Prepared in cooperation with the
TAHOE REGIONAL PLANNING AGENCY

Surface- and Ground-Water Characteristics in the Upper Truckee River and Trout Creek Watersheds, South Lake Tahoe, California and Nevada, July-December 1996

Water-Resources Investigations Report 00-4001

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

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

Surface- and Ground-Water Characteristics in the Upper Truckee River and Trout Creek Watersheds, South Lake Tahoe, California and Nevada, July-December 1996

By Timothy G. Rowe and Kip K. Allander

Water-Resources Investigations Report 00-4001

Prepared in cooperation with the
TAHOE REGIONAL PLANNING AGENCY

Carson City, Nevada
2000

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
CHARLES G. GROAT, Director

For additional information
contact:

District Chief
U.S. Geological Survey
333 West Nye Lane, Room 203
Carson City, NV 89706-0866

email: GS-W-NVpublic-info@usgs.gov

http://nevada.usgs.gov

Copies of this report can be
purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225-0286

CONTENTS

PLATE

[Plate is in pocket at back of report]

FIGURES

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per mile ($ft^3/s/mi$)	0.01760	cubic meter per second per kilometer
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (^oC) can be converted to degrees Fahrenheit (^oF) by using the formula $^oF = [1.8(^oC)]+32$. Degrees Fahrenheit can be converted to degrees Celsius by using the formula $^oC = 0.556(^oF-32)$.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called “Sea-Level Datum of 1929”), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Abbreviated Water-Quality Units Used in this Report

μg/L (microgram per liter)
mg/L (milligram per liter)
mL (milliliter)

Surface- and Ground-Water Characteristics in the Upper Truckee River and Trout Creek Watersheds, South Lake Tahoe, California and Nevada, July-December 1996

By Timothy G. Rowe *and* Kip K. Allander

Abstract

The Upper Truckee River and Trout Creek watersheds, South Lake Tahoe, California and Nevada, were studied from July to December 1996 to develop a better understanding of the relation between surface water and ground water. Base flows at 63 streamflow sites were measured in late September 1996 in the Upper Truckee River and Trout Creek watersheds. Most reaches of the main stem of the Upper Truckee River and Trout Creek had gaining or steady flows, with one losing reach in the mid-section of each stream.

Twenty-seven of the streamflow sites measured in the Upper Truckee River watershed were on 14 tributaries to the main stem of the Upper Truckee River. Sixteen of the 40 streamflow sites measured in the Upper Truckee River watershed had no measurable flow. Streamflow in Upper Truckee River watershed ranged from 0 to 11.6 cubic feet per second (ft^3/s). The discharge into Lake Tahoe from the Upper Truckee River was 11.6 ft^3/s, of which, 40 percent of the flow was from ground-water discharge into the main stem, 40 percent was from tributary inflows, and the remaining 20 percent was the beginning flow. Gains from or losses to ground water along streams ranged from a 1.4 cubic feet per second per mile (ft^3/s/mi) gain to a 0.5 ft^3/s/mi loss along the main stem.

Fourteen of the streamflow sites measured in the Trout Creek watershed were on eight tributaries to the main stem of Trout Creek. Of the 23 streamflow sites measured in the Trout Creek watershed, only one site had no flow. Flows in the Trout Creek watershed ranged from zero to 23.0 ft^3/s. Discharge into Lake Tahoe from Trout Creek was 23.0 ft^3/s, of which, about 5 percent of the flow was from ground-water discharge into the main stem, 75 percent was from tributary inflows, and the remaining 20 percent was the beginning flow. Ground-water seepage rates ranged from a 1.4 ft^3/s/mi gain to a 0.9 ft^3/s/mi loss along the main stem.

Specific conductances measured during the seepage run in September 1996 increased in a downstream direction in the main stem of the Upper Truckee River and remained relatively constant in the main stem of Trout Creek. Water temperatures measured during the seepage run also increased in a downstream direction in both watersheds.

Depths to ground water measured at 62 wells in the study area were used with the results of the seepage run to produce a water-level map in the Upper Truckee River and Trout Creek watersheds. Ground-water levels ranged from 1.3 to 69.8 feet below land surface. In the upper sections of the watersheds ground-water flow is generally toward the main stems of Upper Truckee River and Trout Creek, whereas in the lower sections, ground-water flow generally parallels the two streams and flows toward Lake Tahoe. The altitude of ground water between Lake Tahoe and Highway 50 was nearly the same as the lake-surface altitude from July to November 1996. This suggests ground-water discharge beneath the Upper Truckee River and Trout Creek drainages directly to Lake Tahoe was minimal and that much of the ground-water discharge was to the channels of the Upper Truckee River and Trout Creek upstream from Highway 50. Hydraulic gradients ranged from near zero to 1,400 feet per mile.

Samples were collected at six surface-water-quality and eight ground-water-quality sites from July through mid-December 1996. Specific conductance of the ground-water-quality sites was higher than that of the surface-water-quality sites. Water temperature and pH median values were similar between ground-water-quality and surface-water-quality sites but ground water had greater variation in pH and surface water had greater variation in water temperature. Ground-water nutrient concentrations were generally higher than those in streams except for bioreactive iron.

INTRODUCTION

Lake Tahoe is an outstanding natural resource and is known for its deep, clear water (fig. 1). Protection of this renowned clarity has become important in the past half century, as clarity has been decreasing by about 1 ft each year (Goldman and others, 1986), mainly due to human activities.

Increased nutrient concentrations within Lake Tahoe are considered the leading cause of algal growth and loss of clarity in the lake. Within the Lake Tahoe Basin, both surface- and ground-water discharge are suspected of being significant mechanisms for nutrient transport to Lake Tahoe (Thodal, 1994, p. 2).

Background

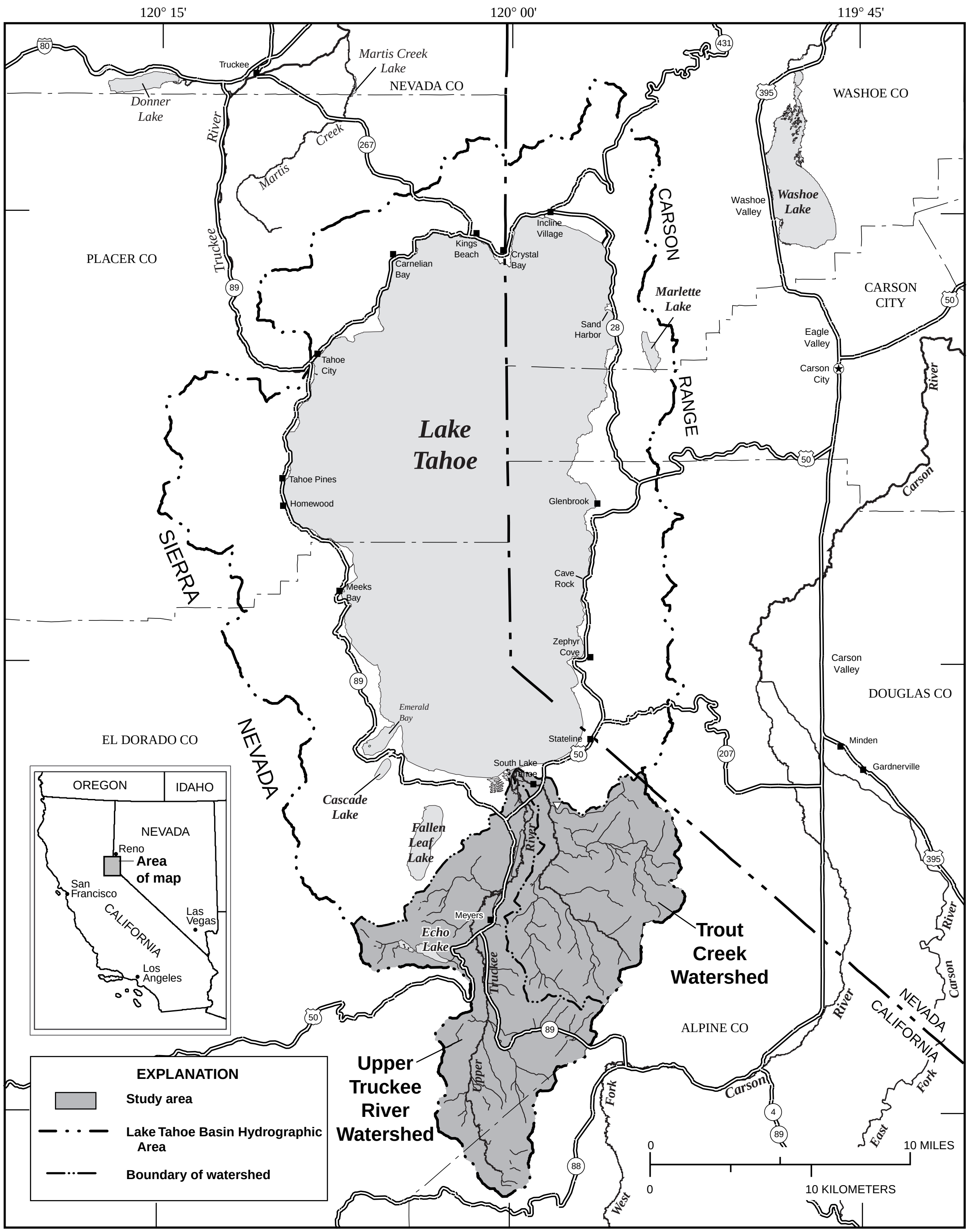
The Tahoe Regional Planning Agency (TRPA) is a bi-state resource management agency that has primary responsibility for the environmental protection of Lake Tahoe. TRPA's principal mission is to reduce the loss of clarity in Lake Tahoe. TRPA oversees the monitoring of existing environmental conditions in the basin through a number of programs. The U.S. Geological Survey (USGS) began a tributary discharge and water-quality monitoring study in 1988 in cooperation with TRPA. TRPA and USGS also instituted a cooperative ground-water monitoring study during 1990-92. A revised ground-water study was reinstated in 1995. Both of these ongoing water-quality data-collection efforts include the involvement of the University of California-Davis, Tahoe Research Group (TRG) and are included in the Lake Tahoe Interagency Monitoring Program (LTIMP). LTIMP was formed in 1978 with 12 State and Federal agencies and TRG (Goldman and others, 1986). Agencies currently participating in LTIMP include TRG; USGS; TRPA; U.S. Forest Service (USFS); U.S. Natural Resources Conservation Service (NRCS); U.S. Environmental Protection Agency (USEPA); Lahontan Regional Water Quality Control Board; California Department of Parks and Recreation; California Department of Fish and Game; California Tahoe Conservancy; Nevada Department of Environmental Protection; University of Nevada, Reno; Douglas County, Nev.; El Dorado County, Calif.; Washoe County, Nev.; and the City of South Lake Tahoe, Calif.

The current USGS-TRPA networks include 32 surface-water sites where suspended sediment, water-quality, and streamflow data are collected, and 32 ground-water sites, where water-quality and water-level data are collected. These surface- and ground-water sites are located throughout the Lake Tahoe Basin. Both of these networks are described in more detail by Boughton and others (1997) and are shown on a map by Rowe and Stone (1997). From these two networks, six surface-water sites and eight ground-water sites were used from within the study area.

In 1996, TRPA developed the Lake Tahoe Federal Legislative Agenda, a public-private partnership of agencies in the Tahoe region (Tahoe Regional Planning Agency, 1996). The plan designated four Lake Tahoe watersheds as high priority for possible watershed restoration projects. TRPA included Third and Incline Creek watersheds in the north, Edgewood Creek watershed in the southeast, and the Upper Truckee River watershed in the south.

In 1996, the Upper Truckee River watershed was chosen for a focused effort to improve water quality within one watershed of the Lake Tahoe Basin. An advisory group, the Upper Truckee River Watershed Focused Group, was formed as a subgroup of LTIMP.

The Upper Truckee River watershed is the largest of the 63 watersheds in the Lake Tahoe Basin. The Upper Truckee River also delivers the largest volume of surface water and may be providing some of the largest nutrient and sediment loads to the lake. Also, the Upper Truckee River watershed has the greatest human population of any watershed in the Lake Tahoe Basin, thus increasing the chances of negative human effects on water quality. The watershed also has several land-uses representative of many water-quality influences that occur throughout the Lake Tahoe Basin. Trout Creek is included in the study area because the watersheds are adjacent to each other and together comprise most of the South Lake Tahoe area.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000, 1969-85
Universal Transverse Mercator projection, Zone 11

Figure 1. Location of Lake Tahoe Basin and Upper Truckee River and Trout Creek watersheds, California and Nevada.

Purpose and Scope

This report presents a compilation of ground-water and surface-water data collected in the Upper Truckee River and Trout Creek watersheds during baseflow conditions from July to December 1996. The data are used to (1) determine ground-water levels and direction of ground-water flow in the watersheds, (2) determine the interaction between ground water and streamflow, and (3) compare the water quality of the ground- and surface-water systems during baseflow conditions.

USGS, in cooperation with TRPA, began a study in July 1996 to improve the understanding of the surface-water and ground-water systems and their interactions within the Upper Truckee River and Trout Creek watersheds. Principle efforts included (1) making streamflow measurements during baseflow conditions on the Upper Truckee River and Trout Creek and their tributaries; (2) inventorying existing wells on the basis of well drillers' reports and canvassing local residents; (3) determining depth to water in located wells; (4) developing a map showing the altitude of the water table using depth-to-water measurements in wells and results of seepage estimates; and (5) collecting additional water-quality data.

Previous Studies

The USGS has been involved with surface-water studies in the Upper Truckee River and Trout Creek watersheds since 1960, when operation of streamflow-gaging stations and surface-water-quality sampling sites first began. Periods of record of daily streamflow, water-quality, and suspended-sediment data are listed in table 1 for eight current and historical sites. Data from these eight sites have been published previously in USGS annual data reports by California and Nevada. Previous USGS surface-water studies in the Upper Truckee River and Trout Creek watersheds have included sediment discharge (Kroll, 1976); flood and related debris-flow hazards map for the South Lake Tahoe area (Katzer and Glancy, 1978); and suspended-sediment factors for the Lake Tahoe Basin (Hill and Nolan, 1988). Jeton (1999) has constructed a precipitation/runoff model for the Lake Tahoe Basin that includes Upper Truckee River and Trout Creek.

TRG has been involved with several studies and has collected physical and chemical data on Upper Truckee River and Trout Creek since the early 1970's. These data are included in LTIMP annual reports. The most recent LTIMP report is by Byron and others (1989).

TRPA also has published annual water-quality reports since 1990 for the Lake Tahoe Basin. These reports have included USGS and TRG data on Upper Truckee River and Trout Creek. The most recent report is by Hill (1996).

USFS also has been involved with several studies collecting physical and chemical data on Upper Truckee River and Trout Creek. USFS has published a water-quality report on the Santa Fe erosion control project by Hoffman (1991); a water-quality report summarizing five baseline stations by Lowry and Meeker (1993); a monitoring report on Hell Hole Road water-quality improvement project by Norman (1996); a water-quality-monitoring report on spring runoff in the Grass Lake research natural area by Norman and Parsons (1997); and a monitoring report on Pope Marsh burn by Norman (1997).

U.S. Army Corps of Engineers (USCOE) published a report on flood-plain information for the Upper Truckee River, South Lake Tahoe, Calif. (U.S. Army Corps of Engineers, 1969). El Dorado County Department of Transportation has been involved in several studies and data collection efforts on the Upper Truckee River and Trout Creek. A recently published report on the Apache Erosion Control project was done by Robinson (1996).

Within the study area, ground water is the primary source for domestic and public water supplies. Historical wastewater disposal practices and current large municipal withdrawals of ground water within the Upper Truckee River and Trout Creek watersheds are the basis for several studies that focused on water quality and quantity. For example, the California Department of Water Resources has been monitoring water levels since 1958 for selected wells to identify long-term trends, if any, within the Lake Tahoe Basin. Two of these wells are within the study area. Thodal (1997) used data from 32 wells to characterize ground-water quality within the Lake Tahoe Basin. Six of these wells are within the study area. Scott and others (1978), Blum (1979), and Woodling (1987) report the results of hydrogeologic investigations in the study area. Results of investigations of ground-water nutrient flux of the Upper Truckee River and Trout Creek watersheds are included in reports by Loeb and Goldman (1979), Loeb (1987), and Thodal (1997).

Table 1. Periods of record for daily streamflow, water-quality, and suspended-sediment data at current and historical U.S. Geological Survey gaging stations and sampling sites for Upper Truckee River and Trout Creek watersheds, California

Water quality: NUT, instantaneous nutrient samples; SC, daily specific conductance; WT, daily water temperature.
Suspended sediment: DAILY, daily suspended sediment; INST, instantaneous suspended sediment discharge.
[Abbreviation: USFS, U.S. Forest Service]

Site no. (pl. 1)	Site name	Station number	Daily streamflow	Water quality	Suspended sediment
	Upper Truckee River watershed				
6	Upper Truckee River at Hwy 50 at South Lake Tahoe (gage)	10336610	1972-74,77, 78,80-current	WT:1972-74,78,80-92 SC:1981-83 NUT:1993-current	DAILY:1972-74,78,80-92 INST: 1993-current
17	Upper Truckee River at Hwy 50 above Meyers (gage)	103366092	1990-current	NUT:1990-current	INST:1990-current
20	Upper Truckee River nr Meyers (inactive gage)	10336600	1961-86		
43	Upper Truckee River at S. Upper Truckee Rd (gage)	10336580	1990-current	NUT:1990-current	INST:1990-current
	Trout Creek watershed				
49	Trout Creek at Hwy 50 at South Lake Tahoe	10336790		WT:1972-74,89-92 NUT:1993-current	DAILY: 1972-74,89-92 INST:1993-current
52	Trout Creek at Martin Ave nr Tahoe Valley (gage)	10336780	1961-current	WT:1972-74,78, 80-85,88 SC:1981-83	DAILY:1972-74,78, 80-85,88
57	Trout Creek at Pioneer Trail nr South Lake Tahoe (gage)	10336775	1990-current	NUT:1990-current	INST:1990-current
68	Trout Creek at USFS Rd 12N01 nr Meyers (gage)	10336770	1990-current	NUT:1990-current	INST:1990-current

Acknowledgments

This work was done in cooperation with the Tahoe Regional Planning Agency. Appreciation is extended to residents in the area who gave permission to access their wells. Many government and private agencies also are acknowledged for providing data and access to their wells: Agra Earth and Environmental; California Department of State Parks and Recreation; California Department of Water Resources; California Tahoe Conservancy; El Dorado County Department of Transportation; Lahontan Water Quality Control Board; South Tahoe Public Utility District; and U.S. Forest Service—Lake Tahoe Basin Management Unit.

