					2,386	Older basin-fill deposits	684
					3,070	Paleozoic rocks	

Table 4. Hydrogeologic units penetrated by oil exploration wells in the upper Humboldt River basin, Nevada.—Continued

[See pl. 1 and fig. 3 for well locations. Data obtained in 2007 from Nevada Bureau of Mines and Geology at http://www.nbmg.unr.edu/lists/oil/oil.htm. American Petroleum Institute (**API**) No.**:** Oil exploration wells are identified by their API number, which consists of three groups of digits separated by dashes. The API number for the first well in this table is 27-007-05010. The first two digits denote state (Nevada is 27). The second three digits denote county (Elko County is 007). The last five digits are assigned sequentially to wells as they are permitted and drilled]

Well No.	Nevada permit No.	API No.	Altitude of land surface (feet)	Total depth (feet)	Depth of unit top (feet)	Hydrogeologic units penetrated	Thickness (feet)
12	590	27-007-05248	6,376	9,050	0	Mississippian clastic rocks	4,498
					4,498	Carbonate rocks	
13	246	27-007-05214	5,443	11,926	0	Older basin-fill deposits	11,926
14	263	27-007-05217	5,557	10,950	0	Younger basin-fill deposits	2,102
					2,102	Older basin-fill deposits	7,436
					9,538	Paleozoic rocks	
15	297	27-007-05223	5,535	10,320	0	Younger basin-fill deposits	3,400
					3,400	Older basin-fill deposits	4,770
					8,170	Paleozoic rocks	
16	716	27-007-05252	5,955	4,157	0	Younger basin-fill deposits	1,710
					1,710	Older basin-fill deposits	1,990
					3,700	Carbonate rocks	

The Elko basin was large, extending from southern Huntington Valley to northern Marys River and from the structurally active Ruby Mountains–East Humboldt Range–Snake Mountains on the east to the structurally inactive Adobe and Pinon Ranges on the west (Wallace and others, 2008, p. 58). Materials eroded from these mountain ranges spread across the basin accumulating as fine-grained lake deposits in lowlands and as alluvial fan and stream flood-plain deposits toward basin margins. This pattern of deposition continued into late Miocene (10–9 Ma) when the Elko basin began to drain externally resulting in non-deposition of sediments and erosion of existing ones (Wallace and others, 2008, p. 63). Non-deposition, erosion, and transport of sediments out of the basin continued through late Miocene and most of the Pliocene except for a brief period in middle Pliocene when ash-rich sediments similar to those of middle Miocene age accumulated (Wallace and others, 2008, p. 61).

Younger basin-fill deposits in the upper Humboldt River basin consist mostly of unconsolidated sand and gravel along active stream channels (pl. 1; Coats, 1987, p. 70–71). The deposits also form a thin cover overlying pediments of older basin-fill deposits in the northern Marys River and North Fork Areas (pl. 1 and A.R. Wallace, U.S. Geological Survey, oral and written commun., 2008). The younger basin-fill deposits in Huntington Valley, especially those on the east side, also could be a thin veneer of glacial outwash of Pleistocene age from the Ruby Mountains overlying older basin fill of middle Miocene age (A.R. Wallace, U.S. Geological Survey, oral commun., 2008). In Huntington Valley, thicknesses of younger basin-fill deposits penetrated by oil exploration wells range from 1,710 to 3,400 ft (wells 14, 15, and 16; table 4). However, distinguishing younger basin fill from older at such depths is problematic and could be open to different interpretations.

The hydraulic properties of basin-fill deposits and volcanic rocks have not been evaluated in the upper Humboldt River basin. Farther west, however, the hydraulic properties of basin-fill deposits have been evaluated at large gold mines along the Carlin Trend. The basin-fill deposits in this area are of Miocene age and accumulated under conditions similar to those of the middle Miocene Elko basin (Wallace and others, 2008, p. 52–58). Near Carlin at the Gold Quarry mine, the transmissivity of older basin-fill deposits ranges from 780 to 3,600 ft^2/d and hydraulic conductivity ranges from 2 to 7 ft/d (Plume, 1995, p. 17). Using well drillers' logs to determine the ratio of coarse- to fine-grained sediments in the upper 100 ft of flood-plain deposits along the Humboldt River (about 60 mi west of the study area), Bredehoeft and Farvolden (1963, p. 201) estimated the sand-shale ratio to vary from 20 to 70 percent. The hydraulic conductivity determined from specific capacity of selected wells varied from 25 to 40 ft/d (Bredehoeft and Farvolden, 1963, p. 201). These ratios and values of hydraulic conductivity also may apply to the upper Humboldt River basin, and a similar analysis of well logs would be very useful for making estimates of basin-fill aquifer properties in the study area.

