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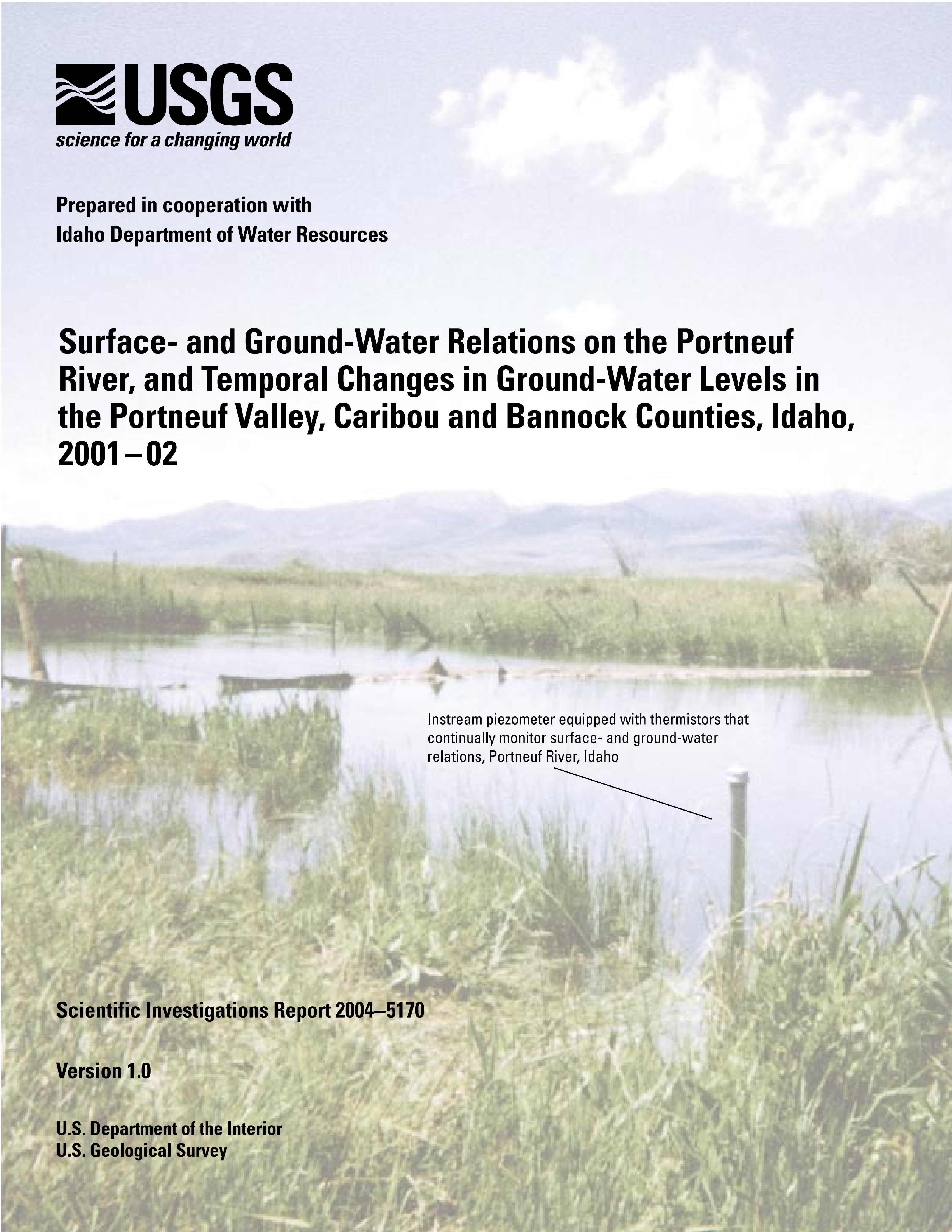
Surface- and Ground-Water Relations on the Portneuf River, and Temporal Changes in Ground-Water Levels in the Portneuf Valley, Caribou and Bannock Counties, Idaho, 2001–02


Instream piezometer equipped with thermistors that continually monitor surface- and ground-water relations, Portneuf River, Idaho

Scientific Investigations Report 2004–5170

Version 1.0

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

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By Gary J. Barton

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

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2004

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Conversion Factors and Datums