DESCRIPTION OF STUDY AREA

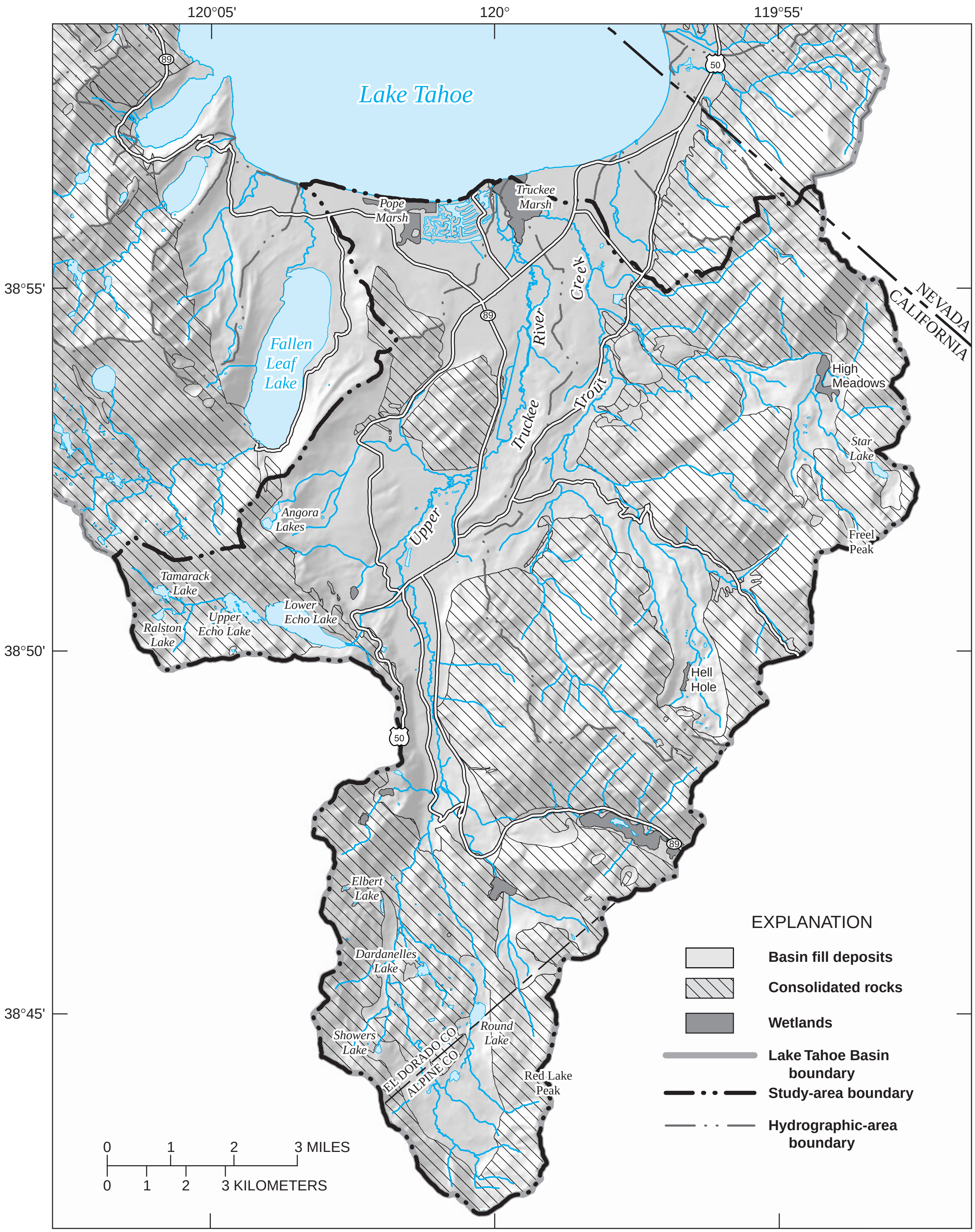
The study area is in the southern part of the Lake Tahoe Basin Hydrographic Area[1] and includes the entire Upper Truckee River and Trout Creek watersheds (figs. 1 and 2) in California. Additionally, samples were taken from wells and a spring adjacent to the study area in California and Nevada.

Historically, Trout Creek was tributary to Upper Truckee River in the Truckee Marsh area near the lake (fig. 2). But with development of the Tahoe Keys, the Upper Truckee River was channeled to the lake and currently the streamflow of the two tributaries combine only during high runoff. Because of this historical combination of the Upper Truckee River and Trout Creek on the surface, speculation is that their ground-water systems also may combine at some point. This is one reason that both watersheds are included in this study.

Geology

The main geologic units identified within the study area are granitic rocks and glacial deposits. Other units that are much less extensive are pluvial

[1]Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960's (Rush, 1968; Cardinalli and others, 1968) for scientific and administrative purposes. 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.



Planimetric base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000, 1969–85
Universal Transverse Mercator Projection, Zone 11.
Shaded-relief base from 1:24,000 Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Geology from Burnett (1971)

Figure 2. Locations of roads, streams, and general surficial geology, Upper Truckee River and Trout Creek watersheds, California.

and alluvial deposits, volcanic rock, and metamorphic rock (Tahoe Regional Planning Agency and U.S. Forest Service, 1971, plate).

The geology of the study area can be characterized by lake and glacial deposits at the lower altitudes, flatlands, and low-lying hills; and by granitic rocks that make up the steep and high mountain slopes and peaks. The only volcanic rocks within the study area are in the extreme headwaters of the Upper Truckee River watershed, and the only metamorphic rocks are two small areas above Echo Lake and two small areas in the low-lying hill between the City of South Lake Tahoe and Fallen Leaf Lake. Lake deposits are evident in a few high-mountain meadows and along the lower stream channels in the Upper Truckee River and Trout Creek watersheds (Tahoe Regional Planning Agency and U.S. Forest Service, 1971, plate).

Landforms of the study area were principally shaped from tectonic and glacial processes. A combination of basin-and-range style fault-bounded blocks and glacial erosional and depositional action resulted in the formation of the present-day landforms. Four periods of major glaciation shaped these landforms (Tahoe Regional Planning Agency and U.S. Forest Service, 1971). The major landforms attributed to glaciation are deep basin-fill deposits, steep mountain slopes adjacent to the upper reaches of the Upper Truckee River and Trout Creek, and large lateral moraines that divide the Trout Creek watershed from the Upper Truckee River watershed and the Upper Truckee River watershed from Fallen Leaf Lake (Tahoe Regional Planning Agency and U.S. Forest Service, 1971).

The basin-fill deposits within the study area are comprised entirely of lake, stream, and glacial deposits. Also, the underlying basement rock is assumed to be entirely granitic. Thicknesses of the basin-fill deposits in the South Lake Tahoe area near Lake Tahoe may be as great as 1,600 - 1,900 ft (Blum, 1979). For the purposes of this report, the areas with basin-fill deposits will be referred to as unconsolidated areas and the areas that have exposed bedrock will be referred to as consolidated areas.

Vegetation

Vegetation in the Upper Truckee River and Trout Creek watersheds is primarily coniferous forest with lodgepole pine, ponderosa pine, Jeffrey pine, white fir, red fir, western white pine, mountain hemlock, and sugar pine. Alders, aspen, and willows are common along the stream zones (Cartier and others, 1993).

Climate

In the Upper Truckee River watershed, precipitation (mostly in the form of snow) ranges from nearly 25 in. to greater than 60 in., with a general decrease from west to east (Twiss and others, 1971). In the Trout Creek watershed, precipitation ranges from nearly 20 in. to about 40 in. with a general decrease from southwest to northeast. The National Weather Service reported above average annual precipitation during 1996 at the long-term weather stations in Tahoe City and Glenbrook. The daily precipitation record for a nearby National Resource Conservation Service (NRCS) Snow Telemetry (SNOTEL) site near Lake Tahoe just north of Fallen Leaf Lake is shown in figure 7. Most of the precipitation for 1996 (approximately 94 percent) occurred between late November 1995 and mid-May 1996. Minor rainfall amounts were recorded at the end of June, mid-July, and mid-August of 1996. Summer thunderstorms, typical of the study area, were almost absent in 1996.

History

Historically, the land use of the Lake Tahoe Basin by humans first began with the Washoe Indian Tribe. Major changes in land use occurred with the discovery of the Comstock Lode in nearby Virginia City, Nev. Many trees in the Lake Tahoe Basin, including those within the study area, were harvested to provide shoring timbers for the Comstock mines (Crippen and Pavelka, 1972). When the Comstock era began to decline during the late 1800’s, the Lake Tahoe Basin began to emerge as a seasonal vacation area. By the end of World War II, the Lake Tahoe Basin had become an established year-round destination.

Upper Truckee River Watershed

The Upper Truckee River watershed is almost entirely within El Dorado County, Calif. (fig. 2). About 3 mi^2 of the southern tip is in Alpine County, Calif. This watershed is the largest in the Lake Tahoe Basin and occupies 56.5 mi^2, which is 18 percent of the total land area tributary to Lake Tahoe (314 mi^2). Upper Truckee River has a drainage perimeter of 53.9 mi (Cartier and others, 1995). The Upper Truckee River main channel length is 21.4 mi. The land-surface altitudes range from lake level to 10,063 ft above sea level at Red Lake Peak (fig. 2).

The lowest land-surface altitude within the study area that is above water is determined by the surface of Lake Tahoe, which can fluctuate from a little below its natural rim of 6,221.9 ft (6,223.0 ft Bureau of Reclamation (BOR) datum) to slightly greater than its legal maximum altitude of 6,228.0 ft (6,229.1 ft BOR datum). For the period of this study, July through December, Lake Tahoe had a maximum lake-surface altitude in July of 6,227.9 ft, a minimum in November of 6,226.1 ft, and a mean of 6,227.0 ft (Bonner and others, 1998).

Percent slope, which describes the steepness of the topography within the watershed, ranges from approximately zero near Lake Tahoe and along the valley bottoms, to as much as 50 in the upper altitudes of the watershed (Cartier and others, 1993). Dominant aspect, which is the compass direction of a slope face, is generally east, west, southwest, and northwest facing slopes.

The main tributary drainages to the Upper Truckee River (pl. 1) include Grass Lake Creek (drainage area of 6.4 mi^2; table 2), Angora Creek (5.7 mi^2), Echo Creek (5.4 mi^2), and Big Meadow Creek (5.1 mi^2). Major wetlands include Grass Lake, Osgood Swamp, Truckee Marsh, Benwood Meadow, and Big Meadow (pl. 1). Major lakes include Upper and Lower Echo Lakes and smaller lakes include Dardanelles, Round, Showers, Elbert, Tamarack, Ralston, and Angora Lakes (fig. 2). The only diversion from this watershed is to the American River Basin from Echo Lake, which has a storage capacity of 1,890 acre-ft (Bostic and others, 1997, p. 260).

Trout Creek Watershed

The Trout Creek watershed is within El Dorado County, Calif., east of the Upper Truckee River watershed (fig. 2). The watershed is the second largest in the Lake Tahoe Basin and occupies 41.2 mi^2, which is 13 percent of the total land area tributary to Lake Tahoe. Trout Creek has a drainage perimeter of 34.8 mi. Trout Creek has a main channel length of 12.1 mi. The land-surface altitudes range from lake level to 10,881 ft at Freel Peak (fig. 2).

Percent slope ranges from approximately zero in the lower reach near Lake Tahoe, to 50 at higher altitudes (Cartier and others, 1993). Aspect is a mixture of generally west, east, north, northwest, and southwest facing slopes.

The main tributaries to Trout Creek include Cold Creek (drainage area of 12.8 mi^2), Saxon Creek (8.2 mi^2), Heavenly Valley Creek (3.0 mi^2), and Hidden Valley Creek (1.7 mi^2; table 2, pl. 1). Major wetland areas include Truckee Marsh, High Meadows, and Hell Hole (pl. 1, fig. 2). The only lake in the Trout Creek watershed is Star Lake (fig. 2). The major basin diversion is ground-water withdrawal for municipal use.

INVENTORY AND MEASUREMENT METHODS

Streamflow and Seepage

Seepage estimates were determined for selected reaches in the Upper Truckee River and Trout Creek watersheds by measuring streamflow entering and leaving the reach and by measuring all tributary flows entering the reach during base-flow conditions. If streamflow leaving the reach exceeded all streamflow entering the reach by at least 5 percent, the difference was assumed to be ground-water seepage to the stream and the reach is referred to as a gaining reach. If flow leaving the reach was less than all inflow to the reach by at least 5 percent, then the streamflow was assumed lost to ground water and the reach is referred to as a losing reach. If flow leaving the reach was within 5 percent of all the inflow to the reach, then the difference was within standard measurement error and the reach is referred to as a steady reach with no losses or gains. This method for estimating seepage along the stream channels assumes no overland runoff, negligible evaporation directly from the stream, negligible evapotranspiration from riparian vegetation along the stream, and no storage changes along the stream channel.

Unit-runoff values were derived by dividing streamflow values by contributing drainage area. Unit-runoff values are defined as the average number of cubic feet per second flowing from each square mile of area drained by a stream, assuming that the runoff is distributed uniformly in time and space. Delineation of drainage areas used in this study are from Cartier and others (1995).

Seventy streamflow measurement sites were established in the study area—45 in the Upper Truckee River watershed and 25 in the Trout Creek watershed.

.

Table 2. Streamflow measurement sites used for seepage estimates in the Upper Truckee River and Trout Creek watersheds, California, September 1996

Site no. (pl. 1)	Site name	Station number	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Drainage area (square miles)	Altitude (feet)	River mile, from mouth (miles)
	Upper Truckee River watershed						
1	Upper Truckee R. at mouth - W. channel-off Venice Dr	10336612	385604	1195957	56.5	6,228	0.5
2	Upper Truckee R. at mouth - E. channel	103366117	385557	1195944		6,228	.9
3	Upper Truckee R. abv marsh - W. channel-off Michael	103366113	385532	1195939		6,228	1.5
4	Upper Truckee R. abv marsh - E. channel-off Michael	10336611	385531	1195937		6,228	1.5
5	D St Drainage at Sky Meadows	103366107	385531	1195939		6,240	1.5
6	Upper Truckee R. at Hwy 50 at S. Lake Tahoe (gage)	10336610	385522	1195925	54.0	6,229	1.9
7	Upper Truckee R. blw SLT Airport - E. channel	1033660987	385447	1195911		6,240	2.8
8	Upper Truckee R. blw SLT Airport - W. channel	1033660985	385453	1195926		6,240	3.1
9	Upper Truckee R. at Hwy 50 blw Meyers	103366098	385231	1200016	50.1	6,280	6.5
10	Sante Fe Trib at Country Club Rd nr Arapahoe St	103366095	385157	1200041	1.0	6,320	7.5
11	Sante Fe Trib blw Hwy 50 off Sante Fe Rd	1033660947	385125	1200041		6,350	8.2
12	Angora Ck. nr Sawmill Rd at Ranch Rd	103366096	385228	1200102	5.7	6,290	7.3
13	Sawmill Pond Outlet at Sawmill Rd	1033660957	385319	1200132		6,340	8.7
14	Angora Ck. at Lake Tahoe Blvd	1033660953	385252	1200221		6,360	8.9
15	Upper Truckee R. abv Golfcourse off Country Club Dr	1033660943	385155	1200114		6,290	8.3
16	Osgood Ck. at N. Upper Truckee Rd	103366094	385114	1200203	1.6	6,380	9.4
17	Upper Truckee R. at Hwy 50 abv Meyers (gage)	103366092	385055	1200134	39.2	6,310	9.8
18	Upper Truckee R. Trib at N. Upper Truckee Rd nr Hwy 50	103366091	385051	1200143		6,360	9.9
19	Echo Ck. at S. Upper Truckee Rd nr Meyers	10336609	385045	1200135	5.4	6,350	10.0
20	Upper Truckee R. nr Meyers (old gage)	10336600	385035	1200125	33.2	6,322	10.3
21	Upper Truckee R. Trib nr Kekin St at S. Upper Truckee Rd	10336599	385020	1200124		6,380	10.6
22	Upper Truckee R. Trib at Celio Ranch at S. Upper Truckee Rd	10336598	385008	1200119		6,380	11.1
23	Upper Truckee R. Trib at Hwy 89 N. of Santa Claus Dr	10336597	384951	1200058		6,400	11.5
24	Upper Truckee R. Trib at Hwy 89 S. of Santa Claus Dr	10336596	384923	1200059		6,410	12.3
25	Upper Truckee R. blw Grass Lake Ck. (blw Portal Rd)	10336594	384858	1200101		6,410	12.8
26	Upper Truckee R. N. Trib at Grass Lk Rd	1033659356	384826	1200052		6,480	13.6
27	Upper Truckee R. S. Trib at Grass Lk. Rd (Grass Lk. Ck. Div)	1033659354	384813	1200052		6,480	13.7
28	Grass Lake Ck. nr Meyers (off Grass Lake Rd)	10336593	384807	1200054	6.4	6,480	13.9
29	Grass Lake Ck. at Hwy 89 (lower)	103365925	384753	1200030		6,880	14.3
30	Grass Lake Ck. abv Big Meadow Ck. at Hwy 89	10336592	384740	1195935		7,440	15.3
31	Grass Lake Ck. Trib W. abv Hwy 89	103365915	384750	1195847		7,640	15.9
32	Grass Lake Ck. Trib MidWest abv Hwy 89	10336591	384751	1195840		7,650	16.2
33	Grass Lake Ck. Trib MidEast abv Hwy 89	103365905	384752	1195805		7,720	16.8
34	Grass Lake Ck. blw Grass Lake	10336590	384740	1195802		7,720	16.8
35	Grass Lake Ck. Trib E. abv Hwy 89	10336588	384741	1195729		7,720	17.5

Table 2. Streamflow measurement sites used for seepage estimates in the Upper Truckee River and Trout Creek watersheds, California, September 1996—Continued

Site no. (pl. 1)	Site name	Station number	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Drainage area (square miles)	Altitude (feet)	River mile, from mouth (miles)
36	Grass Lake Ck. Trib abv Hwy 89 nr Luther Pass	10336587	384738	1195715		7,720	17.8
37	Big Meadow Ck. at mouth off Grass Lake Rd	1033659352	384803	1200050	5.1	6,480	14.0
38	Big Meadow Ck. at Hwy 89 (lower)	103365935	384732	1200035		7,010	14.7
39	Big Meadow Ck. abv Hwy 89	103365932	384711	1200011		7,160	15.4
40	Benwood Meadows Trib N. at S. Upper Truckee Rd	10336584	384806	1200105	1.4	6,480	14.0
41	Benwood Meadows Trib Middle at S. Upper Truckee Rd	10336583	384804	1200105		6,480	14.0
42	Benwood Meadows Trib S. at S. Upper Truckee Rd	10336582	384803	1200103		6,480	14.0
43	Upper Truckee R. at S. Upper Truckee Rd (gage)	10336580	384745	1200106	14.2	6,490	14.3
44	Upper Truckee R. Trib abv Hawley Grade Rd	10336579	384727	1200110		6,600	14.7
45	Upper Truckee R. abv Trib abv Hawley Grade Rd	10336578	384727	1200115		6,600	14.8
	Trout Creek watershed						
46	Trout Ck. nr mouth - E. channel-off Bellevue/El Dorado Ave	10336795	385611	1195917	41.0	6,230	.7
47	Trout Ck. nr mouth - middle channel-off Bellevue/El Dorado Ave	10336794	385607	1195920		6,230	.7
48	Trout Ck. nr mouth - W. channel-off Bellevue/El Dorado	10336793	385605	1195922		6,230	1.1
49	Trout Ck. at Hwy 50 at S. Lake Tahoe	10336790	385556	1195842	40.4	6,240	1.5
50	Heavenly Valley Ck. at Black Bart nr Tahoe Valley	10336785	385517	1195813	3.0	6,260	2.8
51	Heavenly Valley Ck. at Pioneer Trail	10336783	385504	1195730		6,300	3.8
52	Trout Ck. at Martin Ave nr Tahoe Valley (gage)	10336780	385512	1195817	36.7	6,241	2.8
53	Cold Ck. at mouth (off Plateau Dr)	10336779	385444	1195806	12.8	6,260	3.6
54	Cold Ck. at Pioneer Trail	10336778	385432	1195739		6,300	4.1
55	Cold Ck. Trib at Del Norte Dr	10336777	385427	1195712		6,440	4.7
56	Cold Ck. off Del Norte Dr	10336776	385406	1195715		6,440	4.8
57	Trout Ck. at Pioneer Trail nr S. Lake Tahoe (gage)	10336775	385413	1195804	23.0	6,270	4.3
58	Trout Ck. Trib off Columbine nr USFS Rd 12N08	103367745	385346	1195751		6,280	5.1
59	Trout Ck. Trib off Pioneer Trail at old RR grade	10336774	385324	1195816		6,280	5.7
60	Trout Ck. blw Saxon Ck. off Powerline Rd	10336773	385302	1195836		6,280	6.3
61	Saxon Ck. blw Landfill at Powerline Rd	103367726	385245	1195858	8.2	6,300	6.8
62	Saxon Ck. at USFS Rd 12N01	10336772	385219	1195855		6,320	7.4
63	Saxon Ck. Trib abv USFS Rd 12N01	103367718	385212	1195845		6,360	7.6
64	Saxon Ck. abv Trib abv old RR grade	103367716	385206	1195853		6,360	7.7
65	Trout Ck. abv Saxon Ck. at Powerline Rd	103367708	385247	1195847		6,300	6.7
66	Hidden Valley Ck. at Trail Crossing	103367706	385220	1195727	1.7	7,000	8.4
67	Trout Ck. Trib blw gage at USFS Rd 12N01	103367702	385151	1195733	1.4	6,940	8.8
68	Trout Ck. at USFS Rd 12N01 nr Meyers (gage)	10336770	385148	1195726	7.4	6,850	8.8
69	Hell Hole Meadow Trib nr mouth	10336768	385117	1195654	2.8	7,520	9.6
70	Trout Ck. abv Hell Hole Trib at Horsetrail Crossing	10336769	385126	1195646		7,500	9.6

Streamflow was determined at 63 of the streamflow measurement sites—40 in the Upper Truckee River watershed and 23 in the Trout Creek watershed. These sites were selected to estimate seepage and unit-runoff values along selected reaches in the main stems and tributaries (tables 3 and 4, pl. 1, fig. 3). Of the 40 sites in the Upper Truckee River watershed with streamflow measurements, 13 are main-stem sites and 27 are tributary sites. The main stem of the Upper Truckee River was divided into 10 reach segments. Of the 23 sites in the Trout Creek watershed with streamflow measurements, 9 are main-stem sites and 14 are tributary sites. The main stem of Trout Creek was divided into six reach segments. Existing streamgage locations and water-quality sampling sites were selected along with sites at the confluence of all inflowing tributaries with the main-stem streams. Additional sites along the major tributaries were selected in each watershed. The selection of these sites was made on the basis of accessibility. Measurements of streamflow were made on the same day within each watershed. Streamflow measurements in the Upper Truckee River watershed were made on September 23, 1996, and streamflow measurements in the Trout Creek watershed were made on September 26, 1996.