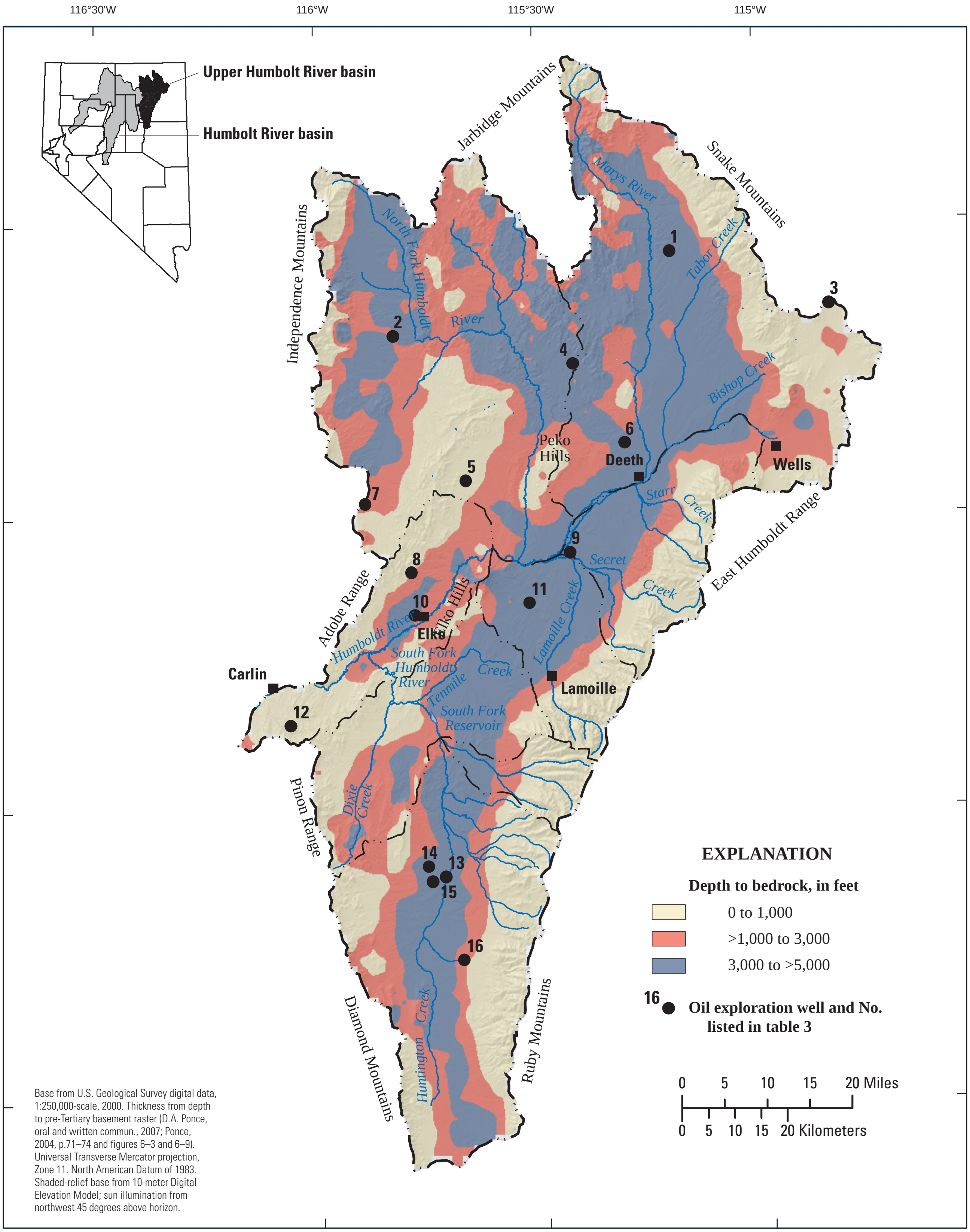

Figure 3. Combined thickness of younger and older basin-fill deposits and volcanic rocks, and location of oil exploration wells, upper Humboldt River basin, northeastern Nevada.

Structural Features

Faults and related fractures can function as enhanced conduits for ground water flow, or impede flow where hydrogeologic units of differing permeability are juxtaposed or filled by fault gouge (pulverized rock along the fault zone produced by friction when a fault moves). Near large gold mines along the Carlin Trend, faults impede the movement of ground water where carbonate rocks are juxtaposed against volcanic and clastic sedimentary rocks (Plume, 2005, p. 6–7). The evidence that faults are barriers to flow in this area is the substantial water level difference, greater than 1,000 ft, across the faults after more than 15 years of pumping for mine dewatering (Plume, 2005, p. 6). In other cases, however, the effects of faults may not be known until large-scale pumping stresses are applied to an aquifer.

Ground Water in the Upper Humboldt River Basin

Occurrence and Movement

The occurrence and movement of ground water in the upper Humboldt River basin is interpreted using ground-water levels in 161 wells measured by personnel from the USGS, Nevada Division of Water Resources, and Newmont Mining Corporation during the spring and summer 2007. Water levels ranged from at or near land surface in younger basin-fill deposits along stream flood plains to 300–400 ft below land surface in older basin-fill deposits mostly along basin margins. Water-level contours in ft above sea level primarily reflect ground-water levels in older and younger basin-fill deposits, but also may reflect water levels in unconfined carbonate rock aquifers (pl. 1).

Driven by hydraulic gradient, ground water moves through permeable zones from areas of recharge to areas of discharge. Recharge occurs mostly along mountain fronts, but also in mountainous areas underlain by carbonate rocks. Discharge occurs mostly on valley floors by evaporation from open water and moist soils and transpiration by plants called phreatophytes[3], ground water seepage to stream channels, and pumpage. The main discharge area in the upper Humboldt River basin is the river flood plain, which can be as much as a mile wide.

In Huntington Valley and the South Fork Area, ground-water flow is from the western base of the Ruby Mountains toward Huntington Creek and its confluence with the South Fork Humboldt River. In Huntington Valley, ground-water flow also is from the eastern base of the Diamond Mountains and Pinon Range toward Huntington Creek. Water-level gradients range from 200 ft/mi adjacent to the Ruby Mountains to 10 ft/mi between the Pinon Range and Huntington Creek (pl. 1). This range of gradients either indicates that more recharge originates from the Ruby Mountains than from mountain ranges on the west side of the valley or that basin-fill deposits on the east side of the valley are less permeable than those on the west side. Rush and Everett (1966, p. 26–27) noted that basin-fill deposits on the east side of Huntington Valley are saturated to near land surface and that potential recharge is rejected and leaves the area as streamflow. The sharp, upstream inflections of water-level contours along the axis of Huntington Valley indicate that ground water discharges to the channel of Huntington Creek. However, ground water also flows northward along the axis of the valley along gradients of 5–10 ft/mi.