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

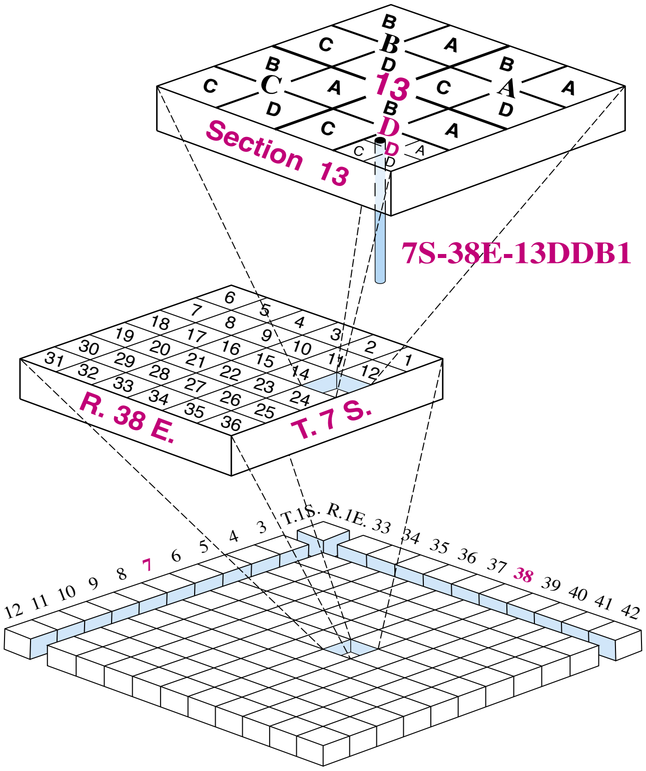
Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).



The well-numbering system used by the USGS in Idaho indicates the location of a well or spring according to the official rectangular subdivisions of the public lands. The first two segments of the number designate the township and range. The third segment designates the section number and is followed by three letters and a numeral, which designate, respectively, the quarter section, the 40-acre tract, the 10-acre tract, and the serial number of the well or spring within the tract. Quarter sections are lettered A, B, C, and D, in a counterclockwise order from the northeast quarter of each section. Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. Thus, well 07S-38E-13DDB1 is in the NW1/4SE1/4SE1/4 sec. 13, T. 07 S., R. 38 E., and was the first well inventoried in that 10-acre tract.

Surface- and Ground-Water Relations on the Portneuf River, and Temporal Changes in Ground-Water Levels in the Portneuf Valley, Caribou and Bannock Counties, Idaho, 2001–02

By Gary J. Barton

Abstract

The State of Idaho and local water users are concerned that streamflow depletion in the Portneuf River in Caribou and Bannock Counties is linked to ground-water withdrawals for irrigated agriculture. A year-long field study during 2001–02 that focused on monitoring surface- and ground-water relations was conducted, in cooperation with the Idaho Department of Water Resources, to address some of the water-user concerns. The study area comprised a 10.2-mile reach of the Portneuf River downstream from the Chesterfield Reservoir in the broad Portneuf Valley (Portneuf River Valley reach) and a 20-mile reach of the Portneuf River in a narrow valley downstream from the Portneuf Valley (Pebble-Topaz reach).

During the field study, the surface- and ground-water relations were dynamic. A losing river reach was delineated in the middle of the Portneuf River Valley reach, centered approximately 7.2 miles downstream from Chesterfield Reservoir. Two seepage studies conducted in the Portneuf Valley during regulated high flows showed that the length of the losing river reach increased from 2.6 to nearly 6 miles as the irrigation season progressed.

Surface- and ground-water relations in the Portneuf Valley also were characterized from an analysis of specific conductance and temperature measurements. In a gaining reach, stratification of specific conductance and temperature across the channel of the Portneuf River was an indicator of ground water seeping into the river.

An evolving method of using heat as a tracer to monitor surface- and ground-water relations was successfully conducted with thermistor arrays at four locations. Heat tracing monitored a gaining reach, where ground water was seeping into the river, and monitored a losing reach, where surface water was seeping down through the riverbed (also referred to as a conveyance loss), at two locations.