Streamflows were measured following USGS guidelines (Buchanan and Somers, 1969). Water and air temperatures were measured using calibrated field thermometers.

River miles (distance from mouth of river to seepage measurement sites) along the main stems were calculated from the mouth of each watershed using a geographical information system (table 2, fig. 3). River miles on the tributaries were calculated by taking the river mile of the main channel at the tributary mouth and then adding the distance of the tributary channel going upstream. River miles were used in computing relative ground-water seepage rates along selected reaches of the Upper Truckee River and Trout Creek.

Wells and Ground-Water Levels

Well drillers' logs in the study area were obtained from the California Department of Water Resources. These logs are used to locate existing domestic and public supply wells and to provide well-construction information such as well depth, screen interval, well diameter, and lithology. A field reconnaissance of existing wells was made from early August 1996 through November 1996. Some wells were found after interviewing local residents in areas of known domestic withdrawals. When a well was found, its location was plotted on a 7.5-minute topographic map and its latitude and longitude coordinates were determined using a Precision Lightweight Global Positioning System Receiver (PLGR). The accuracy of these locations is ±100 ft, or approximately 1 second of latitude or longitude.

Field information collected for each well included casing diameter, well depth, well-owner information, measuring-point height, land-surface altitude, well and water-use status, and water level (table 5). All land-surface altitudes were taken from USGS 7.5-minute topographic quadrangle maps except for those wells that already had land-surface altitudes determined by conventional surveying techniques. The accuracy of land-surface altitudes estimated from the maps is typically within 20 ft and often within 10 ft, depending on the topographic-contour interval (plus or minus one-half of the topographic-contour interval). For land-surface altitudes determined by surveying techniques, accuracies are within 0.1 ft. All water-level measurements were made using either a steel or electric tape. Because water levels were determined by subtracting depth to water from land-surface altitudes, they carry the same uncertainties as the land-surface altitudes. Domestic wells were frequently used for yard irrigation during the late summer and early fall when data were collected. Water levels from these pumping wells are not representative of static conditions (table 5). Data for wells presented in this report are stored in the USGS National Water Information System (NWIS) data base.

Between July 16 and November 8, 1996, USGS staff inventoried 94 wells and 1 spring. Of the 94 wells, 79 are within the study-area boundaries. The other 15 wells and 1 spring are adjacent to the study area. Most of the sites adjacent to the study area were included in this study to help interpret water-level contours and hydraulic gradients at the study area boundaries. The remainder of these sites were included because the information from them is previously unpublished.
Of the 79 wells within the study area, water levels were measured at 62 wells. Seventeen wells were not measured because they were either flowing, inaccessible, or pumping almost continuously. Thirteen of the wells measured had been pumped recently (identified with an R on table 5), and may not represent a static water level. Two of the wells measured were pumping; these water levels are not representative of static levels

Table 3. Streamflow and water-quality data for streamflow sites in the Upper Truckee River and Trout Creek watersheds, California, September 1996

[Abbreviations and symbol: ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; $ft^3/s/mi^2$, cubic feet per second per square mile; --, not measured]

Site no. (pl. 1)	Flow (ft^3/s)	Specific conductance (μS/cm)	Air temperature (degrees Celsius)	Water temperature (degrees Celsius)	Unit runoff ($ft^3/s/mi^2$)
			Upper Truckee River watershed		
1	--	99	--	--	--
2	0	--	--	--	--
3	11.6	98	16.0	12.0	0.21
4	0	--	--	--	--
5	0	--	--	--	0
6	11.2	96	--	13.5	.21
7	10.1	98	14.0	12.0	--
8	0	--	--	--	--
9	10.3	98	18.5	11.5	.21
10	0	--	--	--	0
11	0	--	--	--	0
12	.8	72	14.5	6.5	.14
13	0	--	--	--	0
14	.2	39	3.5	4.5	--
15	10.4	99	18.5	12.0	--
16	.1	31	5.0	5.5	.06
17	8.5	91	14.5	9.5	.22
18	0	--	--	--	0
19	.1	148	15.5	9.0	.02
20	7.7	84	14.0	10.5	.23
21	0	--	--	--	0
22	0	--	--	--	0
23	0	--	--	--	0
24	0	--	--	--	0
25	6.4	75	20.0	11.0	--
26	0	--	--	--	0
27	.9	73	19.5	8.5	--
28	1.1	73	16.5	7.5	.31
29	--	--	--	--	--
30	2.6	65	18.5	8.5	--
31	.1	36	17.0	9.5	--
32	.3	43	17.5	7.5	--
33	.2	--	--	--	--
34	1.0	43	18.0	11.5	--
35	--	--	--	--	--

Table 3. Streamflow and water-quality data for streamflow sites in the Upper Truckee River and Trout Creek watersheds, California, September, 1996—Continued

Site no. (pl. 1)	Flow (ft^3/s)	Specific conductance (μS/cm)	Air temperature (degrees Celsius)	Water temperature (degrees Celsius)	Unit runoff ($ft^3/s/mi^2$)
36	--	--	--	--	--
37	0.9	69	10.0	7.5	0.18
38	--	--	--	--	--
39	.5	50	18.5	8.0	--
40	0	--	--	--	0
41	0	--	--	--	--
42	0	--	--	--	--
43	3.1	51	10.0	6.0	.22
44	.6	50	14.5	7.0	--
45	2.6	50	25.0	9.0	--
Trout Creek watershed					
46	11.8	50	17.0	11.5	.56
47	8.4	50	15.5	10.5	--
48	2.8	50	15.5	11.5	--
49	22.6	50	14.0	7.0	.56
50	.2	52	20.5	7.0	.07
51	.4	50	11.0	7.0	--
52	20.6	52	--	10.5	.56
53	11.2	43	27.0	8.0	.88
54	11.3	44	30.0	7.0	--
55	0	--	--	--	0
56	--	--	--	--	--
57	10.8	54	14.5	10.5	.47
58	.1	92	17.0	9.0	--
59	.1	75	16.0	9.0	--
60	--	--	--	--	--
61	2.4	55	15.5	6.5	.29
62	2.5	46	19.0	7.5	--
63	.2	54	19.5	7.5	--
64	2.0	45	18.0	7.5	--
65	9.8	52	18.5	6.0	--
66	.8	51	18.0	7.0	.47
67	1.4	44	17.0	6.0	1.00
68	6.2	53	9.5	5.0	.84
69	1.0	54	11.5	6.0	.36
70	4.7	49	12.0	7.0	--

Table 4. Streamflow measurement data and seepage estimates for designated main-stem reaches in the Upper Truckee River and Trout Creek, California, September 1996

[Abbreviations and symbol: ft^3/s, cubic feet per second; $ft^3/s/mi$, cubic feet per second per mile; nd, streamflow not determined; --, not applicable]

Reach number (pl. 1)	Reach segment (between site numbers)	Flow at beginning of reach (ft^3/s)	Tributary flows (ft^3/s)	Flow out of reach (ft^3/s)	Percent change in flow [1]	Estimated ground-water seepage (ft^3/s) [2]	Reach designation [3]	Estimated gain (+) or loss (-) per unit length ($ft^3/s/mi$) [4]
				Upper Truckee River				
1	1 to 3	11.6	0	nd	--	--	--	--
2	3 to 6	11.2	0	11.6	+3.6	--	Steady	--
3	6 to 7	10.1	0	11.2	+11	+1.1	Gaining	+1.2
4	7 to 9	10.3	0	10.1	-1.9	--	Steady	--
5	9 to 15	10.4	.8	10.3	-8.0	-0.9	Losing	-0.50
6	15 to 17	8.5	.1	10.4	+21	+1.8	Gaining	+1.2
7	17 to 20	7.7	.1	8.5	+9.0	+0.7	Gaining	+1.4
8	20 to 25	6.4	0	7.7	+20	+1.3	Gaining	+0.52
9	25 to 43	3.1	2.9	6.4	+6.7	+0.4	Gaining	+0.27
10	43 to 45	2.6	.6	3.1	-3.1	--	Steady	--
				Trout Creek				
11	46 to 49	22.6	0	23.0	+1.8	--	Steady	--
12	49 to 52	20.6	.2	22.6	+8.7	+1.8	Gaining	+1.4
13	52 to 57	10.8	11.2	20.6	-6.4	-1.4	Losing	-0.93
14	57 to 65	9.8	2.6	10.8	-13	-1.6	Losing	-0.67
15	65 to 68	6.2	2.2	9.8	+17	+1.4	Gaining	+0.67
16	68 to 70	4.7	1.0	6.2	+8.8	+0.5	Gaining	+0.62

[1] Percent change in flow determined as difference between flow out of reach and sum of flow at beginning of reach and all tributary flows.

[2] Ground-water seepage is difference between flow out of reach and sum of flow at beginning of reach and all tributary flows.

[3] If percent change in flow is greater than 5 percent, then reach is designated as gaining (gaining flow from ground-water seepage into reach). If percent change in flow is less than -5 percent, then reach is designated as losing (losing flow to ground-water seepage out of reach). If percent change in flow is greater than -5 percent and less than 5 percent, then reach is designated as steady (no change in flow due to ground-water seepage).

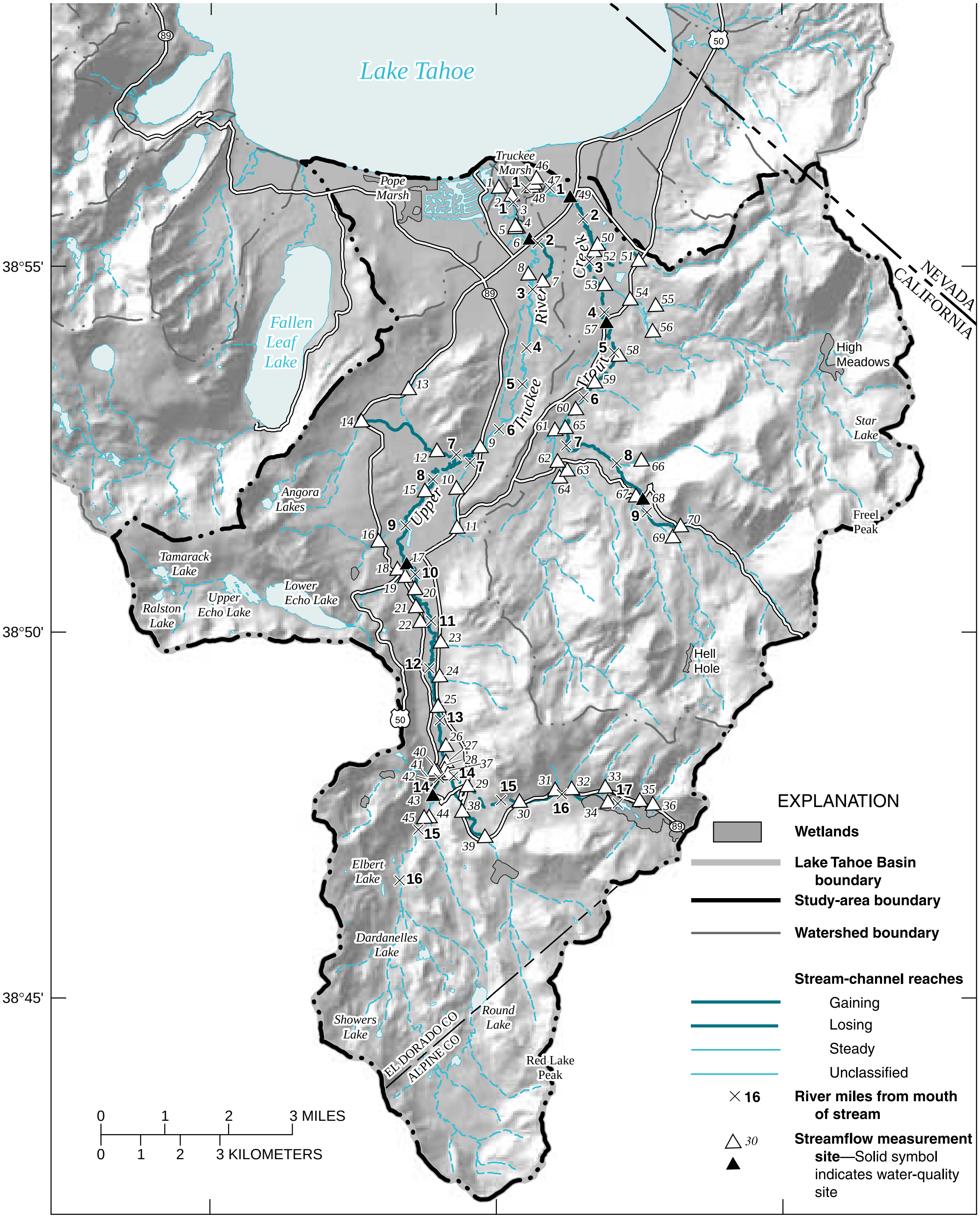
[4] Gain (+) or loss (-) is estimated ground-water seepage divided by length of reach (see table 2 for river mile designations).

but do give a lower boundary for the water surface (water level in parentheses in table 5). The water-use distribution for the 79 wells within the study area is as follows: 11 wells are used for public supply; 45 wells are used for domestic purposes; and 23 wells are used for monitoring purposes (fig. 4).

Well locations and associated water-level altitudes were used along with seepage estimates to develop a water-level map of the study area (pl. 1). Directions of ground-water flow in the study area were determined from the water levels on plate 1.

Hydraulic gradients in the study area were determined also from water levels shown on plate 1. Because of the uncertainties in water-level altitudes, an inherent uncertainty is associated with the hydraulic gradients. These uncertainties are generally greatest in the middle part of the study area (Tahoe Paradise area) and the least in the steeply sloping area above Christmas Valley along Luther Pass.

The 94 wells inventoried for this study are a sample of the entire population of wells in and adjacent to the study area. How many wells make up the entire well population is unknown due to inconsistent reporting of well drilling in the past as well as undocumented destruction of wells. The sample distribution of wells is assumed to be representative of the total well distribution. This results in clusters of wells in areas of current domestic withdrawals and areas of environmental ground-water monitoring. Three major clusters are apparent on plate 1. The largest cluster is in the south end of Christmas Valley, where the residential population is still on domestic-well systems. Another cluster is on the south side of Twin Peaks, where the



Planimetric base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000, 1969–85
Universal Transverse Mercator Projection, Zone 11.
Shaded-relief base from 1:24,000 Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Figure 3. Streamflow measurement sites, Upper Truckee River and Trout Creek watersheds, California, September 1996.

Table 5. Selected characteristics of ground-water monitoring sites in Upper Truckee River and Trout Creek watersheds, California and Nevada, July-November 1996

Land-surface altitude uncertainties: ±0.1 foot, altitudes determined from surveying techniques; ±6, 10, and 20 feet, altitudes determined from map with uncertainty being + or - one-half topographic contour interval. Topographic contour interval for this region is 40 feet for altitudes greater than 6,280 feet with a supplementary contour interval of 20 feet for altitudes less than 6,280 feet, and using a Lake Tahoe altitude of 6,228 feet. Contour interval for altitudes less than 6,240 feet is 12 feet.
Site status: D, dry well; F, flowing well, but head was not measured; P, well being pumped; R, well pumped recently; S, site is a spring, water level is at land-surface; Z, unable to access for water level measurement. If no status is indicated, reported water level measurement represents static level. Water level may represent local conditions only.
Method: S, steel tape; T, electric tape; O, observed in field.