The high permeability of carbonate rocks likely result in recharge rather than runoff as indicated by the absence of perennial streams in the southern Ruby Mountains (fig. 1 and pl. 1). This, combined with the eastward dip of the rocks, probably results in ground-water flow from the west side of the southern Ruby Mountains to Ruby Valley east of the study area where numerous large springs emanate from the eastern base of the Ruby Mountains (Rush and Everett, 1966, p. 15; Dudley, 1967, p. 88–98). Dudley (1967, p. 97) also determined that the ground-water divide between Huntington and Ruby Valleys may be as much as 2 mi west of the topographic divide between the two valleys suggesting that most of the high-altitude precipitation in the southern Ruby Mountains does not recharge the upper Humboldt River basin.

Ground-water flow from Huntington Valley and the South Fork Area continues northward into the Dixie Creek–Tenmile Creek Area. In addition, ground water flows west and northwest from the recharge area along the mountain front of the Ruby Mountains and north and northeast from the Pinon Range. A low topographic divide separates the Dixie Creek–Tenmile Creek Area from Lamoille Valley to the northeast. A group of unnamed hills separates the Dixie Creek–Tenmile Creek Area from the Humboldt River downstream from Elko. The water-level contours on plate 1 indicate that ground water flows northwest through these hills to the river flood plain.

In Lamoille Valley and Starr Valley Area ground-water flow is from a recharge area along the base of the Ruby Mountains, which are composed entirely of low permeability crystalline rocks. As a result, ground-water recharge is predominantly from infiltration of runoff from the mountains as it crosses the pediment between the mountains and Humboldt River flood plain. A portion of the water leaves the two basins as runoff because aquifers in both valleys are saturated to near land surface and have limited storage available for recharge (Eakin and Lamke, 1966. p. 31).

[3] Phreatophytes are plants that have their roots in ground water. They include greasewood, big sage, rabbit brush, various meadow grasses, willows, and cottonwoods. Evapotranspiration is the primary ground-water discharge process in the Humboldt River Basin and the term incorporates two processes—evaporation from open water and soils, and transpiration by phreatophytes.

Ground-water flow is to the northwest in Lamoille Valley and to the west in Starr Valley Area. Water-level gradients range from 50–100 ft/mi adjacent to the mountains to 10–30 ft/mi near the Humboldt River flood plain.

Ground-water flow in the Marys River Area generally is southward to the Humboldt River. The lower reaches of Marys River are ephemeral, and water-level contours have no upstream inflection unlike other streams in the study area. Near the Humboldt River flood plain, water-level gradients are about 20 ft/mi.

The North Fork Area consists of upper and lower topographic basins that are connected by streamflow through a canyon in the northern Adobe Range (fig. 1). The upper basin consists of an east sloping pediment of flat-lying to tilted older basin-fill deposits overlain by a thin cover of younger basin-fill deposits (A.R. Wallace, U.S. Geological Survey, oral commun., 2008), as much as 5 mi wide, between the Independence Mountains to the west and Double Mountain and the Adobe Range to the east. Sparse water-level data indicate that ground-water flow is eastward from a recharge area along the eastern base of the Independence Mountains. Water-level data are not sufficient to determine whether the direction of ground-water flow on the east side of the area turns northeastward parallel with the Adobe Range or continues eastward through the range. The first possibility would require a sharp change in the direction of flow from eastward to northeastward. The second does not seem likely because the principle rock types the Adobe Range are 4,000–5,500 ft of poorly permeable shale and sandstone of the Diamond Peak Formation and Chainman Shale (oil wells 8 and 5, pl. 1, table 4).

Ground-water flow in the lower part of the North Fork Area is southeastward from the Adobe Range, and as indicated by the 5,300- and 5,400-ft water-level contours southwestward from the Peko Hills toward the North Fork Humboldt River and then southward along the basin axis toward the Humboldt River (pl. 1). The Peko Hills are underlain by the Diamond Peak Formation, Chainman Shale, and by older and younger carbonate rocks.

Sharp upstream inflections of the water-level contours indicate that the Humboldt River gains flow from ground-water seepage from a few miles west of Wells to the west boundary of the study area. Water-level gradients along the flood plain range from about 7 to 30 ft/mi east of the Elko Hills. Ground-water flow in the Elko Segment (Elko Hills to the west boundary of the study area) is to the southeast from the Adobe Range and northwest from the Dixie Creek–Tenmile Creek Area through the unnamed hills between the Elko Hills and the South Fork Humboldt River. Streamflow gains of the river in the Elko Segment are about 6,600 acre-ft/yr. This ground-water seepage to the river channel primarily moves through a 10-mi wide section of the unnamed hills (pl. 1) under a water-level gradient of 40 ft/mi (0.008 ft/ft).

Transmissivity can be estimated using these values and a form of Darcy's law:

$$T = Q/(iw), \tag{1}$$

where

T is transmissivity, in feet squared per day;
Q is flow through the section, in cubic feet per day;
i is the water table gradient, in feet per foot; and
w is the width of the flow section, in feet.

The estimated transmissivity of the rocks and deposits in the flow section is about 2,000 ft^2/d. However, this is a rough estimate because some subsurface flow resulting in the streamflow gains comes from the Adobe Range.

Water-Level Change

Water levels in the upper Humboldt River basin fluctuate: (1) annually in response to wetter (spring runoff) and drier (lack of summer rain) hydrologic conditions; and (2) to longer term (multiyear) variations in climate. Water-level data from nine wells were used to evaluate these fluctuations. The locations of these wells are shown in figure 4.

Wells 1 and 2 near Deeth and Lamoille, respectively, were measured monthly from 1949 to 1958 (fig. 4, fig. 5 *A–B*). Well 1 (fig. 5*A*) is in the flood plain near the confluence of Marys River and the Humboldt River, and water levels at this well probably respond rapidly to changes in stage of either stream. Water levels were about 10 ft below land surface in late winter to early spring, but rapidly rose to within 5 feet of land surface by early to late June. Although no drillers' log is available for well 1, the log for a nearby well (Nevada log number 76997, table 5) penetrated interbedded sand, gravel, and clay from land surface to depths of 28 ft and blue clay to a depth of 112 ft. The sands and gravels above the blue clay function as a shallow water-table aquifer that is recharged mostly by the spring snowmelt runoff.