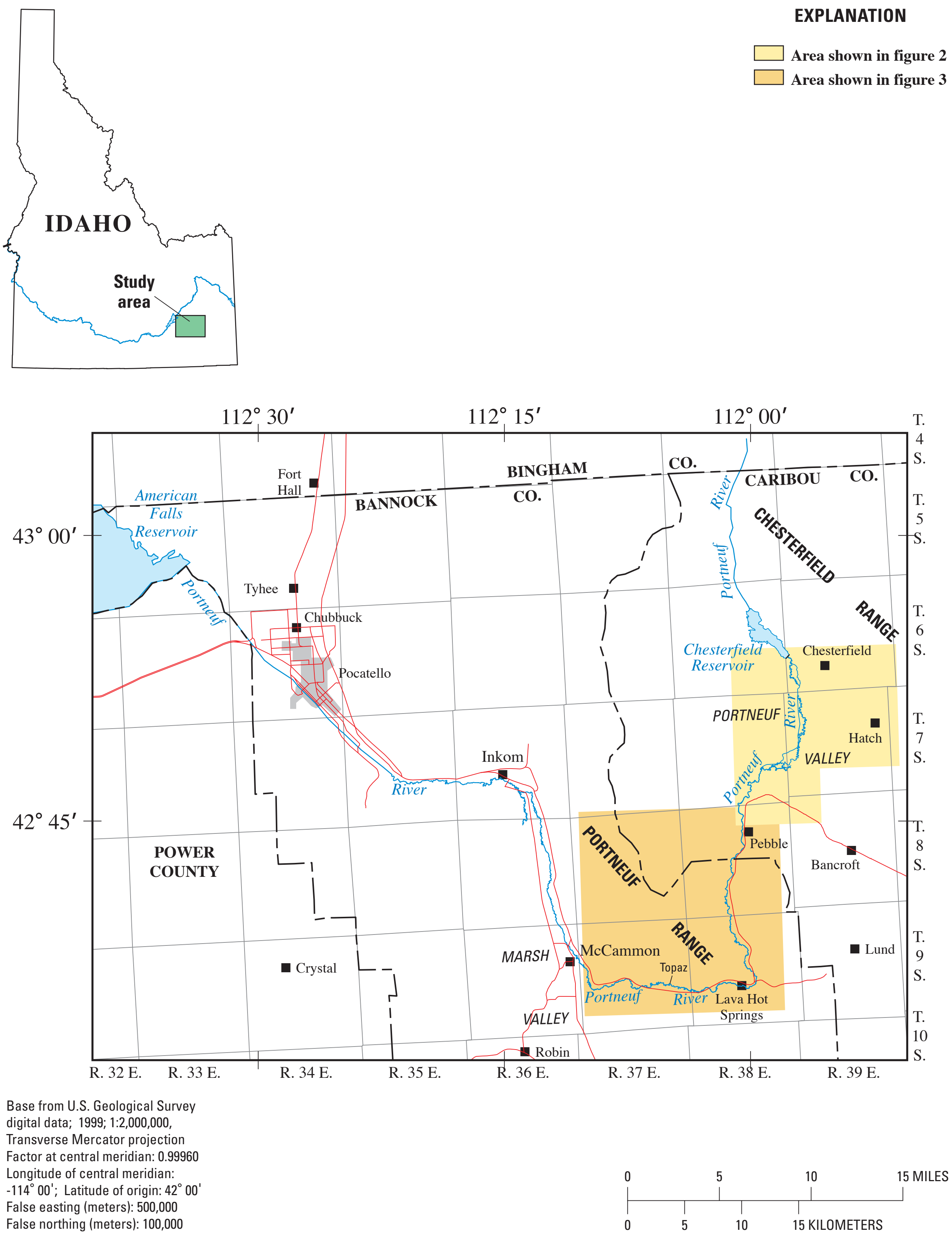
Conveyance losses in the Portneuf River Valley reach were greatest, about 20 cubic feet per second, during the mid-summer regulated high flows. Conveyance losses in the Pebble-Topaz reach were greatest, about 283 cubic feet per second, during the spring regulated high flows and were attributed to a hydroelectric project.