[Symbols: --, unknown; <, less than; >, greater than]

Well no. (pl. 1)	U.S. Geological Survey site identification number [1]	Local identification number [2]	Station name	Land-surface altitude (feet above sea level)	Land-surface altitude uncertainty (+ or - feet)	Well casing: Diameter (inches)	Well casing: Depth (feet below land surface)	Well casing: Open interval (feet below land surface)	Measured water level: Date measured	Measured water level: Depth (feet below land surface)	Measured water level: Water-level altitude (feet)	Measured water level: Site status/ Method
			Upper Truckee River watershed									
71	385613120014801	90 N13 E18 06ABBC1	USGS TM-2A [3]	6,235	6	2	20.45	15.45 - 20.45	11-08-96	3.16	6,232	/S
72	385559120001301	90 N12 E18 05AADD1	KEYS 1 [3]	6,230	6	--	318	--	11-22-96	--	--	P/
73	385519120004601	90 N12 E18 05CAAD1	LOPEZ	6,257.6	.1	8	60	36 - 60	10-23-96	25.0	6,232.6	/T
74	385518119593801	90 N12 E18 04CAAD1	LITTLE TRUCKEE MOBILE PARK	6,240	10	--	--	--	09-17-96	13.21	6,227	R/S
75	385517119593901	90 N12 E18 04CAAD2	SWEATT	6,240	10	6	68	56 - 66	10-01-96	15.3	6,225	/T
76	385511119593301	90 N12 E18 04DBCB1	EDS AUTO BODY	6,240	10	6	72	47 - 71	10-04-96	17.8	6,222	/T
77	385507119593002	90 N12 E18 04DBCA2	HELEN 2 [3]	6,240	6	12	150	90 - 150	07-16-96	--	--	P/
78	385504119595201	90 N12 E18 04CACC1	MATTERHORN MOTEL	6,250	10	8	125	--	09-17-96	27.54	6,222	R/S
79	385428120001101	90 N12 E18 08AAAD1	HURLEY	6,285	20	6	68	44 - 64	10-21-96	37.0	6,248	/T
80	385423119593601	90 N12 E18 09ABC 1	AIRPORT 2 [3]	6,240	10	12	380	186 - 366	07-16-96	--	--	P/
81	385318120000301	90 N12 E18 16BCCA1	MCGEE	6,300	20	6	412	--	11-19-96	--	>6,300	F/O
82	385251120022601	90 N12 E18 18CCCB1	ANGORA CR SED BASIN 1	6,340	20	1.5	8	--	10-11-96	2.00	6,338	/S
83	385251120022401	90 N12 E18 18CCCB2	ANGORA CR SED BASIN 2	6,340	20	1.5	8	--	10-11-96	3.01	6,337	/S
84	385245120001601	90 N12 E18 20AAAB1	BROWN ABANDONED HOUSE	6,330	20	6	--	--	08-21-96	12.00	6,318	/S
85	385234120002401	90 N12 E18 20ADBB2	LOEFLER	6,280	20	6	70	--	08-20-96	17.27	6,263	/S
86	385232120002401	90 N12 E18 20ADBB1	GUARNERO	6,270	10	6	--	--	08-19-96	12.96	6,257	R/S
87	385232120002301	90 N12 E18 20ADBD2	YANT1	6,270	10	8	--	--	08-21-96	--	--	Z/
88	385231120004001	90 N12 E18 20ACBD1	SKALBERG	6,310	20	6	425	--	08-21-96	(6.99) [4]	>6,303	P/S
89	385231120001901	90 N12 E18 20ADBD1	FRAZIER	6,265	10	8	58	--	08-20-96	5.86	6,259	/S
90	385227120004601	90 N12 E18 20BDDA1	ANGORA CREEK 10	6,270	10	2	4	--	10-10-96	1.61	6,268	/S
91	385227120003701	90 N12 E18 20ACCA2	ANGORA CREEK 18	6,270	10	2	4	--	10-10-96	3.47	6,267	/S
92	385226120003701	90 N12 E18 20ACCA1	ANGORA CREEK 15	6,270	10	2	4	--	10-10-96	2.22	6,268	/S
93	385225120004801	90 N12 E18 20BDDB1	ANGORA CREEK 2	6,270	10	2	5	--	10-10-96	1.67	6,268	/S
94	385223120004601	90 N12 E18 20BDDD1	ANGORA CREEK 4	6,270	10	2	3	--	10-10-96	1.33	6,269	/S
95	385210120012502	90 N12 E18 19DADC2	WASHOE MEADOW STATE PARK 2	6,300	20	4	6	--	10-09-96	2.89	6,297	/S

Table 5. Well information for ground-water monitoring sites in Upper Truckee River and Trout Creek watersheds, California and Nevada, July-November 1996—Continued

Well no. (pl. 1)	U.S. Geological Survey site identification number [1]	Local identification number [2]	Station name	Land-surface altitude (feet above sea level)	Land-surface altitude uncertainty (+ or - feet)	Well casing: Diameter (inches)	Well casing: Depth (feet below land surface)	Well casing: Open interval (feet below land surface)	Measured water level: Date measured	Measured water level: Depth (feet below land surface)	Measured water level: Water-level altitude (feet)	Site status/ Method
96	385210120012501	90 N12 E18 19DADC1	WASHOE MEADOW STATE PARK 1	6,300	20	4	5	--	10-09-96	2.89	6,297	/S
97	385118120010601	90 N12 E18 29CBD 1	ARROWHEAD 2 [3]	6,340	20	20	268	218 - 268	07-16-96	--	--	P/
98	385110120010701	90 N12 E18 29CCAD1	CHRIS CAFE	6,335	20	1.5	8	--	10-30-96	--	<6,327	D/S
99	384917120004401	90 N11 E18 08BAAA1	SHIELDS	6,620	20	6	86	16 - 70	08-09-96	--	>6,620	F/O
100	384837120010501	90 N11 E18 08CCAB1	MYERS	6,440	20	6	48	24 - 48	08-06-96	9.42	6,431	/S
101	384832120011001	90 N11 E18 08CCBD1	CHARSHAFIAN	6,470	20	6.63	80	41 - 76	08-08-96	35.51	6,434	/S
102	384832120010501	90 N11 E18 08CCAC1	PAULING	6,440	20	6	--	--	08-08-96	6.91	6,433	/S
103	384831120011001	90 N11 E18 08CCCA1	AMUNDSON	6,470	20	6	--	--	08-08-96	(33.58)[4]	>6,436	P/S
104	384828120010501	90 N11 E18 08CCDB1	WILKIE	6,460	20	6	40	--	08-15-96	6.70	6,453	/S
105	384828120005301	90 N11 E18 08CDCA1	BAGINSKI	6,460	20	6	73	53 - 73	08-07-96	32.67	6,427	R/S
106	384826120010801	90 N11 E18 08CCCD1	PAULSON	6,470	20	6	60	40 - 60	08-07-96	25.87	6,444	/S
107	384825120005201	90 N11 E18 08CDCD1	CAPELLA	6,470	20	6	91	71 - 91	08-09-96	--	--	P/
108	384824120010901	90 N11 E18 17BBBA1	RENNISON	6,480	20	6	130	--	08-08-96	33.17	6,447	/S
109	384823120005301	90 N11 E18 17BABA1	MOSBACHER 1	6,460	20	6	80	--	08-09-96	6.93	6,453	R/S
110	384822120005201	90 N11 E18 17BABA2	FEVES	6,470	20	6	60	40 - 60	08-16-96	9.06	6,461	/S
111	384821120010801	90 N11 E18 17BBAB1	RECORD	6,480	20	6	65	45 - 65	08-07-96	25.94	6,454	R/S
112	384821120010602	90 N11 E18 17BBAB3	HOSMAN 2	6,470	20	6	300	60 - 300	08-07-96	--	>6,470	F/O
113	384821120010601	90 N11 E18 17BBAB2	HOSMAN 1	6,470	20	6.63	100	94 - 100	08-07-96	17.02	6,453	/S
114	384821120010001	90 N11 E18 17BBAA1	ULRICH	6,450	20	8	72	--	08-15-96	10.87	6,439	R/S
115	384820120005002	90 N11 E18 17BAAC2	ZAIGER 2	6,470	20	6	--	--	08-13-96	--	--	Z/
116	384820120005001	90 N11 E18 17BAAC1	ZAIGER 1	6,470	20	6	--	--	08-13-96	11.03	6,459	/S
117	384818120010201	90 N11 E18 17BBAD1	YURE	6,460	20	6.63	54	40 - 53	08-15-96	12.40	6,448	R/S
118	384817120010501	90 N11 E18 17BBDB1	WILLIAMS	6,470	20	6	190	63 - 190	08-15-96	17.60	6,452	/S
119	384817120005201	90 N11 E18 17BACA1	MOSBACHER 2	6,450	20	6	--	--	08-13-96	4.92	6,445	R/S
120	384814120005301	90 N11 E18 17BACD1	ROMAN	6,460	20	6.63	80	62 - 70	08-08-96	--	>6,460	F/O

Table 5. Well information for ground-water monitoring sites in Upper Truckee River and Trout Creek watersheds, California and Nevada, July-November 1996—Continued

Well no. (pl. 1)	U.S. Geological Survey site identification number [1]	Local identification number [2]	Station name	Land-surface altitude (feet above sea level)	Land-surface altitude uncertainty (+ or - feet)	Well casing: Diameter (inches)	Well casing: Depth (feet below land surface)	Well casing: Open interval (feet below land surface)	Measured water level: Date measured	Measured water level: Depth (feet below land surface)	Measured water level: Water-level altitude (feet)	Measured water level: Site status/ Method
121	384813120010701	90 N11 E18 17BBDC1	GINOTTI	6,480	20	6	200	160 - 180	08-08-96	--	>6,480	F/O
122	384813120010601	90 N11 E18 17BBDC1	ALI	6,470	20	6	--	--	09-04-96	--	>6,470	F/O
123	384813120010301	90 N11 E18 17BBDD2	RADEKAN 1	6,470	20	6	100	--	08-14-96	15.28	6,455	R/S
124	384813120010101	90 N11 E18 17BBDD3	RADEKAN 2	6,470	20	8	44	--	08-14-96	14.33	6,456	/S
125	384812120005301	90 N11 E18 17BACD2	JETT-PEARCE	6,460	20	6	49	29 - 40	08-21-96	5.33	6,455	R/S
126	384811120010201	90 N11 E18 17BBDD1	SHEA	6,470	20	6	--	--	08-13-96	14.75	6,455	/S
127	384811120005501	90 N11 E18 17BDBA1	CHILCOTES	6,460	20	6	31	--	08-09-96	5.96	6,454	/S
128	384810120010301	90 N11 E18 17BCAA1	ROBERSON	6,470	20	6	60	20 - 60	08-13-96	16.02	6,454	/S
129	384807120005801	90 N11 E18 17BDBC1	AGEE	6,460	20	6	--	--	08-13-96	5.64	6,454	R/S
130	384721119595901	90 N11 E18 21BDBB1	USFS BIG MEADOW TRAILHEAD	7,260	20	6.63	108	65 - 105	08-14-96	12.40	7,248	/S
			Trout Creek watershed									
131	385624119592401	90 N13 E18 32CCCC1	SCHWABL	6,235	6	6	40	24 - 40	10-24-96	11.20	6,224	/S
132	385609119590701	90 N12 E18 04AAAD1	HARCOTUNIAN	6,240	6	8.62	77	63 - 73	10-22-96	10.5	6,230	/T
133	385602119584201	90 N12 E18 03BACD1	EPPLER	6,260	10	6	78	54 - 74	09-25-96	29.2	6,231	/T
134	385549119590301	90 N12 E18 03BCBB1	GERKEN	6,245	10	8	76	52 - 76	11-04-96	19.4	6,226	/T
135	385538119585001	90 N12 E18 03BCC 1	SKY LAKE LODGE [6]	6,260	10	--	--	--	11-21-96	--	--	P/
136	385535119585801	90 N12 E18 03ACCA1	SILVER DOLLAR MOTEL	6,255	10	8	65	--	09-17-96	30.94	6,224	R/S
137	385522119580204	90 N12 E18 03DAAB4	USGS TCF-4 [3]	6,260	10	2	135	130 - 135	10-07-96	69.85	6,190	/S
138	385514119581601	90 N12 E18 03DBAD1	BLACK BART	6,250	10	1.5	7	--	10-11-96	5.13	6,245	/S
139	385432119574201	90 N12 E18 11BBAA1	LAKE CHRISTOPHER WELL	6,275	10	1.5	7	--	10-11-96	6.09	6,269	/S
140	385413119580801	90 N12 E18 10ADCA1	GOLDEN BEAR	6,270	10	1.5	6	--	10-11-96	4.62	6,265	/S
141	385235119590701	90 N12 E18 21AADC1	MEYERS LANDFILL 10	6,335.1	.1	2	24	9 - 23	11-04-96	15.94	6,319.2	/S
142	385231119590901	90 N12 E18 21ADAB1	MEYERS LANDFILL 4	6,376.3	.1	2.5	44	--	11-01-96	29.31	6,347.0	/S
143	385231119590301	90 N12 E18 22BCBB1	MEYERS LANDFILL 9 [3]	6,340.5	.1	2	27	12 - 26	11-04-96	20.98	6,319.5	/S
144	385229119591102	90 N12 E18 21ADAC2	MEYERS LANDFILL M-5	6,380.8	.1	4	71	--	11-01-96	58.53	6,322.3	/S
145	385229119591101	90 N12 E18 21ADAC1	MEYERS LANDFILL M-3	6,380.3	.1	4	39	--	11-01-96	--	<6,380.3	D/S

Table 5. Well information for ground-water monitoring sites in Upper Truckee River and Trout Creek watersheds, California and Nevada, July-November 1996—Continued

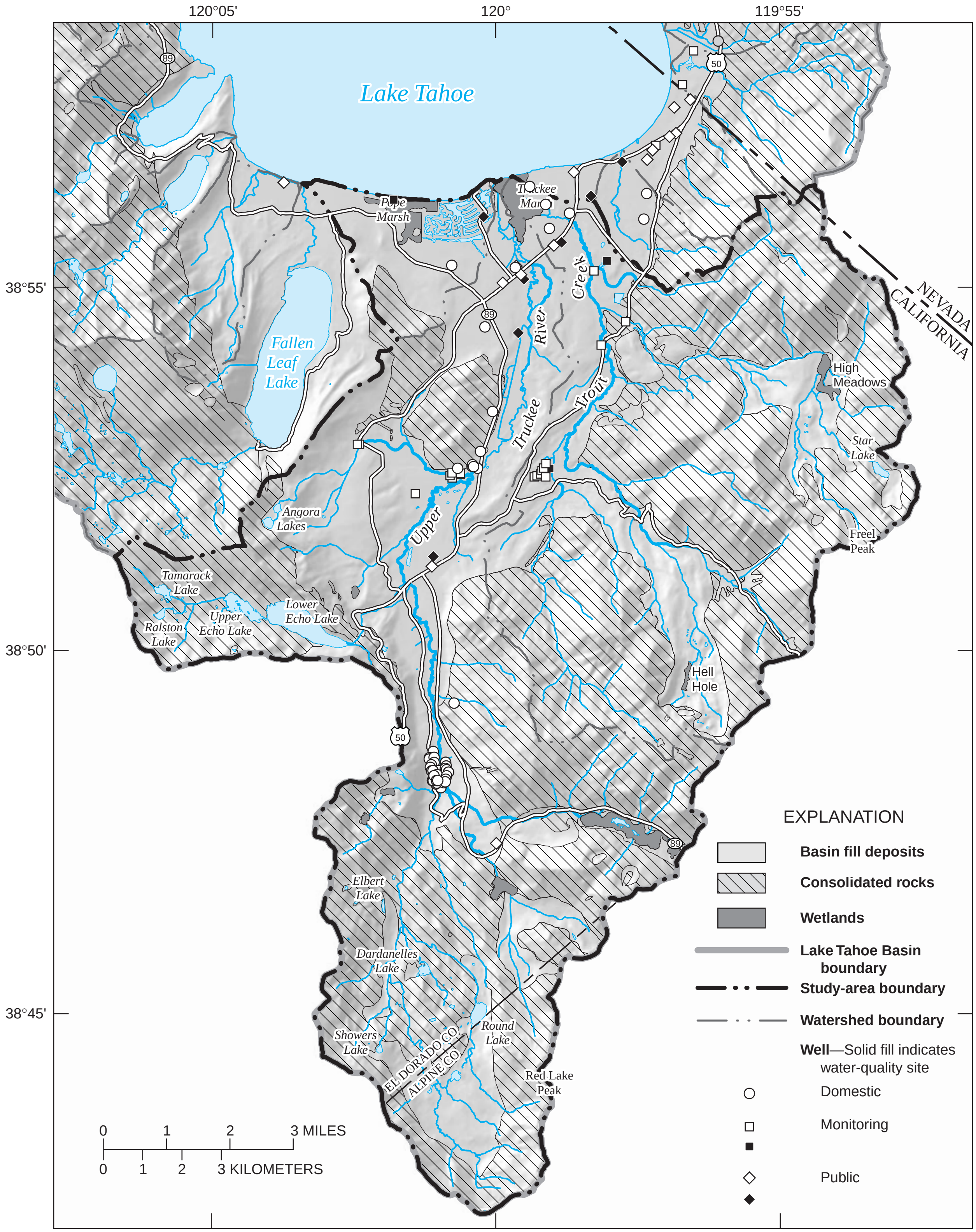
Well no. (pl. 1)	U.S. Geological Survey site identification number [1]	Local identification number [2]	Station name	Land-surface altitude (feet above sea level)	Land-surface altitude uncertainty (+ or - feet)	Well casing			Measured water level			
						Diameter (inches)	Depth (feet below land surface)	Open interval (feet below land surface)	Date measured	Depth (feet below land surface)	Water-level altitude (feet)	Site status/ Method
146	385226119591201	90 N12 E18 21ADCA1	MEYERS LANDFILL 2	6,380.1	.1	2.5	37	--	11-01-96	--	<6,380.1	D/S
147	385225119591601	90 N12 E18 21ADCB1	MEYERS LANDFILL 1	6,374.2	.1	4	22	--	11-01-96	18.73	6,355.5	/S
148	385224119591901	90 N12 E18 21ADCC1	MEYERS LANDFILL M-7	6,400.4	.1	2	35	30 - 35	11-01-96	21.13	6,379.3	/S
149	385224119590701	90 N12 E18 21ADDC1	MEYERS LANDFILL 8	6,352.5	.1	2	32	16 - 31	11-04-96	31.57	6,320.9	/S
			Adjacent to study area									
150	385627120034401	90 N13 E17 26DDBA1	USFS BALDWIN BEACH 1	6,235	6	8.63	100	70 - 100	11-21-96	.62	6234	/S
151	385824119550401	90 N13 E18 23CBB 1	FOLSOM SPRING	6,335	20	--	--	--	11-20-96	0	6335	S/O
152	385816119563001	90 N13 E18 22DCA 1	EDGEWOOD4	6,260	10	2	24	--	11-08-96	14.52	6245	/S
153	385742119565701	90 N13 E18 27BDA 1	EDGEWOOD1	6,245	10	2	23	--	10-07-96	10.53	6234	/S
154	385736119563401	90 N13 E18 27DBBC1	TAHOE TROPICANA LODGE	6,276.7	.1	8	116	88 - 112	11-06-96	33.2	6243.5	/T
155	385729119565101	90 N13 E18 27CACC1	STATION HOUSE INN	6,240	6	10	--	--	09-19-96	--	>6,240	F/O
156	385708119564901	90 N13 E18 34BACA1	MIDWAY MOTEL ANNEX	6,260	10	--	70	--	09-19-96	(23.19)[4]	>6,237	P/S
157	385705119565601	90 N13 E18 34BBDA1	MI TIERRA	6,250	10	--	58	--	09-18-96	11.62	6,238	R/S
158	385658119571001	90 N13 E18 34BCBC1	OSGOOD 4	6,235	6	4	8	--	10-11-96	4.33	6,231	/S
159	385654119571401	90 N13 E18 33ADDA1	COPPER LANTERN MOTEL	6,240	6	6	77	--	09-17-96	(5.17)[4]	>6,235	P/S
160	385646119571901	90 N13 E18 33DAAB1	ALDER INN MOTEL	6,250	10	8	--	--	09-17-96	(22.80)[4]	>6,227	P/S
161	385644119574601	90 N13 E18 33CAD 1	BEVERLY LODGE [6]	6,235	6	--	76	--	11-21-96	--	--	P/
162	385636119583701	90 N13 E18 32DCAA1	TIMBERLAKE INN	6,250	10	8	97	--	09-19-96	(33.40)[4]	>6,217	P/S
163	385618119572001	90 N12 E18 02ABBB1	ROEDER	6,270	10	6.63	117	97 - 117	09-12-96	35.78	6,234	/S
164	385651119581701	90 N12 E18 03ABA 1	AL TAHOE SCHOOL [6]	6,260	10	12	125	--	11-22-96	32.06	6,228	R/S
165	385557119572301	90 N12 E18 02BDDD1	EPPS	6,291.1	.1	6	76	44 - 72	11-04-96	65.6	6,225.5	/T

[1] Sites are identified by standard U.S. Geological Survey identification number, which is a unique number based on grid system of latitude and longitude of the site. Number consists of 15 digits: First six denote degrees, minutes, and seconds of latitude; next seven denote degrees, minutes, and seconds of longitude; and last two digits (assigned sequentially) identify sites within 1-second grid. For example, site 385816119563001 refers to 38° 58′ 16″ latitude and 119° 56′ 30″ longitude, and is first site recorded in that 1-second grid. If more precise latitude and longitude subsequently are determined, initial site-identification number is retained.