Monthly water-level fluctuations at well 2 were similar to those at well 1 (fig. 5*B*). Well 2 is located about one-half mile from Lamoille Creek in an area dissected by a network of ditches used to irrigate meadows and fields. Depth to water at this well was more than 10 ft in early to late winter, but typically rose abruptly between May and June approaching land surface by late spring or early summer. Annual water-level rises at this well are dependent on the distribution and timing of irrigation and not necessarily on the magnitude of the spring snowmelt runoff. The rapid water-level rise each year indicates a good hydraulic connection through a thin unsaturated zone and limited available storage in the aquifer, which agrees with conclusions from the reconnaissance reports published decades earlier (Eakin and Lamke, 1966, p. 31; Rush and Everett, 1966, p. 26–27).

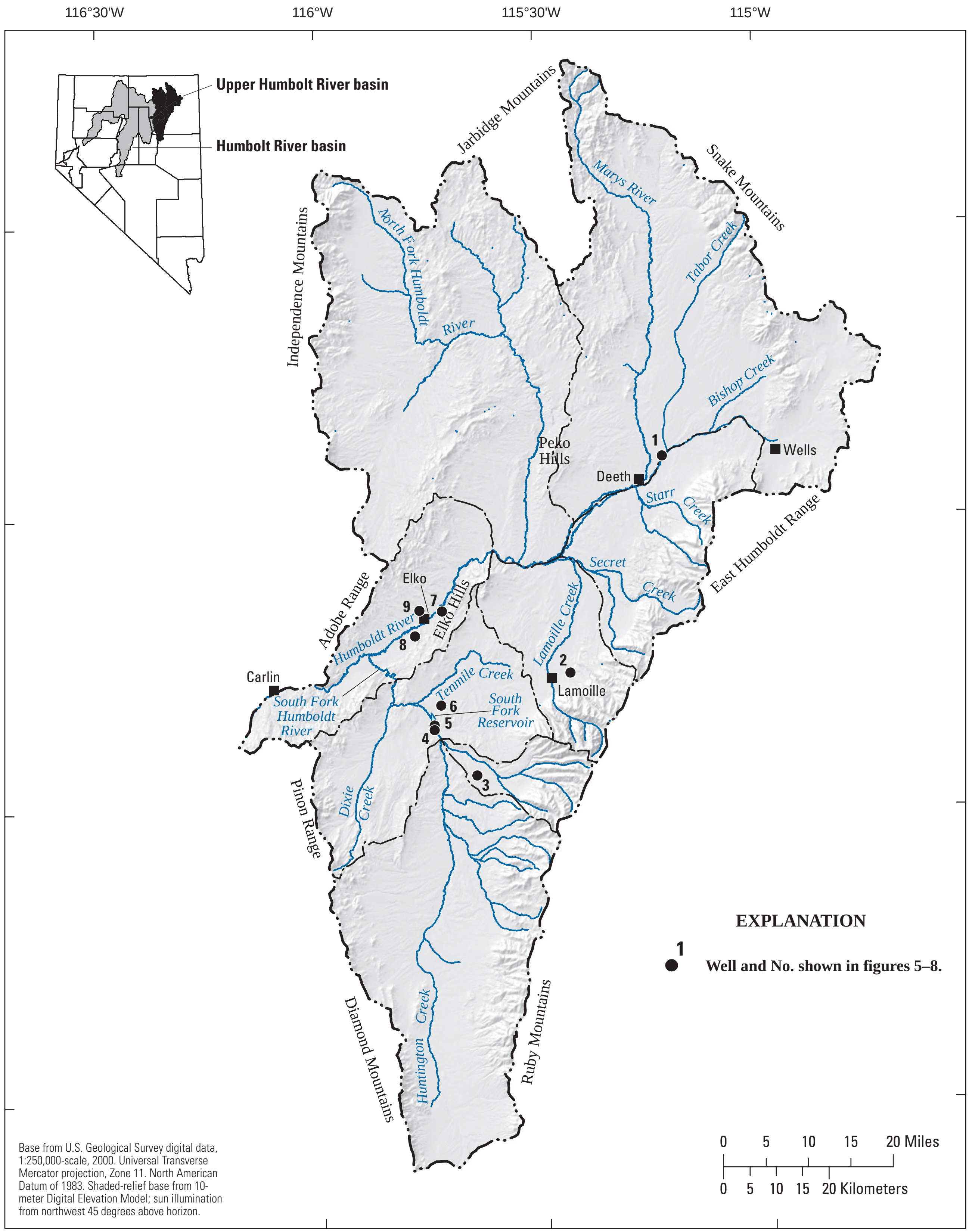

Figure 4. Selected wells where water levels have fluctuated, upper Humboldt River basin, northeastern Nevada.

Table 5. Lithologies penetrated by wells 1–9, upper Humboldt River basin, northeastern Nevada.