[2] Locations are assigned using a grid system referenced to Mount Diablo base line and meridian for official rectangular subdivision of public lands. Location consists of four units: First unit is the hydrographic area number (Rush, 1968), Second unit is township, preceded by N or S to indicate location north or south of base line. Third unit is range, preceded by E to indicate location east of meridian. 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 quarters, respectively), followed by number indicating sequence in which site was recorded. For example, well 90 N11 E18 21BDBB1 is in the Lake Tahoe Basin (hydrographic area 90). It is the first site recorded in the northwest quarter (B) of the northwest quarter (B) of the southeast quarter (D) of the northwest quarter (B) of section 21, Township 11 North, Range 18 East, Mount Diablo base line and meridian.

[3] Ground-water-quality sites used in this study.

[4] Water levels in parenthesis are pumping levels and probably do not represent static water level. Pumping levels were used as a lower boundary for static water level on plate 1.



Planimetric base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000, 1969–85
Universal Transverse Mercator Projection, Zone 11.
Shaded-relief base from 1:24,000 Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Geology from Burnett (1971)

Figure 4. Locations of well sites and general surficial geology, Upper Truckee River and Trout Creek watersheds, California, September 1996.

residential population still uses wells for domestic supply and where environmental monitoring of ground water is done in a nearby meadow. The third cluster is in the Trout Creek watershed at the old landfill near Meyers, Calif. This cluster of observation wells was established to monitor environmental effects of the landfill on the local ground water.

Water Quality

Samples were collected to determine specific conductance at each streamflow site at the time of measurement (table 3). Specific conductance is the ability of a substance to conduct an electric current at a specific temperature. In water, specific conductance is a good indicator of the concentration of dissolved solids. The greater the specific conductance, the greater the concentration of dissolved solids (Hem, 1985). Samples for specific-conductance measurements were collected by hand dipping a field-rinsed 250-mL polyethylene bottle in the center of flow at each site. Readings were then made within 24 hours of collection for each sample at the USGS Nevada District Laboratory using a calibrated specific conductance field meter adjusted to conductance at 25°C.

Six surface-water-quality sites (fig. 3; three on the Upper Truckee River and three on Trout Creek) were sampled periodically from July through December 1996 (table 6). These sites were sampled for total kjeldahl (ammonia plus organic nitrogen), total phosphorous, dissolved orthophosphorus, dissolved ammonia, dissolved nitrite plus nitrate, and total bioreactive iron. Field measurements of specific conductance, pH, water temperature, and dissolved oxygen were collected also. Historical USGS water-quality data, dating back to 1992, are available for all these sites. Standard USGS methods were used for sample collection. The method used for this study to collect water-quality samples was the equal-width increment (EWI) method, which is a depth- and width-integration method. This method involves collecting depth-integrated samples from equal-width segments of the cross section of a stream. The sample was then composited and mixed in a churn. The samples for measurements of total constituents were collected directly from the churn and the dissolved samples were filtered from the churn. These water-quality samples were then preserved (nutrients were chilled to 4°C and stored in the dark, and iron samples were acidified with concentrated nitric acid to a pH below 2) and shipped overnight to the UC Davis-TRG laboratories in Davis and Tahoe City, Calif. The samples were analyzed for iron and nutrients within 8 days according to procedures described by Hunter and others (1993). Specific-conductance and pH measurements were made from water taken from the churn after thoroughly mixing. The water temperature and dissolved oxygen were measured directly in the stream at the time of sampling. Specific conductance, pH, and dissolved oxygen were measured with field meters that were calibrated before each sample.

Summary statistics were computed for the combined samples of all six surface-water-quality sites on the Upper Truckee River and Trout Creek for July through December 1996 (figs. 5 and 6). For all 6 sites, only samples collected the same day or within 1 day were used in the analysis to compare with the summary statistics for the ground-water-quality sites.

Seven wells in the study area (five in the Upper Truckee River watershed and two in the Trout Creek watershed) and one well adjacent to the study area were sampled in July 1996 (table 7). These wells were sampled for dissolved nitrite plus nitrate, dissolved ammonia, dissolved kjeldahl (ammonia plus organic nitrogen), dissolved phosphorous, dissolved orthophosphorus, and dissolved bioreactive iron. Historical USGS water-quality data dating back to 1990 is available for these wells. These eight wells and well 143 (table 7) were sampled in November and December 1996. Seven of these are public supply wells and two are observation wells. The public-supply wells were sampled from the delivery system using existing pumps. For these wells, water was collected as close to the wellhead as possible to ensure that the sample was not affected by any treatment or storage of the water. Because these samples were collected from public-supply wells that are heavily used, it is assumed that the water is representative of the aquifer water. The two observation wells were sampled using a submersible pump. Because these wells are not pumped regularly, more than three casing volumes of water were pumped prior to sampling and specific conductance and water temperature were checked until stabilized, to assure that the water was representative of the aquifer water. These water-quality samples were filtered (through 0.45-μm filter) in the field and then preserved (nutrients were chilled to 4°C and stored in the dark and iron samples were acidified with concentrated nitric acid to a pH below 2) and shipped to the UC Davis-TRG laboratories in Davis and Tahoe City, Calif. The samples were analyzed for iron and for nutrients within 8 days according to the procedures described by Hunter and others (1993). Specific conductance,

Table 6. Water-quality data for selected streamflow sites in Upper Truckee River and Trout Creek watersheds, California, July - December 1996

[Abbreviations: ft^3/s, cubic feet per second; mg/L, milligrams per liter; µs/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, USFS, U.S. Forest Service. Symbol: --, not determined]

Date	Time	Discharge, instantaneous (ft^3/s)	Specific conductance (µs/cm)	pH field (standard units)	Air temper-ature (°C)	Water temper-ature (°C)	Oxygen, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Phosphorus total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Iron, bio-reactive total (µg/L as Fe)
Upper Truckee River watershed													
Site No. 6 - Upper Truckee River at South Lake Tahoe													
07-03-96	1110	130	35	--	23.5	13.5	--	0.008	0.001	0.11	0.028	0.006	318
07-19-96	1320	57	51	7.8	20.0	16.0	8.4	.003	<.001	.07	.038	.006	228
08-16-96	1030	24	77	--	23.0	17.0	--	.003	<.001	.05	.019	.004	53
09-06-96	1115	11	96	7.8	14.0	12.0	9.4	.008	<.001	.13	.028	.003	352
09-23-96	1147	11	96	--	--	13.5	--	--	--	--	--	--	--
10-01-96	1030	10	100	7.7	14.0	11.5	8.8	.011	.004	.15	.023	.003	215
11-05-96	1240	12	90	--	5.0	3.0	--	.009	.001	.33	.017	.006	372
11-18-96	1530	627	27	--	7.5	4.5	--	.020	.005	.27	.105	.015	1,630
11-19-96	1335	200	25	--	2.5	4.5	--	.018	.002	.28	.067	.006	1,030
12-05-96	1315	770	39	--	1.5	1.0	--	.011	.010	.08	.144	.032	919
12-09-96	1430	70	57	--	3.0	3.0	--	.017	.002	.19	.020	.007	278
12-12-96	1400	700	43	--	4.5	2.5	--	.010	.013	.20	.074	.016	737
12-13-96	1300	200	40	--	6.5	3.5	--	.006	.008	.17	.047	.009	767
12-31-96	1545	200	40	--	7.0	1.5	--	.012	.003	.34	.078	.010	231
Site No. 17 - Upper Truckee River at Hwy 50 abv Meyers													
07-03-96	1310	118	34	--	24.0	13.0	--	.008	.001	.12	.021	.006	186
07-19-96	1400	45	47	7.6	23.0	14.0	8.3	.007	<.001	.14	.037	.007	198
07-31-96	0915	29	43	--	19.0	13.0	--	--	--	--	--	--	--
08-16-96	1230	19	71	--	24.0	15.0	--	.010	<.001	.06	.019	.007	45
09-06-96	1300	9.7	87	7.8	22.5	12.5	9.4	.002	<.001	.07	.033	.016	182
09-23-96	1030	8.5	91	--	14.5	9.5	--	--	--	--	--	--	--
10-02-96	1630	7.1	101	--	16.0	12.5	--	.010	.003	.51	.016	.004	430
11-05-96	1350	8.8	82	--	5.0	3.5	--	.012	.001	.16	.014	.005	206
11-18-96	1610	445	22	--	6.0	4.5	--	.016	.001	.15	.031	.005	484
11-19-96	1605	277	21	--	3.0	4.0	--	.012	<.001	.09	.016	.003	859
12-12-96	1515	290	41	--	2.0	2.0	--	.007	.005	.07	.032	.008	1,180

Table 6. Water-quality data for selected streamflow sites in Upper Truckee River and Trout Creek watersheds, California, July - December 1996—Continued

Date	Time	Discharge, instantaneous (ft^3/s)	Specific conductance (µs/cm)	pH field (standard units)	Air temper-ature (°C)	Water temper-ature (°C)	Oxygen, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Phosphorus total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Iron, bio-reactive total (µg/L as Fe)
Site No. 43 - Upper Truckee River at S. Upper Truckee Rd													
07-03-96	1440	73	23	--	23.0	12.0	--	0.004	0.002	0.04	0.022	0.009	115
07-19-96	1520	30	31	7.6	22.5	12.0	8.6	.006	.003	.06	.043	.014	167
07-31-96	1200	13	37	--	24.0	13.0	--	--	--	--	--	--	--
08-16-96	1305	12	41	--	26.0	13.0	--	.015	.007	.08	.030	.018	139
09-06-96	1410	3.7	49	7.8	23.0	10.0	9.5	.021	<.001	.06	.056	.034	180
09-23-96	0930	3.1	51	--	10.0	6.0	--	--	--	--	--	--	--
10-02-96	1710	3.0	52	--	14.0	9.5	--	.036	.013	.42	.032	.026	438
11-05-96	1430	2.7	49	--	4.5	1.5	--	.002	.001	.17	.021	.021	187
11-18-96	1700	102	18	--	3.5	2.0	--	.012	.002	.22	.032	.007	170
11-19-96	1705	67	24	--	4.0	3.0	--	.008	<.001	.09	.026	.008	221
12-05-96	1550	103	18	--	.5	1.0	--	.003	<.001	.23	.021	.007	246
12-12-96	1600	109	17	--	1.0	1.0	--	.003	.002	.28	.016	.006	135
Trout Creek watershed													
Site No. 49 - Trout Creek at South Lake Tahoe													
07-02-96	1040	87	33	--	20.5	10.0	--	.006	.002	.17	.038	.009	657
07-19-96	1235	66	35	7.3	18.0	10.0	--	.007	.001	.25	.062	.009	689
08-16-96	0950	34	44	--	19.0	12.0	--	.010	<.001	.12	.030	.009	397
09-06-96	1030	25	46	7.6	13.0	7.0	9.8	.003	<.001	.26	.030	.012	137
09-26-96	1010	23	50	--	14.0	7.0	--	--	--	--	--	--	--
10-02-96	1840	20	50	--	14.0	10.5	--	.004	.002	.24	.023	.009	273
11-05-96	1200	22	52	--	5.0	3.0	--	.007	.002	.22	.019	.009	283
11-18-96	1410	70	41	--	8.0	4.5	--	.017	.003	.37	.133	.018	2,650
12-05-96	1120	150	40	--	3.0	0.5	--	.014	<.001	.24	.241	.020	1,680
12-09-96	1340	40	50	--	2.5	2.0	--	.006	.002	.17	.027	.012	600
12-12-96	1210	40	46	--	4.5	2.5	--	.011	.002	.31	.109	.016	357
12-31-96	1415	100	48	--	6.5	2.0	--	.010	<.001	.28	.067	.011	440

Table 6. Water-quality data for selected streamflow sites in Upper Truckee River and Trout Creek watersheds, California, July - December 1996—Continued

Date	Time	Discharge, instantaneous (ft^3/s)	Specific conductance (μs/cm)	pH field (standard units)	Air temper-ature (°C)	Water temper-ature (°C)	Oxygen, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Phosphorus total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Iron, bio-reactive total (μg/L as Fe)
Site No. 57 - Trout Creek at Pioneer Trail													
07-02-96	1205	41	34	--	23.0	10.5	--	0.004	0.002	0.10	0.032	0.009	362
07-19-96	1555	20	40	6.6	21.5	13.0	8.3	.004	.001	.15	.040	.009	442
07-29-96	0935	24	54	--	19.0	11.0	--	--	--	--	--	--	--
08-16-96	1500	18	49	--	23.0	14.5	--	.005	<.001	.12	.028	.010	146
09-06-96	1615	14	51	7.7	20.0	11.5	8.7	.005	.001	.40	.026	.011	202
09-26-96	1547	11	54	--	14.5	10.5	--	--	--	--	--	--	--
10-02-96	1420	11	55	--	20.0	10.0	--	.004	.003	.31	.020	.007	313
11-05-96	1510	12	53	--	3.0	2.0	--	.004	.001	.19	.016	.006	197
11-18-96	1640	36	43	--	5.5	4.0	--	.015	.002	.25	.074	.014	1,060
12-05-96	1520	72	38	--	1.0	1.0	--	.010	.001	.18	.087	.016	758
12-12-96	1530	79	41	--	2.0	2.5	--	.009	.001	.32	.071	.018	629
Site No. 68 - Trout Creek at USFS Rd 12N01													
07-02-96	1300	22	31	--	25.0	10.0	--	.003	.001	.16	.025	.009	130
07-19-96	1440	14	37	7.1	18.5	10.0	8.7	.004	.001	.06	.039	.009	144
07-29-96	1300	12	46	--	23.0	11.0	--	--	--	--	--	--	--
08-16-96	1430	10	47	--	23.0	10.5	--	.003	.001	.07	.021	.009	65
09-06-96	1530	8.4	49	7.7	18.5	7.5	9.3	.006	<.001	.35	.027	.011	125
09-26-96	1014	6.1	53	--	9.5	5.0	--	--	--	--	--	--	--
10-02-96	1455	5.5	52	--	16.5	7.0	--	.004	.003	.25	.018	.009	137
11-04-96	1145	7.2	50	--	4.5	2.0	--	.002	.002	.13	.016	.009	127
11-21-96	1455	10	46	--	6.5	4.5	--	.003	<.001	.27	.018	.009	79
12-13-96	1040	8.0	46	--	3.0	2.5	--	.003	.001	.07	.022	.010	194

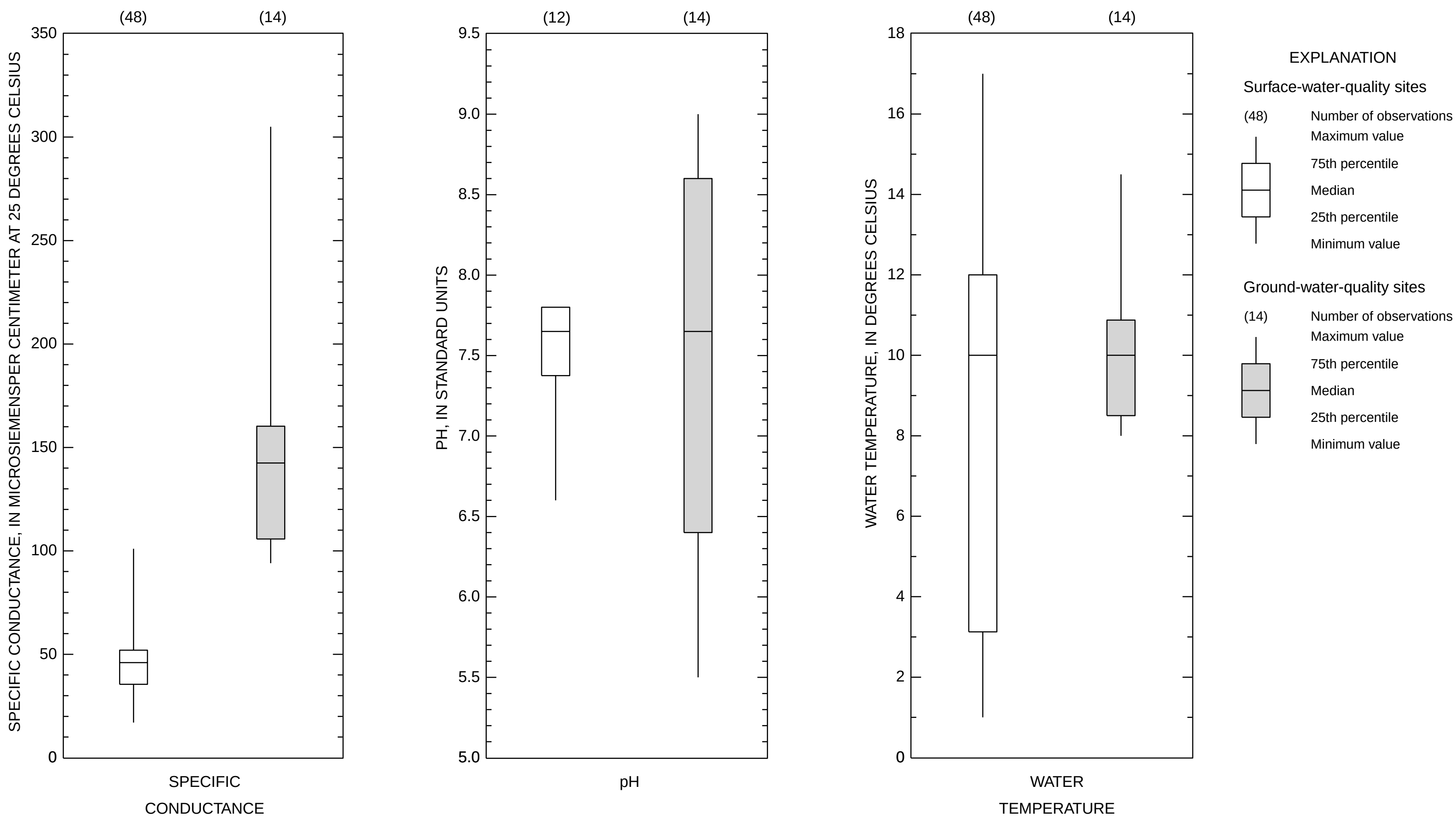


Figure 5. Water-quality field measurements for surface- and ground-water sites, Upper Truckee River and Trout Creek watersheds, Californ ia, July-December 1996.

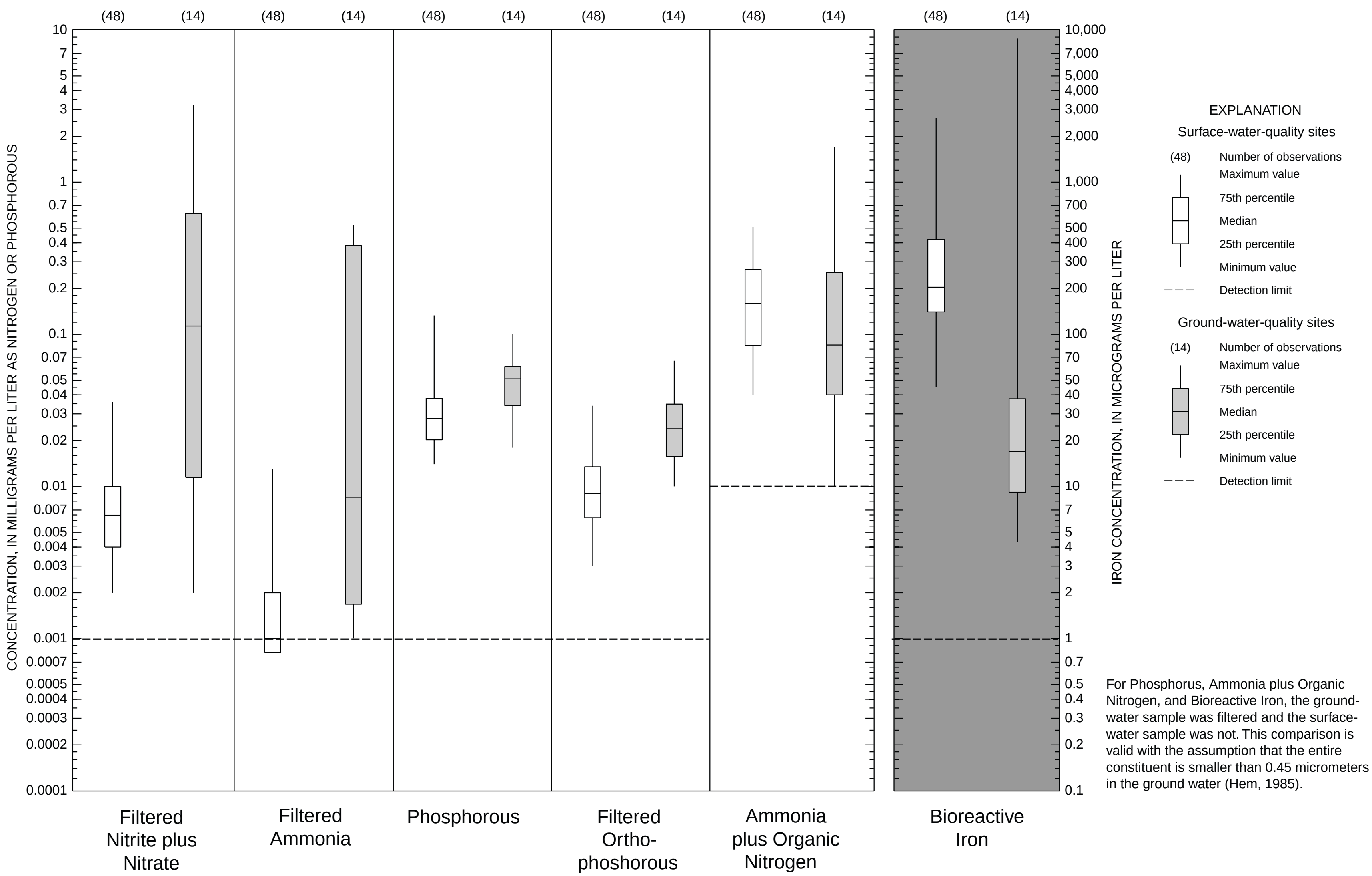


Figure 6. Nutrient concentrations for surface- and ground-water sites, Upper Truckee River and Trout Creek watersheds, California, July-December 1996.

Table 7. Water-quality data for ground-water monitoring sites in Upper Truckee River and Trout Creek watersheds, California, July-December 1996

[Abbreviations: ft^3/s, cubic feet per second; mg/L, milligrams per liter; µs/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius.

Site no. (pl. 1)	Date	Time	Specific conductance (µs/cm)	pH field (standard units)	Air temperature (°C)	Water temperature (°C)	Nitrogen NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia+ organic dissolved (mg/L as N)	Phosphorus dissolved (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)	Iron, bio-reactive dissolved (µg/L as Fe)
Upper Truckee River watershed												
71	07-15-96	1145	154	6.5	22.5	9.5	0.059	0.523	1.2	0.074	0.041	8,800
71	11-21-96	1255	155	5.5	10.0	8.0	.073	.429	1.7	.047	.032	1,800
72	07-15-96	1420	106	8.2	24.5	10.0	.454	.001	.10	.051	.019	4.3
72	11-22-96	1325	105	7.5	5.5	10.0	.393	.003	<.01	.031	.018	16
77	07-16-96	0755	131	7.8	14.0	8.5	.531	.018	.05	.059	.033	9.0
77	12-13-96	0750	160	7.9	3.5	8.0	.999	.002	.04	.034	.025	9.0
80	07-16-96	0955	110	9.0	18.5	10.5	.010	.009	.10	.101	.067	25
80	12-13-96	0830	110	8.9	4.0	10.0	.012	.008	.05	.056	.056	18
97	07-16-96	0940	161	8.6	20.0	14.5	.095	.001	.07	.051	.016	9.5
97	12-13-96	0900	156	8.6	4.0	14.0	.135	.010	.22	.038	.015	31
Trout Creek watershed												
135	07-15-96	1320	305	6.4	25.0	12.0	2.02	.006	.12	.055	.010	24
135	11-21-96	1130	173	6.4	12.0	8.5	3.24	.001	.03	.018	.012	13
137	07-18-96	1350	94	6.4	22.5	10.0	.002	.409	.36	.069	.026	9.2
137	11-26-96	1255	94	6.6	4.0	8.5	.002	.375	.04	.034	.023	68
143	11-26-96	1400	542	6.3	5.0	11.0	1.89	.002	.13	.039	.029	1,800
Adjacent to study area												
164	07-15-96	0950	101	6.5	19.5	9.0	.449	.001	.01	.055	.014	8.5
164	11-22-96	1240	98	7.0	5.0	8.0	.430	.001	.01	.020	.014	29

water temperature, water level, and pH were measured in the field during sampling. Specific conductance and pH measurements were made from water taken with field meters that were calibrated before each sample.

Ground-water-quality data are presented in table 7. The ground-water data are reported also in the 1996 annual data report for Nevada (Bostic and others, 1997, p. 532-536).

Summary statistics were computed for the combined samples of the seven ground-water-quality sites within the Upper Truckee and Trout Creek watersheds that were sampled in July 1996 and in November-December 1996 (figs. 5 and 6). Well 143 was not used in the analysis because only one sample was collected during the study period. Also, this well is suspected of being affected by the landfill near Meyers, which is directly upgradient, and therefore probably is not a good representation of the overall ground-water quality in that area.

SURFACE- AND GROUND-WATER CONDITIONS

Streamflow and Seepage Estimates

The measured streamflows in the Upper Truckee River watershed ranged from zero to 11.6 ft^3/s (table 3). Streamflow measured along the main stem of the Upper Truckee River increased from 2.6 ft^3/s at site 45 to 11.6 ft^3/s at site 3 in a downstream direction (fig. 3, pl. 1). At site 1, flow was not measured because the river was too deep to wade and velocities too slow for an accurate measurement due to backwater effects caused by the high level of Lake Tahoe on September 23, 1996. Three of the 13 remaining main-stem sites had no streamflow because these sites were on dry, divergent branches of the main stem. Of the 31 streamflow measurement sites that are tributary to the Upper Truckee River or are along the tributaries, 13 had no measurable streamflow. Major tributary inflows to the Upper Truckee River on September 23, 1996, included 2.0 ft^3/s at sites 27 and 28 (sum of divergent flows in tributary), 0.9 ft^3/s at site 37, and 0.8 ft^3/s at site 12.

The measured streamflows in the Trout Creek watershed ranged from 0 to 23.0 ft^3/s. Streamflow measured along the main stem of Trout Creek increased from 4.7 ft^3/s at site 70 to 23.0 ft^3/s for combined sites 46-48 (fig. 3, pl. 1). All the main stem sites had streamflow. Of the 14 streamflow measurement sites that are tributary to Trout Creek or are along the tributaries, only 1 (site 55) had no measurable streamflow. Major tributary inflows to Trout Creek on September 26, 1996, included 11.2 ft^3/s at site 53, 2.4 ft^3/s at site 61, 1.4 ft^3/s at site 67, and 0.8 ft^3/s at site 66.

The streamflows measured in September 1996, for both watersheds, were representative of base-flow conditions from August through December. The smallest daily streamflow for the 1996 water year at the most downstream gage on the Upper Truckee River (site 6) was 7.7 ft^3/s in late October 1995 (Bostic and others, 1997, p. 268). The lowest monthly mean streamflow, 10.2 ft^3/s, occurred during November 1995. The lowest daily streamflow for the 1996 water year at the most downstream gage on Trout Creek (site 52) was 14.0 ft^3/s in late December 1995. The lowest monthly mean streamflow occurred during November 1995, and was 22.0 ft^3/s (Bostic and others, 1997, p. 333). Hydrographs for these two streamgages are shown in figure 7, along with the daily precipitation record for a nearby NRCS SNOTEL site.

All streamflow data were entered into the USGS National Water Information System (NWIS) databases. Streamflow measurement data for September 1996 also appear in the annual data report for Nevada (Bostic and others, 1997).

Results of the streamflow measurements, seepage estimates, seepage rates per unit length, and unit runoffs are listed in table 4. In addition, the location of gaining, losing, and steady reaches are shown on plate 1 and figure 3.

Seepage estimates for reaches along the Upper Truckee River indicate that, of the 11.6 ft^3/s streamflow near the mouth at site 3, 4.4 ft^3/s (38 percent) was gained from ground-water seepage to the main stem, 4.5 ft^3/s (39 percent) was gained from tributary inflows, and 2.6 ft^3/s (23 percent) was the beginning streamflow at site 45. The average rate of gain per unit length along the main stem over the distance from site 45 to site 3 (13.3 mi) was 0.33 ft^3/s per mile. Of the 10 reach segments along the main stem of the Upper Truckee River, 5 were gaining from ground-water seepage, 1 was losing due to ground-water seepage, 3 had no measurable influence due to ground water, and 1 was undetermined because a streamflow measurement was not possible (fig. 8).

Seepage estimates for reaches along Trout Creek indicate that, of the 23.0 ft^3/s streamflow near the mouth at sites 46-48, 0.7 ft^3/s (3 percent) was gained from ground-water seepage to the main stem, 17.4 ft^3/s (76 percent) was gained from tributary inflows, and 4.7 ft^3/s (21 percent) is the beginning streamflow at site 70.

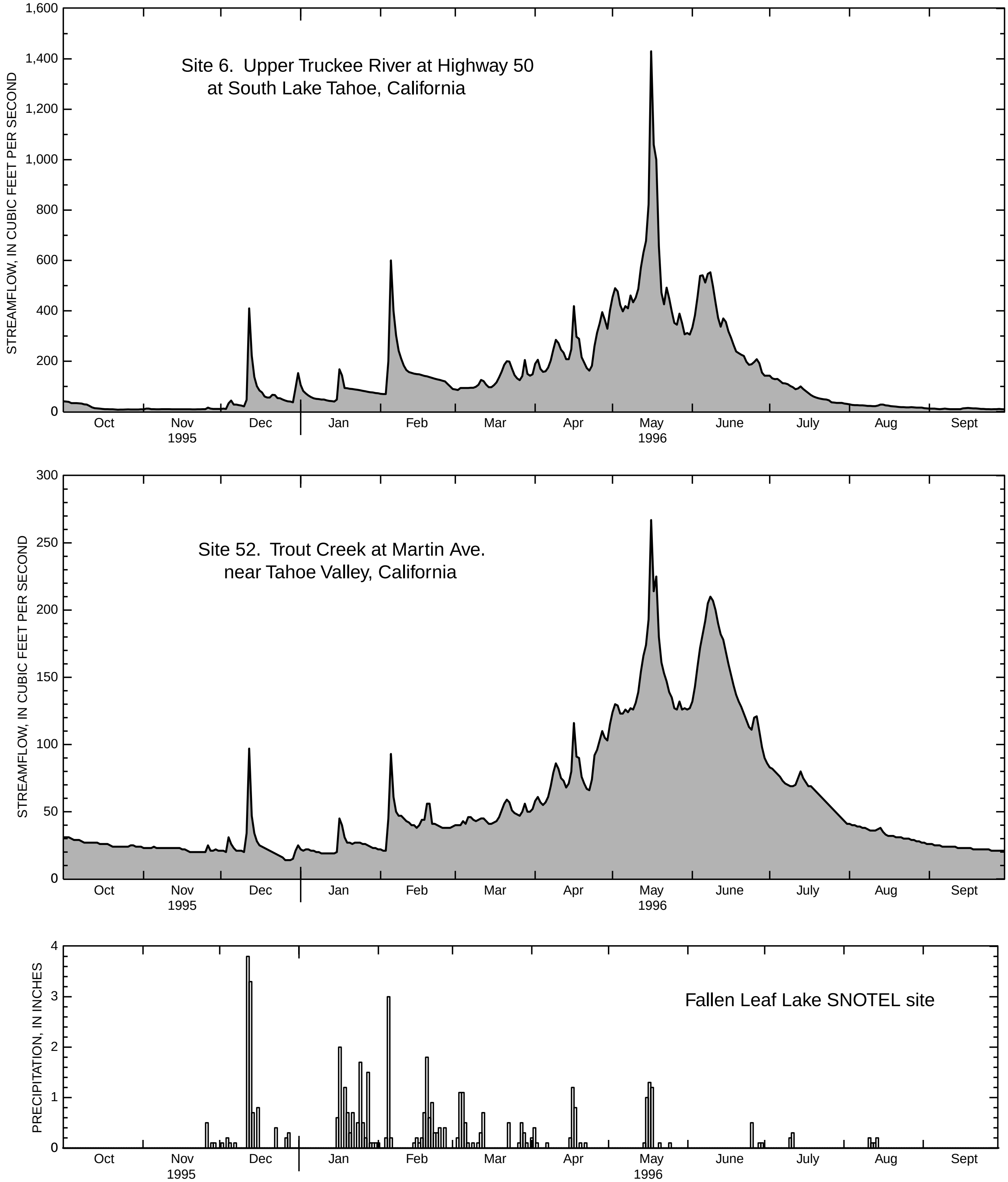


Figure 7. Streamflow for the Upper Truckee River at South Lake Tahoe, California, and for Trout Creek near Tahoe Valley, California, and daily precipitation below Fallen Leaf Lake, California, 1996 water year. (Precipitation data courtesy of National Resource Conservation Service.)

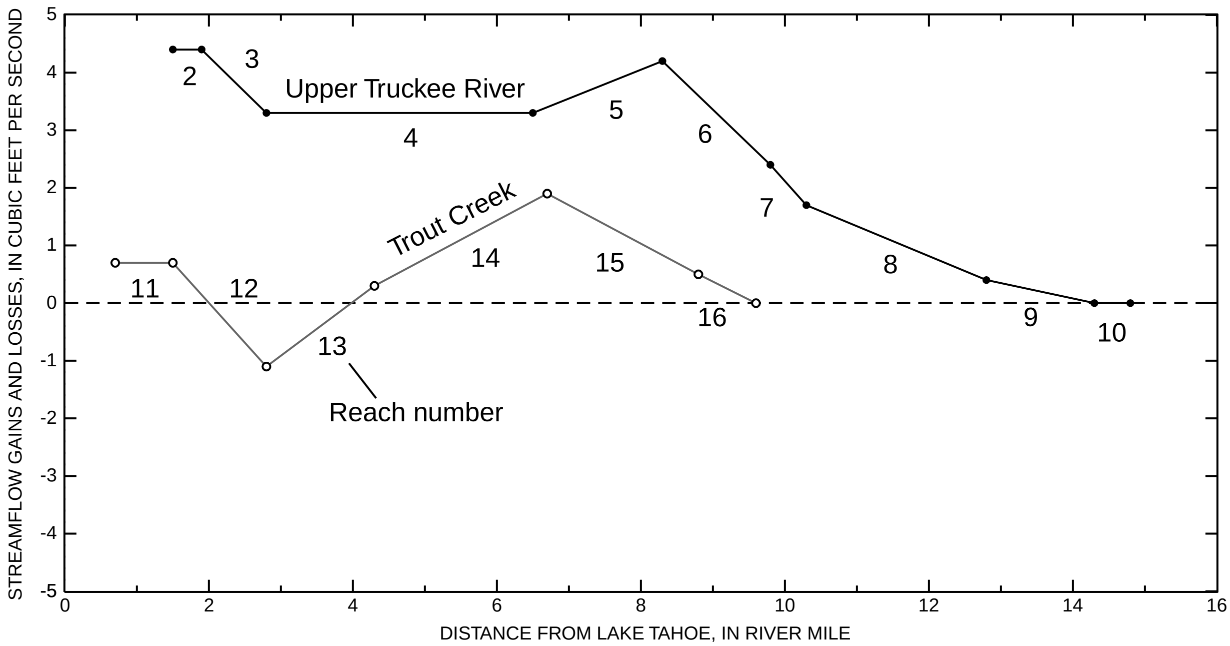


Figure 8. Cumulative streamflow gains and losses for Upper Truckee River and Trout Creek, California, September 1996.

The average rate of gain per unit length along the main stem over the distance from site 70 (8.9 mi) to sites 46-48 was about 0.08 ft^3/s per mile. Of the six reach segments along the main stem of Trout Creek, three were gaining from ground-water seepage, two were losing, and one had no measurable loss or gain (fig. 8).

The Upper Truckee River and Trout Creek have similar characteristics in the location of ground-water seepage contributions to their streamflows. Both streams are gaining in their upper reaches, both are steady or losing through their middle reaches, and both gain streamflow over a mile reach starting at about 2.5 mi upstream from Lake Tahoe (fig. 8).

The value obtained when discharge is divided by contributing drainage area, termed unit runoff, is often useful in comparing the magnitude of flow between two basins or the discharge at two or more locations in one basin. Unit runoff along the main stem of the Upper Truckee River ranged only slightly from 0.21 to 0.23 $ft^3/s/mi^2$ while its tributaries had greater variation, from zero at many of the tributaries to 0.31 $ft^3/s/mi^2$ at site 28 (table 3). Unit runoff along the main stem of Trout Creek ranged from 0.56 $ft^3/s/mi^2$ in the lower reaches to 0.84 $ft^3/s/mi^2$ in the upper reaches while its tributaries ranged from 0.07 $ft^3/s/mi^2$ at site 50 to 1.00 $ft^3/s/mi^2$ at site 67. The unit runoff in Trout Creek is larger than that of the Upper Truckee River. This is because most of the streamflow into Trout Creek is from the Cold Creek tributary whose unit runoff is 0.88 $ft^3/s/mi^2$. The high unit runoff of the Cold Creek tributary is assumed to be from delayed snowpack melt because the drainage has a significant percentage of north-facing aspect (Peltz and others, 1994) or because the capacity of ground-water storage within the Cold Creek watershed is large.

Ground-Water Levels and Direction of Flow

The distribution of inventoried wells, their water use, and geology (consolidated rock or unconsolidated basin fill) of the study area are shown in figure 4. Because of the lack of drillers' reports for many wells, the distribution of wells completed in unconsolidated basin-fill deposits or consolidated rock is unknown. For wells with drillers' reports, most are completed in basin-fill deposits (unconsolidated) with a few wells completed in fractured granite (consolidated).

The median depth to water on the basis of measurements from 60 non-pumping wells was 12.7 ft below land surface and ranged from 1.33 ft below land surface at well 94 to 69.85 ft below land surface at well 137. Depths to water were generally shallow in observation wells in meadows and particularly along the meadow near the mouth of Angora Creek where it is tributary to the Upper Truckee River. Depths to water were the greatest in observation wells in the old landfill near Meyers.