[Well locations are shown in figure 4]

Well No.	Nevada log No.	Altitude (feet)	Total depth (feet)	Perforated interval (feet)	Depth of top (feet)	Lithology penetrated	Thickness (feet)
1*	76997	5,340	112	90–112	0	Topsoil	5
					5	Sand and gravel	1
					6	Clay	9
					15	sand and gravel	13
					28	Blue clay	
2	23164	5,880	123	102–122	0	Soil	2
					2	Gravel	33
					35	Sandy Clay	65
					100	Sand and gravel	
4	28404	5,320	258	220–258	0	Topsoil	2
					2	Sand and gravel	34
					36	Sand and clay	27
					63	Gravel	17
					80	Sand and clay	92
					172	Sand	18
					190	Sand and clay	20
					210	Sand	40
					250	Sand and clay	
5	13830	5,260	157	107–157	0	Soil	2
					2	Sandy clay	8
					10	Gravel and cobbles	16
					26	Sand, gravel, clay	117
					143	Gravel	1
					144	Clay	
6	30036	5,340	170	150–170	0	Soil	4
					4	Green clay	23
					27	Soft sandstone	118
					145	Green clay	3
					148	Sand	
7	15700	5,240	510	128–510	0	Soil	4
					4	Alluvium	106
					110	Gravel	2
					112	Volcanic rocks	66
					178	Shale	77
					255	Limestone	7
					262	Fractured shale	
8	9288	5,200	200	160–180	0	Gravel	15
					15	Sandstone	5
					20	Sandy clay	140
					160	Sand and gravel	2
					162	Rock and clay	
9	11004	5,090	415		0	Clay and gravel	27
					27	Gravel	4
					31	Gravel and clay	27
					58	Clay and gravel	42
					100	Gravel	5
					115	Clay and gravel	87
					202	Gravel and clay	63
					265	Gravel	7
					272	Gravel and clay	33
					305	Gravel	15
					320	Sandy clay	27
					347	Clay	15
					362	Sandy clay	

* No log is available for well 1. The log shown here is for a well about 500 feet to the west.

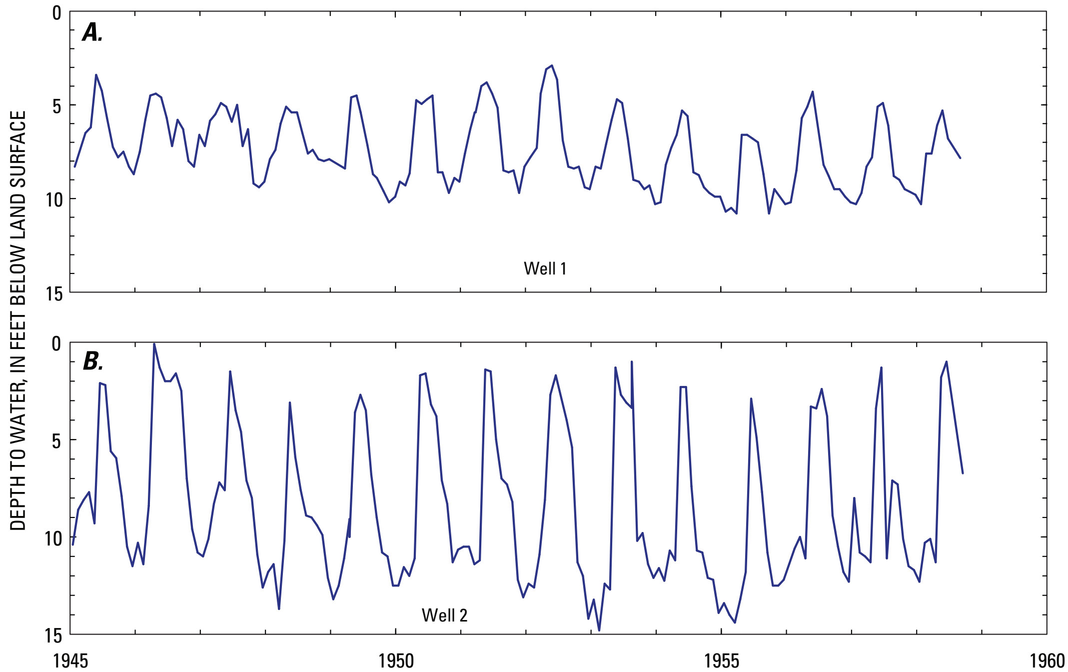

Figure 5. Water-level fluctuations at (*A*) wells near Deeth (well 1) and (*B*) Lamoille (well 2). See figure 4 for well locations.

Well 3 is a stock well at the southwest side of the South Fork Area that has been measured annually by USGS since 1964 (fig. 6*A*). Depth to water at this well ranged from about 71 ft in 1984 and 1986 to 98 ft in 1995. Annual water levels in the well show multiyear periods of increasing and decreasing levels. Water levels rose 20 ft from 1970 to 1986, declined 27 ft from 1986 to 1995, rose 16 ft from 1995 to 2001, and declined 16 ft by 2003 (fig. 6*A*). These periods of water-level rise and fall generally correspond to long-term variations in annual precipitation (fig. 6*B*). The water-level rise from 1970 to 1984 was a 15-year period during which annual precipitation was 8 to 90 percent above average during 8 years and 5 to 50 percent below average during 7 years. However, the total amount of precipitation during above average years was about twice the amount during below average years. Overall, the 15-year period was one of well above average precipitation, and this explains the upward trend of water levels in the well during that period. Similarly, a severe and continuous drought from 1985 through 1994 (fig. 6*B*) coincides with the abrupt water-level decline from 1986 to 1995 (fig. 6*A*). The water-level rise from 1995 to 2001 and its decline by 2003 also can be explained by the precipitation record, indicating that water levels in well 3 respond rapidly to variations in climate.

Filling of the South Fork Reservoir has resulted in water-level rises in basin-fill deposits over an area of uncertain extent. The Nevada Division of Water Resources began measuring water levels in wells in the vicinity of the South Fork Reservoir when filling began in December 1987. The time required for filling to a spillway elevation of 5,231 ft is not known and the stage of the reservoir probably fluctuates annually in response to runoff from the South Fork Area and Huntington Valley. Since 1988, water levels have risen 6 ft and 8 ft at two wells about 3,000 ft and 1,000 ft, respectively, from the southwest side of the reservoir (wells 4 and 5 figs. 4 and 7*A–B*). Both wells are adjacent to the flood plain of the South Fork Humboldt River and penetrate interbedded clay, sand, and gravel to depths of 144–250 ft (table 5). Water levels at a stock well about 1 mi northeast of the reservoir were at about 89 ft through 1992, rose 2 ft in 1993, and fluctuated 1–2 ft through 1997 (well 6, figs. 4 and 7*C*). Water levels were not measured at the well again until 2005 when the depth to water was about 83 ft. Since then the water level has not changed. Although this well is at a higher altitude than the South Fork Reservoir, the well depth, at 170 ft (5,172 ft altitude), is below the reservoir elevation of 5,231 ft. In addition, this well penetrated interbedded clay and sand (table 5). Water-level rises at the wells 4, 5, and 6 are the result of infiltration of surface water during filling of the reservoir.