Well locations, results of seepage estimates, water-level contours, generalized directions of ground-water flow, and consolidated and unconsolidated geology are shown on plate 1. Water-level contours derived from measured water levels and results of seepage estimates are represented on plate 1 by solid lines; contours determined by using a median depth to water of about 13 ft are represented on plate 1 by dashed lines. The interpretation of the water-level contours in areas with wells that have land-surface altitudes determined from topographic maps has an inherent uncertainty due to uncertainties associated with the water-level altitudes. In steeply sloping terrain, the horizontal uncertainty of the water-level contours is small. In the more gently sloping terrain, where the topographic-contour interval is 40 ft, this horizontal uncertainty can be greater. Where the topographic-contour interval is 20 ft or less, the horizontal uncertainty is less. Water-level contours exist only in the unconsolidated sediments of the study area and do not cross consolidated rock. The water-level contour interval on plate 1 is variable and in general increases to the south, from about 10 ft in South Lake Tahoe to 200 ft along Highway 89 near Luther Pass.

Ground-water altitudes (pl. 1) in the Upper Truckee River watershed range from about 6,220 ft at well 76 in the northern part of the study area near Lake Tahoe to 7,250 ft at well 130 in the southern part of the study area. Ground-water altitudes in the Trout Creek watershed range from 6,190 ft at well 137 in the northern part of the study area to 6,380 ft at well 148 in the old Meyers landfill. Ground-water altitudes in the study area generally mimic the topography, with higher altitudes in the upland areas and lower altitudes near Lake Tahoe.

Ground-water levels in two wells in the study area (wells 73 and 131) have been monitored by California Department of Water Resources since June 1962. These two wells have responded to climatic variations such as drought and wet years (fig. 9).

In general, ground water in the study area is flowing northward toward Lake Tahoe (pl. 1) and parallels surface-water flow. Ground water generally discharges to the Upper Truckee River and Trout Creek along the upper reaches, whereas in the middle reaches ground water is flowing parallel to both streams. In the middle reach, the Upper Truckee River is losing streamflow for about 1.9 mi and Trout Creek has a net loss over its middle reaches. Ground water discharges to both streams between river miles 1.5 and 2.8 as both streams have a net gain in streamflow that is not accounted for by tributary flows. Both streams show little gain in flow further downstream suggesting that little ground water discharges to the two streams close to Lake Tahoe (table 4, pl. 1).

From July to November 1996, altitude of ground water in wells in the area between Lake Tahoe and Highway 50 (about river mile 1.5 on both stems) was nearly the same as the lake-surface altitude (table 5, pl. 1). This suggests that the ground-water flow beneath the Upper Truckee River and Trout Creek drainages between Highway 50 and Lake Tahoe was minimal during the study. Much of the ground-water discharge in these drainages was to the channels of the Upper Truckee River and Trout Creek upstream from Highway 50 (pl. 1).

Hydraulic gradients in the study area upstream from Highway 50 ranged from 10 to 1,400 ft/mi. Hydraulic gradients in the Upper Truckee River watershed are greatest in the upland areas. For example, the gradient near Luther Pass is 700 to 1,400 ft/mi. Hydraulic gradients tend to decrease rapidly in the lower areas, such as Christmas Valley, where gradients ranged from 30 to 60 ft/mi. In the Tahoe Paradise area, the hydraulic gradients ranged from about 20 to 40 ft/mi. In the northern part of the study area, the hydraulic gradients ranged from 10 ft/mi along the Upper Truckee River near the airport to as much as 50 ft/mi in the South Lake Tahoe area near the intersection of Highway 50 and Highway 89 in the Upper Truckee River watershed. The hydraulic gradients in the Trout Creek watershed ranged from about 420 ft/mi for areas along Saxon Creek to about 20 ft/mi along the lower reaches of Trout Creek upstream from the confluence of Heavenly Valley Creek. In the South Lake Tahoe area of the Trout Creek watershed, just south of Highway 50, the hydraulic gradient is about 30 ft/mi except in the area of well 137, where a cone of depression is caused by municipal pumping (Woodling, 1987, p. 21) and the hydraulic gradient is as high as 300 ft/mi. Hydraulic gradients vary on either side of the large lateral glacial moraine that divides the Trout Creek watershed from the Upper Truckee River watershed.

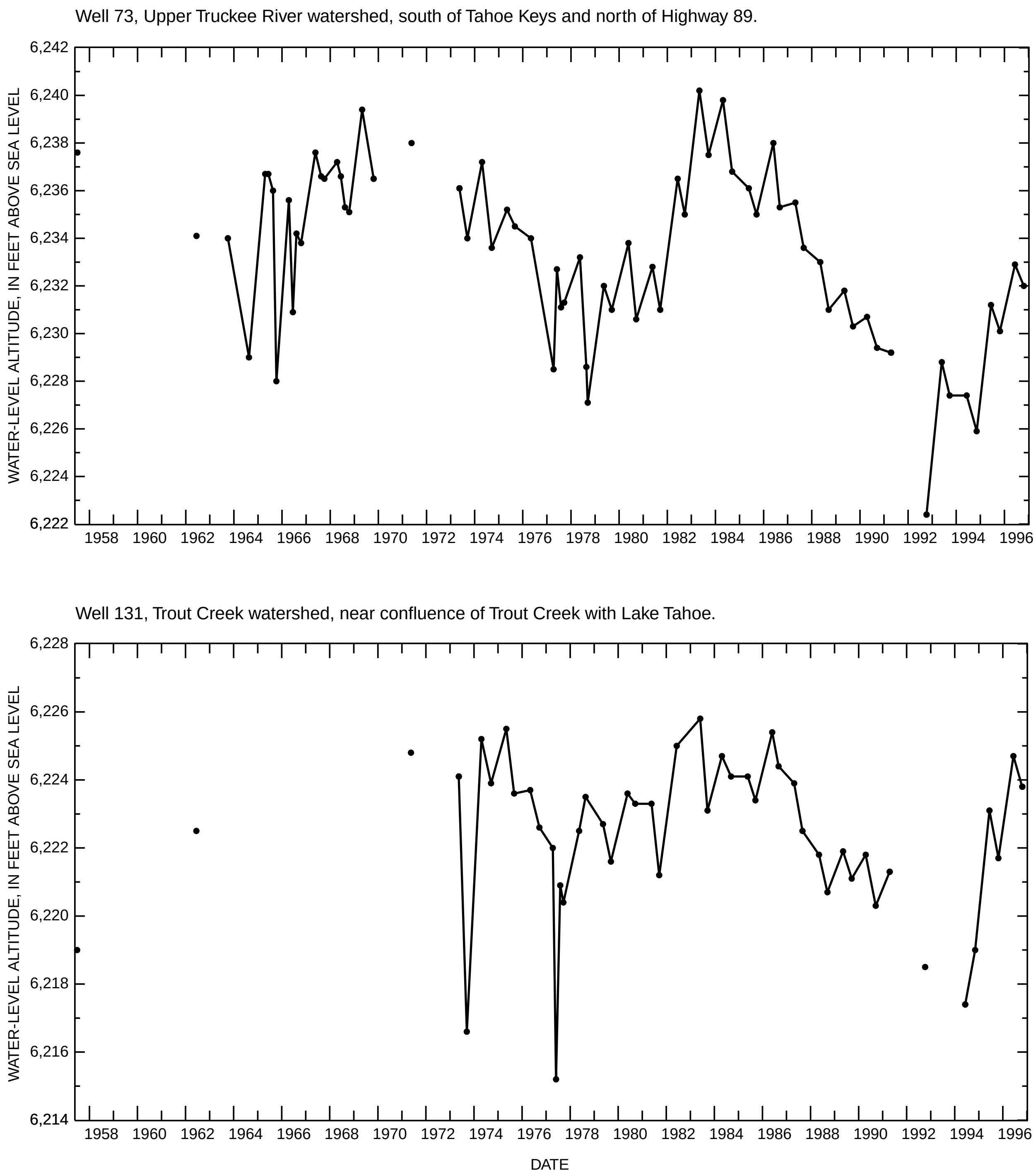


Figure 9. Water-level changes in wells 73 and 131 in Upper Truckee River and Trout Creek watersheds, California. (Data courtesy of California Department of Water Resources.) Location of wells is shown on plate 1.

Hydraulic gradients ranged from 170 to 1,300 ft/mi on the west side of the moraine and from 60 to 730 ft/mi on the east side.

Water Quality

Specific conductance of surface-water samples from sites in the Upper Truckee River watershed on September 23, 1996, ranged from 31 µS/cm at site 16 to 148 µS/cm at site 19 (table 3). Specific conductance in the main channel of the Upper Truckee River increased in a downstream direction from 50 µS/cm at site 45 to 99 µS/cm at site 15 and then remained relatively constant from site 15 to site 1 with a range of only 96 to 99 µS/cm (fig. 10). The relatively large increase in specific conductance with downstream direction for the upper half of the Upper Truckee River was probably caused by the relatively large component of higher conductance ground water contributing to the rivers streamflow for this segment (fig. 3, tables 3 and 4). The lower half of the Upper Truckee River has relatively constant specific conductance probably because streamflow has almost no gain from ground-water seepage for this segment (fig. 3, tables 3 and 4). The specific conductance values found along the main stem of the Upper Truckee River during base-flow conditions are similar to the highest values found during the 1996 water year. For the 1996 water year, specific conductance ranged from 22 to 96 µS/cm at site 6 near the mouth to 14 to 51 µS/cm at site 43 (Bostic and others, 1997, p. 263-269). Specific conductances are usually greatest during the low streamflow of late summer through fall and immediately following some storms prior to snowmelt. Specific conductances are lowest during snowmelt runoff, which generally peaks in late spring through early summer.

Specific conductance of surface-water samples from sites in the Trout Creek watershed on September 26, 1996, ranged from 43 µS/cm at site 53 to 92 µS/cm at site 58 (table 3). The specific conductance measured in the main channel of Trout Creek ranged from 49 to 54 µS/cm (fig. 10). The lack of increase in specific conductance with downstream direction in Trout Creek as compared with the Upper Truckee River might be due to the minimal contribution of ground-water seepage to streamflow. The specific conductance values found along the main stem of Trout Creek during base-flow conditions are similar to the highest values found during the 1996 water year. For the 1996 water year, specific conductance ranged from 25 to 54 µS/cm at site 49 near the mouth and from 19 to 53 µS/cm at site 68 (Bostic and others, 1997, p. 329 and 334). Specific conductances also are the greatest during the low-flow periods of late summer through fall and the smallest during snow melt runoff in late spring to early summer.

Specific conductance of surface-water samples for the three Upper Truckee River water-quality sites from early July through mid-December 1996, ranged from 17 µS/cm at site 43 to 101 µS/cm at site 17 (table 6). Specific conductances for the three Trout Creek water-quality network sites for the same period ranged from 31 µS/cm at site 68 to 55 µS/cm at site 57.

Specific conductance of ground-water samples for wells in the Upper Truckee River and Trout Creek watersheds from mid-July through mid-December 1996, ranged from 94 µS/cm at well 137 to 542 µS/cm at well 143 (table 7). As stated earlier, the water-quality results from well 143 may not represent the overall ground-water conditions due to the proximity of the old Meyers landfill. The next highest value of specific conductance is 305 µS/cm at well 135. Specific conductances varied in only two wells between summer and fall samples (fig. 11). Specific conductance did not appear to have any trend with respect to distance from Lake Tahoe (fig. 11).

Water temperatures measured at streamflow sites in the Upper Truckee River watershed on September 23, 1996, ranged from 4.5°C at site 14 to 13.5°C in the lower reaches of the main channel at site 6 (table 3). The main channel water temperatures generally increased in a downstream direction. Water temperatures ranged from 6.0 to 9.5°C at the upper sites and ranged from 11.5 to 13.5°C at the lower sites. Water temperatures can be affected by air temperatures, which ranged from 3.5°C in the morning to 25.0°C in the afternoon. Water temperature measured at streamflow sites in the Trout Creek watershed on September 26, 1996, ranged from 5.0°C at site 68 to 11.5°C near the mouth at sites 46 and 48. Water temperatures also increased in a downstream direction with a range of 5.0 to 6.5°C in the upper reaches to 7.0 to 11.5°C in the lower reaches. The air temperatures ranged from 9.5°C in the morning to 30.0°C in the afternoon. Weather was clear and warm on both days of the seepage run.

Water temperatures for the six surface-water-quality sites in the Upper Truckee River and Trout Creek watersheds ranged from 0.5°C at site 49 in early December to 16.0°C at site 6 in mid-July. Water temperatures of ground water for the seven wells in both watersheds ranged from 8.0°C at wells 71 and 77 in late

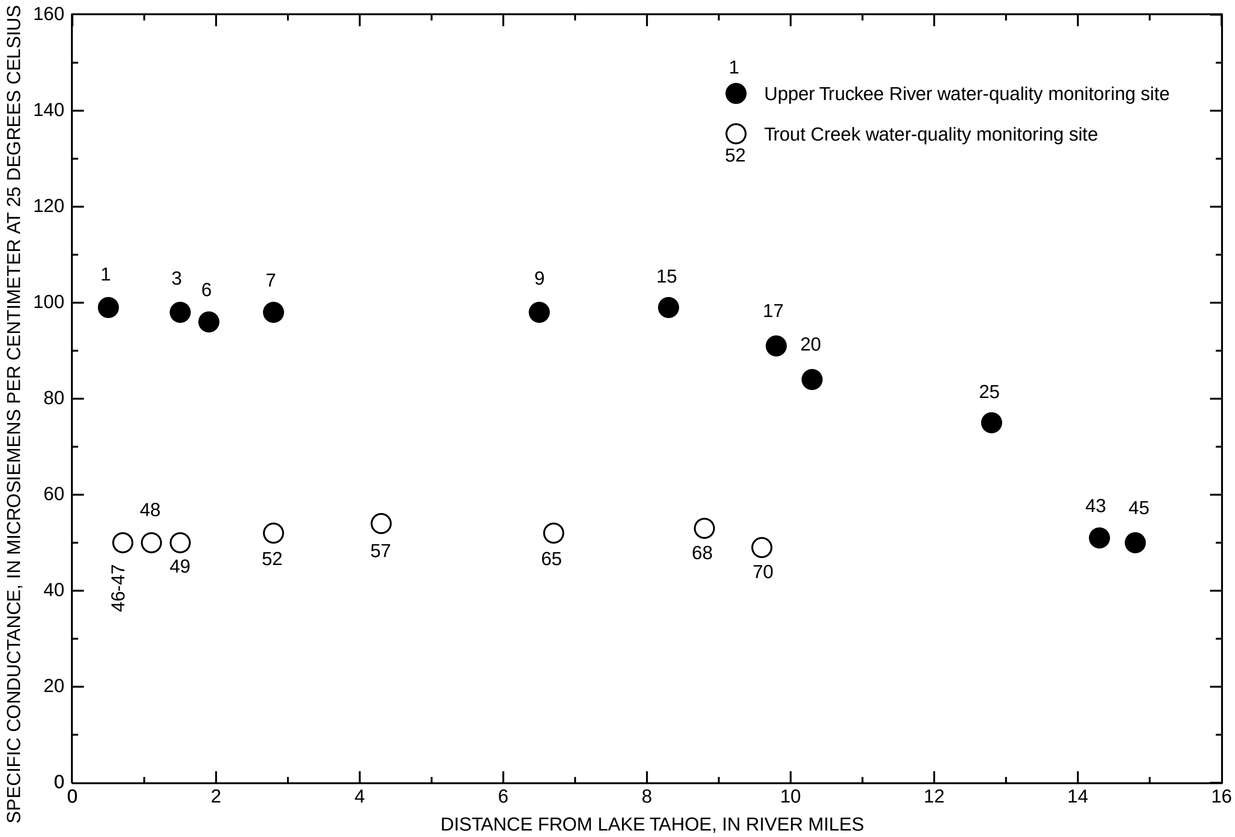


Figure 10. Relation between distance from Lake Tahoe and specific conductance for surface-water-quality monitoring sites on Upper Truckee River and Trout Creek, California, September 1996, as listed in table 4.

November and mid-December to 14.5°C at well 97 in mid-July. Ground-water temperatures varied seasonally by more than a half degree Celsius at only three wells (fig. 10).

Values of pH in surface water for the six sites for the Upper Truckee River and Trout Creek had a narrow range from 6.6 at site 57 to 7.8 at sites 6, 17, and 43 (table 6). Values of pH in ground water for the seven wells in both watersheds had a greater range from 5.5 at well 71 to 9.0 at well 80 (table 7). About 53 percent of ground-water quality sites had pH values from 6 to 8. Determination of the cause of this variability is beyond the scope of this study. The variation of values between summer and fall samples were small except for well 71, which varied by 1 pH unit (fig. 11). Values of pH did not appear to have any trends with respect to distance from Lake Tahoe (fig. 11).

Nutrient data collected from the six surface-water-quality sites for July through December 1996 are listed in table 6. Nitrite plus nitrate (NO_2+NO_3) concentrations ranged from 0.002 to 0.036 mg/L. The NO_2+NO_3 concentrations are well below the USEPA drinking water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996). Ammonia nitrogen (NH_4) concentrations ranged from less than the detection limit of 0.001 to 0.013 mg/L. Kjeldahl (NH_4 plus organic nitrogen) concentrations ranged from 0.04 to 0.51 mg/L. Phosphorous (P) concentrations ranged from 0.014 to 0.241 mg/L. Orthophosphorus concentrations ranged from 0.003 to 0.032 mg/L. Bioreactive iron (Fe) concentrations ranged from 45 to 2,650 ug/L. Some of these extreme values were from samples collected during storms and are not representative of normal flow conditions. Samples collected during storms were not used in the summary statistic comparisons between surface- and ground-water quality in figure 6 because they were not randomly collected.