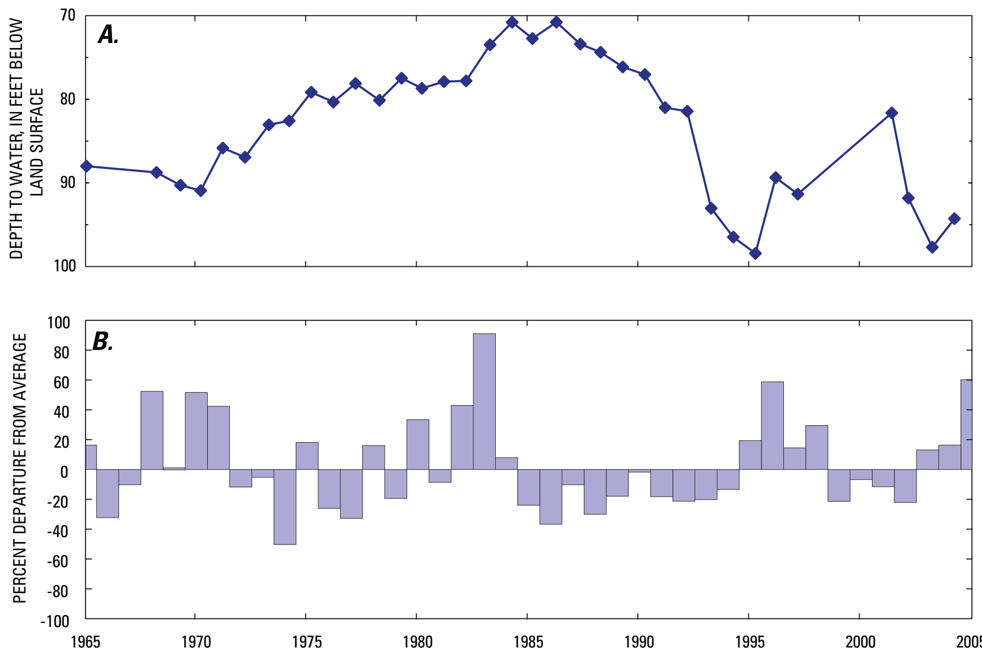

Figure 6. (*A*) water-level fluctuation at well 3, 1965–2005 (fig. 4), and (*B*) annual precipitation as percent departure from average at Elko, Nevada, 1965–2005. Long-term (1947–2007) average is 9.6 inches per year.

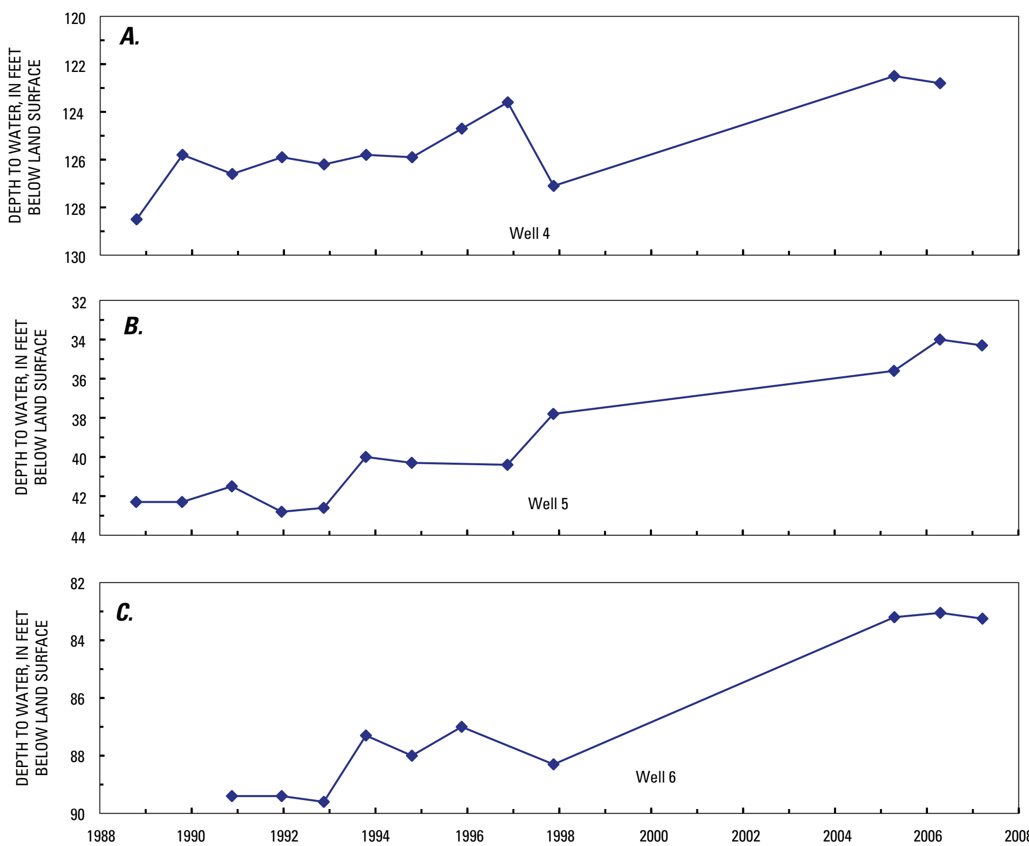

Figure 7. Water-level fluctuations at wells 4, 5, and 6 near South Fork Reservoir, Elko, Nevada.

Water levels also have risen at two wells on the northwest side of the group of hills that extends from the Elko Hills on the northeast to the north end of the Pinon Range on the southwest (wells *7* and 8, figs. 4 and 8*A–B*). These hills lie between the Humboldt River flood plain and the Dixie Creek-Tenmile Creek Area. The depth to water at well 7 rose from 225 ft in 1989 to 109 ft in 2008. This well was drilled in 1976 and its log (well 7, table 5) indicates that it penetrated alluvium and gravel to 112 ft, volcanic rocks from 112 to 178 ft, shale from 178 to 255 ft, limestone from 255 to 262 ft, and then faulted shale to a depth of 510 ft. The casing was perforated from 128 to 510 ft. The reason for the continuous water-level rise at this well is not clear because no nearby source of water is evident. One reason could be infiltration from the South Fork Reservoir into carbonate rocks, which are exposed in the canyon where the dam was constructed (pl. 1; Coats, 1987, pl. 1). However, the distance between the dam and well 7 is about 10 mi.

Water levels at well 8 rose from a depth of about 200 ft in 1989 to 145 ft by 2003 (fig. 8*B*). This well was drilled in 1966 and its log (table 5) indicates that it penetrated gravel, clay, and sandstone to 162 ft and rock and clay from 162 to 200 ft. The casing was perforated from 160 to 180 ft. Center-pivot irrigation and infiltration ponds for disposing of treated sewage, both constructed just west of this well in the early 1990s, are the reason for the water-level rise.

Pumping in the Elko Segment, especially for municipal purposes, probably has resulted in water-level declines. However, water-level monitoring has not been sufficient to identify the areal extent or magnitude of any declines. A secondary effect of municipal pumping can be that of water levels rising because of lawn watering in residential neighborhoods. The graph for well 9 (figs. 4 and 8*C*) indicates that water levels rose about 43 ft from 1988 through 2008. This well is next to a park and residential neighborhoods on the west side of Elko.

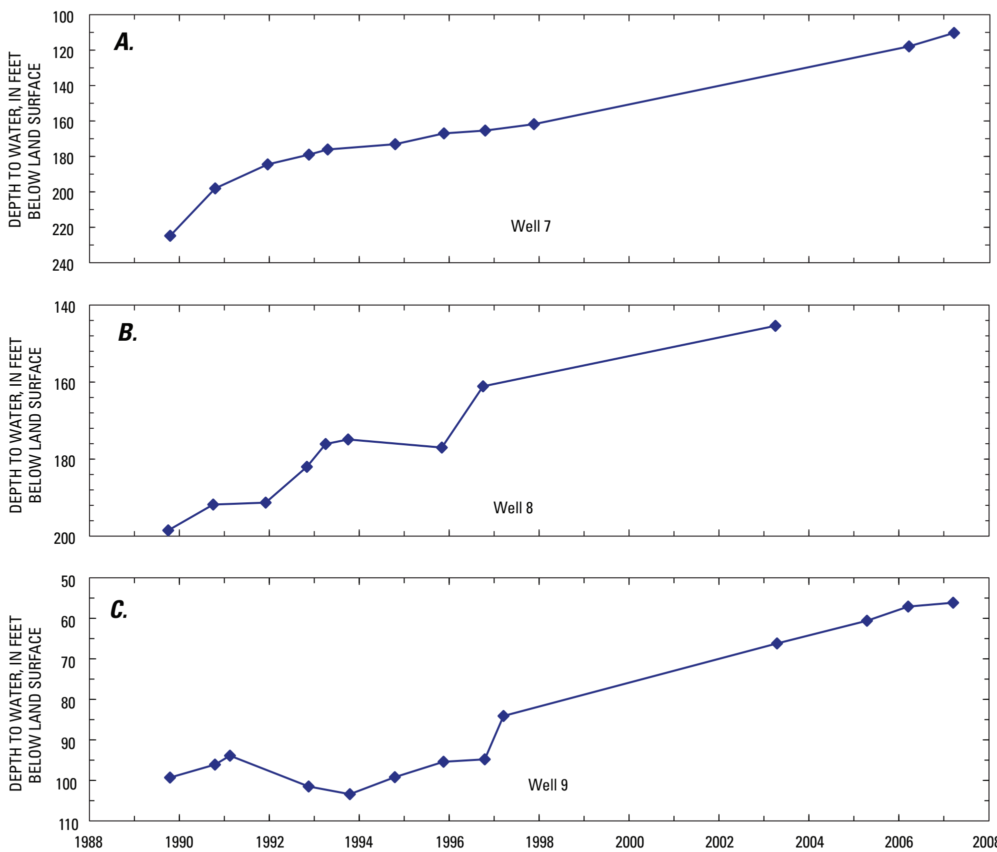

Figure 8. Water-level fluctuations at wells 7, 8, and 9 near Elko, Nevada.

Summary

This report presents the results of a study of the water resources of the upper Humboldt River basin done in 2007–08 by the U.S. Geological Survey in cooperation with Elko County. The report provides Elko County and State water-resource managers information needed to make informed decisions regarding future use and development of the ground-water resources of the basin. The overall objective of the report is to develop an improved understanding of the water resources of the upper Humboldt River basin. This report describes the hydrogeologic framework, and the occurrence and movement of ground water.

The upper Humboldt River basin covers an area of 4,364 mi^2 in northeastern Nevada, and consists of eight hydrographic areas—Marys River Area, Starr Valley Area, North Fork Area, Lamoille Valley, South Fork Area, Huntington Valley, Dixie Creek–Tenmile Creek Area, and the Elko Segment. These eight areas are the headwaters of the Humboldt River, and nearly all of the annual flow of the river in years of average flow originates in these areas. The main tributaries of the upper Humboldt River are South Fork Humboldt River, North Fork Humboldt River, Lamoille Creek, Marys River, and Bishop Creek. High flows during the spring and early summer are dominated by snowmelt runoff and low flows of late summer and autumn of each stream generally are sustained by ground-water discharge to the stream channel. The main exception is the lower reach of Marys River, which has no baseflow and goes dry every summer and autumn.