Nutrient data collected from nine ground-water-quality sites in July through December 1996 are listed in table 7. NO_2+NO_3 concentrations ranged

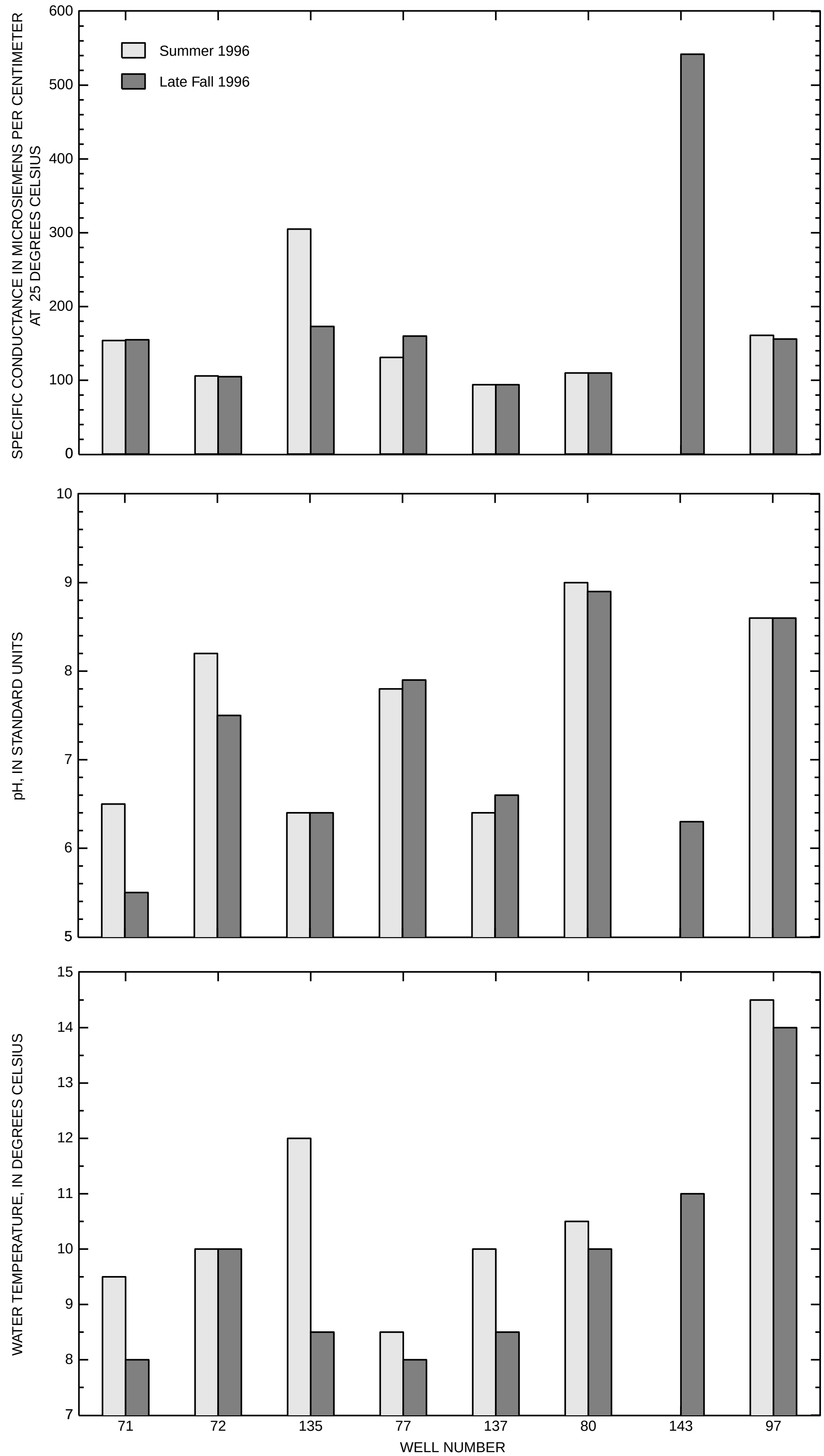


Figure 11. Field ground-water-quality measurements, Upper Truckee River and Trout Creek watersheds, California, July-December 1996. Sites are listed with increasing distance from Lake Tahoe from left to right.

from 0.002 to 3.24 mg/L. Three samples, all from the Trout Creek watershed, were greater than 1.8 mg/L, whereas, 75 percent of concentrations were below 0.76 mg/L. These NO_2+NO_3 concentrations are below the USEPA drinking water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996). Ammonia (NH_4) concentrations ranged from 0.001 to 0.523 mg/L, with 75 percent below 0.2 mg/L. Kjeldahl (ammonia plus organic nitrogen) concentrations ranged from less than 0.01 to 1.7 mg/L, with two samples greater than 1.2 mg/L and 75 percent below 0.18 mg/L. Phosphorus (P) concentrations ranged from 0.018 to 0.101 mg/L, with 75 percent below 0.06 mg/L. Phosphorus concentrations were lower in samples collected in the fall than in the summer at all wells. Orthophosphorus concentrations ranged from 0.010 to 0.067 mg/L, with 75 percent below 0.032 mg/L. Bioreactive iron (Fe) concentrations ranged from 4.3 to 8,800 ug/L, with 75 percent of samples having concentrations below 32 μg/L. The highest values of the ammonia species of nitrogen nutrients occurred in one shallow observation well near the Truckee Marsh (well 71). Ground water from this well also had high concentrations of ammonia in the 1995 and 1996 water years (Bauer and others, 1996; Bostic and others, 1997). These high values probably are due to decomposition of organic material from the wetland.

SUMMARY AND CONCLUSIONS

Lake Tahoe is an outstanding natural resource and known for its deep, clear waters. Increased nutrient concentrations within Lake Tahoe are considered the leading cause of algal growth and loss of clarity in the lake. Surface- and ground-water discharge throughout the Lake Tahoe Basin are assumed to be significant mechanisms for nutrient transport to Lake Tahoe. The Tahoe Regional Planning Agency has primary responsibility for the environmental protection of Lake Tahoe with an emphasis on reducing the loss of lake clarity in Lake Tahoe.

The Upper Truckee River and Trout Creek watersheds are the two largest watersheds and have the greatest areas of urban land use within the Lake Tahoe Basin. In 1996, the USGS, in cooperation with TRPA, began a study to improve the understanding of the surface-water and ground-water systems and their interactions within the Upper Truckee River and Trout Creek watersheds.

The contribution of ground water to surface-water streamflow, the unit runoff, the general direction of ground-water flow, and the comparisons of water quality from the surface-water system to the ground-water system during a period of minimal snowmelt runoff for the Upper Truckee River and Trout Creek watersheds were evaluated. Streamflow and water-quality data were collected at existing and supplemental surface-water streamflow and water-quality sites and water-level and water-quality data were collected at existing and supplemental ground-water sites.

Seepage estimates were determined for the Upper Truckee River and Trout Creek by measuring streamflow at designated sites used to define reach segments. Seepage gains and losses were determined for the selected reaches by subtracting the sum of the flow at the upstream end of the reach plus any tributary inflows from the flow at the downstream end of the reach. Unit-runoff values were determined by normalizing streamflow to contributing drainage-area size. Specific conductance and water temperature were determined at the time of streamflow measurements to provide synoptic field water-quality conditions for both watersheds.

Water levels were determined for wells within the study area and were used to produce a water-level altitude map, to determine directions of ground-water flow, and to determine hydraulic gradients.

Samples from six surface-water-quality and eight ground-water-quality sites were collected for nutrient species and iron as well as the basic field measurements of specific conductance, pH, and water temperature. Summary statistics for the chemical and field data were computed for surface- and ground-water-quality sites.

Streamflows measured during the seepage run were during a base flow period for both the Upper Truckee River and Trout Creek. All but 3 of the 13 streamflow measurement sites on the main stem of the Upper Truckee River had measurable streamflow. The three dry sites were divergent branches of the main stem. Forty-eight percent of the streamflow measurement sites that are tributary to the Upper Truckee River or along the tributaries were dry. All the streamflow measurement sites on the main stem of Trout Creek had measurable flow. Only one of the streamflow sites measured in the Trout Creek watershed was dry. This indicates that streamflows in the Trout Creek watershed are more perennial than those in the Upper Truckee River.

The largest tributary inflow into the Upper Truckee River was from Grass Lake Creek, which accounted for 17 percent of the total flow near the mouth of the Upper Truckee River. The largest tributary inflow into Trout Creek was Cold Creek, which accounted for 49 percent of the total flow near the mouth of Trout Creek.

The Upper Truckee River has greater ground-water seepage contributing to its overall streamflow than Trout Creek, while Trout Creek has greater tributary inflows contributing to its overall streamflow. Both streams had a similar proportion of streamflow at their uppermost main stem sites (when computed as a percentage of the most downstream sites). The total streamflow of the Upper Truckee River near its mouth was 38 percent ground-water seepage to the main stem, 39 percent tributary inflows, and 23 percent was the streamflow at the uppermost main stem site. The total streamflow of Trout Creek near its mouth was 4 percent ground-water seepage to the main stem, 76 percent tributary inflows, and 20 percent streamflow from the upper most main stem site.

Both the Upper Truckee River and Trout Creek had streamflow that was gaining from ground-water seepage in their upper reaches, both were steady or losing to ground-water seepage in their middle reaches, and both were again gaining flow from ground-water seepage in their lower reaches.

Unit runoff values for the Upper Truckee River watershed were less than those of the Trout Creek watershed. This was mainly due to the large contribution of flow from the Cold Creek tributary to Trout Creek. The large unit runoff of the Cold Creek tributary is assumed to be due to protracted snowmelt resulting from the high percentage of north-facing aspect or due to the delayed release of ground water from storage.

The median depth to water in the study area during this period was 12.7 ft below land surface with a range of 1.33 to 69.85 ft below land surface. Depths to water were generally least in meadows and greatest in the old Meyers landfill. Ground-water altitudes in the study area ranged from 6,190 to 7,250 ft and generally mimicked the land-surface topography.

Ground-water in the study area generally flows parallel to surface water. In the upper reaches of both watersheds, ground water flows towards the stream channels and in the middle reaches it flows parallel to the main channels. In the lower reaches near Lake Tahoe, ground-water levels and the water level at Lake Tahoe are nearly equal resulting in a very small hydraulic gradient. This suggests that ground-water discharge directly to Lake Tahoe is minimal.

Hydraulic gradients in the study area varied greatly, ranging from nearly zero to 1,400 ft/mi upstream from Highway 50. Hydraulic gradients were the greatest in upland areas and least near Lake Tahoe and along the middle reaches of the main stems of both streams.

The specific conductance of surface water measured during the seepage study had a greater range in the Upper Truckee River watershed than in the Trout Creek watershed and was generally greater in value also. In the Upper Truckee River watershed, specific conductance ranged from 31 to 148 µS/cm and in the Trout Creek watershed it ranged from 43 to 92 µS/cm. The specific conductance of water in the upper half of the main stem of the Upper Truckee River increased in the downstream direction and was consistent for the lower half. The specific conductance for Trout Creek was consistent throughout the length of its main stem. This is likely attributed to the larger ground-water seepage component of total streamflow in the upper half of the Upper Truckee River than in Trout Creek.

Specific conductance for surface water was much less than that of ground water and had a much smaller range. Specific conductance for the six surface-water-quality sites for the period of study ranged from 17 to 101 µS/cm. Specific conductance for the ground-water-quality sites for the same period ranged from 94 to 305 µS/cm for wells that were considered representative of general ground-water conditions.

Temperature of surface water measured during the seepage study was generally lowest at upstream sites and highest at downstream sites in both the Upper Truckee River and Trout Creek. The overall range was 4.5 to 13.5°C. Air temperatures ranged from 3.5 to 30.0°C during the seepage study.

Median values of water temperature for both surface water and ground water were similar. Surface-water temperatures (0.5 to 16.0°C) had a significantly greater range than those measured in ground water (8.0 to 14.5°C).

Median values of pH for surface and ground water were similar; however, pH ranges for ground water (5.5 to 9.0) were significantly greater than those measured for surface water (6.6 to 7.8).

Concentrations of nitrite plus nitrate, ammonia, and orthophosphorus were greater for the ground-water samples than for the surface-water samples collected.

Concentrations of bioreactive iron were generally greater for ground-water samples than for surface-water samples. Both surface- and ground-water samples had similar concentrations of phosphorous and kjeldahl (ammonia plus organic nitrogen). Ground water typically had greater variation in nitrite plus nitrate, ammonia, kjeldahl, and bioreactive iron concentrations than surface water. Surface- and ground-water samples had similar variations in phosphorous and orthophosphorus.

The most important results of this study are that, even though the Upper Truckee River and Trout Creek share many similarities in geology, vegetation, land use, and location, they had significantly different characteristics with respect to their interactions with the ground-water system. In particular, 38 percent of the streamflow of the Upper Truckee River near its mouth originated from ground-water seepage to its main channel while that of Trout Creek was only 4 percent. Ground-water contribution to streamflow also can be seen in the field measurement of specific conductance because ground water generally has greater conductivity. At the upper sites of both streams, specific conductance values are similar. However, the specific conductance increased in the downstream direction along the upper half of the Upper Truckee River but remained relatively constant along the lower half of the main stem. Specific conductance remained fairly constant for the entire length of Trout Creek.

Another important result is that during July to November 1996, the altitude of ground-water between Lake Tahoe and Highway 50 was nearly the same as the lake-surface altitude. This suggests ground-water discharge beneath the Upper Truckee River and Trout Creek drainages directly to Lake Tahoe was minimal and that much of the ground-water discharge was to the channels of the Upper Truckee River and Trout Creek upstream from Highway 50.

REFERENCES CITED

Bauer, D.J., Foster, B.J., Joyner, J.D., Swanson, R.A., 1996, Water resources data, Nevada, water year 1995: U.S. Geological Survey Water-Data Report NV-95-1, 734 p.

Blum, J.L., 1979, Geologic and gravimetric investigation of the South Lake Tahoe groundwater basin, California: University of California, Davis, unpublished M.S. thesis, 96 p.

Bonner, L.J., Elliot, P.E., Etchemendy, L.P., Swartwood, J.R., 1998, Water resources data, Nevada, water year 1997: U.S. Geological Survey Water-Data Report NV-97-1, 636 p.

Bostic, R.E., Kane, R.L., Kipfer, K.M., and Johnson, A.W., 1997, Water resources data, Nevada, water year 1996: U.S. Geological Survey Water-Data Report NV-96-1, 611 p.

Boughton, C.J., Rowe, T.G., Allander, K.K., and Robledo, A.R., 1997, Stream and ground-water monitoring program, Lake Tahoe Basin, Nevada and California: U.S. Geological Survey Fact Sheet FS-100-97, 6 p.

Buchanan, T.J., and Somers, W.P., 1969, Discharge measurements at gaging stations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chapter A8, 65 p.

Byron, E.R., Goldman, C.R., and Hackley, S.H., 1989, Lake Tahoe Interagency Monitoring Program, Ninth Annual Report, water year 1988: Tahoe Research Group, University of California, Davis, 78 p.

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

Cartier, K.D., Peltz, L.A., and Long, Katie, 1995, Hydrologic basins and hydrologic-monitoring sites of Lake Tahoe Basin, California and Nevada: U.S. Geological Survey Open-File Report 95-316, 1 sheet.

Cartier, K.D., Peltz, L.A., and Smith, J.L., 1993, Development and documentation of spatial data bases for the Lake Tahoe Basin, California and Nevada: U. S. Geological Survey Water-Resources Investigations Report 93-4182, 65 p.

Crippen, J.R., and Pavelka, B.R., 1972, The Lake Tahoe Basin, California-Nevada: U.S. Geological Survey Water-Supply Paper 1972, 56 p.

Goldman, C.R., and Byron, E.R., 1986, Changing water quality at Lake Tahoe—The first five years of the Lake Tahoe Interagency Monitoring Program: Tahoe Research Group, University of California, Davis, 12 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 283 p.

Hill, B.R., and Nolan, K.M., 1988, Suspended-sediment factors, Lake Tahoe Basin, California-Nevada, *in* Poppoff, I.G., Goldman, C.R., Loeb, S.L., and Leopold, L.B., eds., Proceedings, International Mountain Watershed Symposium, Lake Tahoe, June 8-10, 1988: South Lake Tahoe, Calif., Tahoe Resource Conservation District, p. 179-189.

Hill, K.J., 1996, Water quality report for water year 1995: Tahoe Regional Planning Agency, 115 p.

Hoffman, K., 1991, Santa Fe Erosion Control Project Water Quality Monitoring Report, water years 1987-90: U.S. Forest Service, Lake Tahoe Basin Management Unit, 24 p.

Hunter, D.A., Reuter, J.E., and Goldman, C.R., 1993, Standard operating procedures - Lake Tahoe Interagency Monitoring Program: Tahoe Research Group, University of California, Davis, 79 p.

Jeton, A.E., 1999, Precipitation-runoff simulations for the Lake Tahoe Basin, California and Nevada: U.S. Geological Survey Water-Resources Investigations Report 99-4110, 61 p.

Katzer, T.L., and Glancy, P.A., 1978, Flood and debris hazards along principal streams, South Lake Tahoe quadrangle [Nevada and California]: Nevada Bureau of Mines and Geology Urban Map Series, South Lake Tahoe Folio, Map 2A1, scale 1:24,000.

Kroll, C.G., 1976, Sediment discharge from highway cutslopes in the Lake Tahoe Basin, California, 1972-74: U.S. Geological Survey Water-Resources Investigations Report 76-19, 85 p.

Loeb, S.L., 1987, Groundwater quality within the Tahoe Basin: Institute of Ecology, University of California, Davis, 265 p.

Loeb, S.L., and Goldman, C.R., 1979, Water and nutrient transport via ground water from Ward Valley into Lake Tahoe: Limnology and Oceanography, v. 24, no. 6, p. 1146-1154.

Lowry, M., and Meeker, D., 1993, Water quality at five baseline stations (Big Meadow Creek, Hidden Valley Creek, Grass Lake Creek, Meeks Creek, and Trout Creek) in the Lake Tahoe Basin: U.S. Forest Service, Lake Tahoe Basin Management Unit, 38 p.

Norman, S., 1996, Hell Hole Road water quality improvement project monitoring report, 1991-95: U.S. Forest Service, Lake Tahoe Basin Management Unit, 26 p.

———1997, Pope Marsh Burn monitoring report, 1995-97: U.S. Forest Service, Lake Tahoe Basin Management Unit, 21 p.

Norman, S., and Parsons, K., 1997, Grass Lake Research Natural Area water quality monitoring report, spring runoff 1994: U.S. Forest Service, Lake Tahoe Basin Management Unit, 14 p.

Peltz, L.A., Smith, J.L., Cartier, K.D., 1994, Slope and aspect classifications of Lake Tahoe Basin, California and Nevada: U.S. Geological Survey Open-File Report 94-105, 1 sheet.

Robinson, C., 1996, Apache Erosion Control Project final water quality monitoring report, 1991-96 water years: El Dorado County Department of Transportation, 121 p.

Rowe, T.G., and Stone, J.C., 1997, Selected hydrologic features of the Lake Tahoe Basin, California and Nevada: U.S. Geological Survey Open-File Report 97-384, 1 sheet.

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

Scott, V.H., Scalmani, J.C., and Matthews, R.A., 1978, Groundwater resources of the South Tahoe Public Utility District: University of California, Davis, Water Science and Engineering Papers, no. 2007, 62 p.

Tahoe Regional Planning Agency, 1996, Lake Tahoe Federal Legislative Agenda—A public-private partnership of the Tahoe Region: Zephyr Cove, Nev., Tahoe Regional Planning Agency, 23 p.

Tahoe Regional Planning Agency and U.S. Forest Service, 1971, Geology and geomorphology of the Lake Tahoe Region—A Guide for Planning: South Lake Tahoe, Calif., 59 p.

Thodal, C.E.,1995, Hydrogeologic setting and ground-water quality of areas tributary to Lake Tahoe in Douglas County and Carson City, Nevada, through 1987: U.S. Geological Survey Water-Resources Investigations Report 94-4079, 31 p.

———1997, Hydrogeology of Lake Tahoe Basin, California and Nevada, and results of a ground-water quality monitoring network, water years 1990-92: U.S. Geological Survey Water-Resources Investigations Report 97-4072, 53 p.

Twiss, R.H., Elford, C.R., James, J.W., Mueller, P.K., Smith, K.C., Warburton, Joseph, and Woo, H.W., 1971, Climate and air quality of the Lake Tahoe region: South Lake Tahoe, Calif., Tahoe Regional Planning Agency and U.S. Forest Service, 31 p.

U.S. Army Corps of Engineers, 1969, Flood plain information, Upper Truckee River, South Lake Tahoe, California: U.S. Army Corps of Engineers Report, 23 p.

U.S. Environmental Protection Agency, 1996, Drinking water regulations and health advisories: Washington, D.C., Environmental Protection Agency, Office of Water (unpaginated).

Woodling, J.K., 1987, A hydrogeologic investigation of ground water-lake interaction in the southern Tahoe Basin: University of California, Davis, unpublished M.S. thesis, 133 p.