The upper Humboldt River basin consists of several deep structural basins in which basin-fill deposits of Tertiary and Quaternary age and volcanic rocks of Tertiary age have accumulated. The bedrock of each basin and adjacent mountains are composed of carbonate and clastic sedimentary rocks of Paleozoic age and crystalline rocks of Paleozoic, Mesozoic and Cenozoic age. The permeability of bedrock generally is very low except for carbonate rocks, which can be very permeable where circulating ground water has widened fractures through geologic time. The contrast in permeability of carbonate rocks with other bedrock is evident in the Ruby Mountains. Watersheds in the south end of the mountain range are underlain by carbonate rocks and are drained by ephemeral streams. Watersheds in central and northern parts of the mountain range are underlain by crystalline rocks and are drained by perennial streams.

A thick sequence of alternating sedimentary deposits and volcanic rocks accumulated in basins of the study area from Eocene time to the present. The sequence consists of three hydrogeologic units—volcanic rocks, older basin-fill deposits, and younger basin-fill deposits. The composite thickness of the three units exceeds 5,000 ft in a deep narrow structural basin that extends from southern Huntington Valley to the northern Marys River Area parallel with the Ruby Mountains, East Humboldt Range, and Snake Mountains. Lithologic logs for oil exploration wells indicate that the older basin-fill deposits and volcanic rocks are commonly interbedded. In addition, older basin-fill deposits usually are tuffaceous and consist of interbedded fine-grained lake deposits and coarse-grained deposits of alluvial fans and stream flood plains. Younger basin-fill deposits consist mostly of unconsolidated sand and gravel along stream channels and as thin veneers covering older basin-fill deposits in the northern Marys River and North Fork Areas and in southern Huntington Valley. The principal aquifers in the upper Humboldt River basin are in basin-fill deposits. However, little is known regarding the hydraulic properties of these aquifers. Analysis of aquifer tests and well drillers' logs would be very useful for making estimates of aquifer properties in the study area.

Ground water in the upper Humboldt River basin moves from recharge areas, which are along mountain fronts, and is discharged as seepage to stream channels, evapotranspiration, and pumpage. The main discharge area in the upper Humboldt River basin is the river flood plain, which can be as much as a mile wide. South of the Humboldt River, ground-water flow is from an extensive recharge area along the western base of the Ruby Mountains and East Humboldt Range and to a lesser extent the eastern base of the Diamond Mountains and Pinon Range. Flow generally is northward along the axes of Huntington Valley and the Dixie Creek–Tenmile Creek Area through a group of unnamed hills to the Humboldt River flood plain west of Elko. Ground-water flow in Lamoille Valley and Starr Valley Area is northwestward directly to the river flood plain. Water-level contours indicate that ground water discharges as seepage to stream channels in areas south of the river.

Ground-water flow in the Marys River Area is to the southwest from the Snake Mountains and south from other parts of the basin to the Humboldt River flood plain. Ground water does not discharge as seepage to the channel of the lower reaches of Marys River.

The North Fork Area consists of two ground-water basins that are connected by streamflow. Sparse water-level data for the upper basin indicate that most ground-water flow is eastward from a recharge area along the base of the Independence Mountains. However, water-level data are not sufficient to determine the direction of ground-water flow in other parts of the upper basin. Ground-water flow in the lower part of the North Fork Area is eastward from the Adobe Range and westward from the Peko Hills toward the North Fork Humboldt River and then southward along the basin axis toward the Humboldt River flood plain.

Water-level contours indicate that the Humboldt River gains flow from ground-water seepage over its entire length in the study area. The contours show sharp upstream inflections where they cross the river and its flood plain from a few miles west of Wells to the west boundary of the study area. Ground-water flow in the Elko Segment is to the southeast from the Adobe Range and northwest from the Dixie Creek–Tenmile Creek Area through the unnamed hills between the Elko Hills and the South Fork Humboldt River. This reach of the river gains about 6,600 acre-ft/yr as ground-water seepage to the river channel. The estimated transmissivity of the aquifer in this flow section is 2,000 ft^2/d.

Water levels in the upper Humboldt River basin fluctuate in response to the annual snowmelt runoff, to long-term variations in climate, and to human activities. From 1949 to 1958, water levels at a well in the Marys River and Humboldt River flood plains near Deeth ranged from 8 to 11 ft below land surface in late winter to early spring, but rapidly rose to within several feet of land surface by early to late June. Annual water-level changes at a well near Lamoille were similar to those at the well near Deeth. The Lamoille well is about half a mile from the nearest stream, but it is in an area where streamflow diverted from Lamoille Creek is distributed to meadows and fields by a network of irrigation ditches. Water levels at the well ranged from 11 to 15 ft in early to late winter and rose abruptly to near land surface by late spring or early summer. Water-level rises at this well are dependent on the distribution and timing of irrigation and not on the magnitude of the spring snowmelt runoff.

Water-level changes at a stock well at the southwest side of the South Fork Area are believed to be related to variations in annual precipitation. Since 1970, water levels either rose or declined during four time periods ranging from a few to 15 years. These periods correspond closely with periods of above or below average annual precipitation measured at Elko, and indicate that water levels in the well respond rapidly to variations in climate.

Filling of the South Fork Reservoir, which began in 1988, has resulted in water-level rises in the basin-fill deposits that underlie uplands on the east and west sides of the reservoir. Water level rises at another well, which is about 10 miles north of the reservoir, also could be the result of infiltration losses. Water-level rises at two wells west of Elko are the result of agricultural irrigation and infiltration of treated sewage and residential lawn watering, respectively.

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