Comparison of water levels in 30 wells in the Portneuf Valley during September and October 1968 and 2001 indicated long-term declines since 1968; the median decline was 3.4 feet. September and October were selected for characterizing long-term ground-water-level fluctuations because declines associated with irrigation reach a maximum at the end of the irrigation season. The average annual snowpack in the study area has declined significantly; 1945–85 average annual snowpack was 16.1 inches, whereas 1986 through 2002 average annual snowpack was 11.6 inches. Water-level declines during 1998–2002 may be partially attributable to the extended dry climatic conditions. It is unclear whether the declines could be partially attributed to increases in ground-water withdrawals. Between 1968 and 1980, water rights for ground-water withdrawals nearly doubled from 23,500 to 46,000 acre-feet per year. During this period, ground-water levels were relatively constant and did not exhibit a declining trend that could be related to increased ground-water withdrawal rights. However, ground-water withdrawals are not measured in the valley; thus, the amount of water pumped is not known.

Since the 1990s, there have been several years when the Chesterfield Reservoir has not completely refilled, and the water in storage behind the reservoir has been depleted by the middle of the irrigation season. In this situation, surface-water diversions for irrigation were terminated before the end of the irrigation season, and irrigators, who were relying in part on diversions from the Portneuf River, had to rely solely on ground water as an alternate supply. Smaller volumes of water in the Chesterfield Reservoir since the 1990s indicate a growing demand for ground-water supplies.

Introduction

The State of Idaho and local water users are concerned that streamflow depletion in the Portneuf River is linked to ground-water withdrawals for irrigated agriculture. In



Base from U.S. Geological Survey digital data; 1999; 1:2,000,000, Transverse Mercator projection
Factor at central meridian: 0.99960
Longitude of central meridian: -114° 00′; Latitude of origin: 42° 00′
False easting (meters): 500,000
False northing (meters): 100,000

Figure 1. Location of Portneuf River study area, Idaho.

addition, the State and local water users are concerned about temporal changes in ground-water levels, specifically, declining water levels. For these reasons, the Idaho Department of Water Resources (IDWR) requested that the U.S. Geological Survey (USGS) conduct a hydrologic study that focused on surface- and ground-water relations on the Portneuf River. In a USGS reconnaissance study, Norvitch and Larson (1970) estimated gains to and losses from the river and concluded that additional work was needed to help characterize the surface- and ground-water relations and the effects of pumping wells on ground-water levels and streamflow.

A decree on water rights for use of water in the Chesterfield Reservoir states that releases from the reservoir shall suffer no conveyance losses (Robert Sutter, Idaho Department of Water Resources, written commun., 2001). Conveyance losses include surface water seeping down through the riverbed, which can be the result of natural surface- and ground-water relations. However, ground-water withdrawals for irrigated agriculture may increase ground-water-level declines and, therefore, increase conveyance losses. The Portneuf River Basin is presently under preliminary water rights adjudication.

Purpose and Scope

The purpose of this report is to (1) characterize the surface- and ground-water relations along a 30.2-mi reach of the Portneuf River downstream from Chesterfield Reservoir in Caribou and Bannock Counties, Idaho, and (2) describe temporal changes in ground-water levels in the Portneuf Valley from 1968 through 2002. Specifically, this report documents the seasonality of gaining and losing reaches in the Portneuf River. The gaining and losing river reaches are identified by means of seepage studies, including a new technique that utilizes water temperature as a tracer. Some insight into streamflow depletion during high flows during the irrigation season is provided. Estimation of long-term fluctuations in ground-water levels since 1968 is limited to an analysis of 32 wells completed in the water-table aquifer in the Portneuf Valley.

Acknowledgments

Thanks are extended to the people of the Portneuf Valley study area for their willing assistance and for allowing the USGS access to their property and wells in order to collect data. The IDWR provided the USGS with data on water use in the Portneuf Valley. Steve Hebdon, District Watermaster of the Portneuf River Marsh Valley Canal, provided the USGS with data on surface-water diversions and much information about the history of development in the Portneuf Valley. Dave Clark, ground-water discipline specialist for the USGS in Boise, Idaho, developed the project proposal and provided technical input on collecting and analyzing data for the project. Sabrina Conti, USGS scientist in Boise, Idaho, and Kim Trask, student intern with the USGS in Tacoma, Washington, assisted in gathering and analyzing the data. Hydrologic technicians in the Idaho Falls Field Office worked long hours to measure streamflow, hydraulic gradients at instream piezometers, and water levels in irrigation wells.

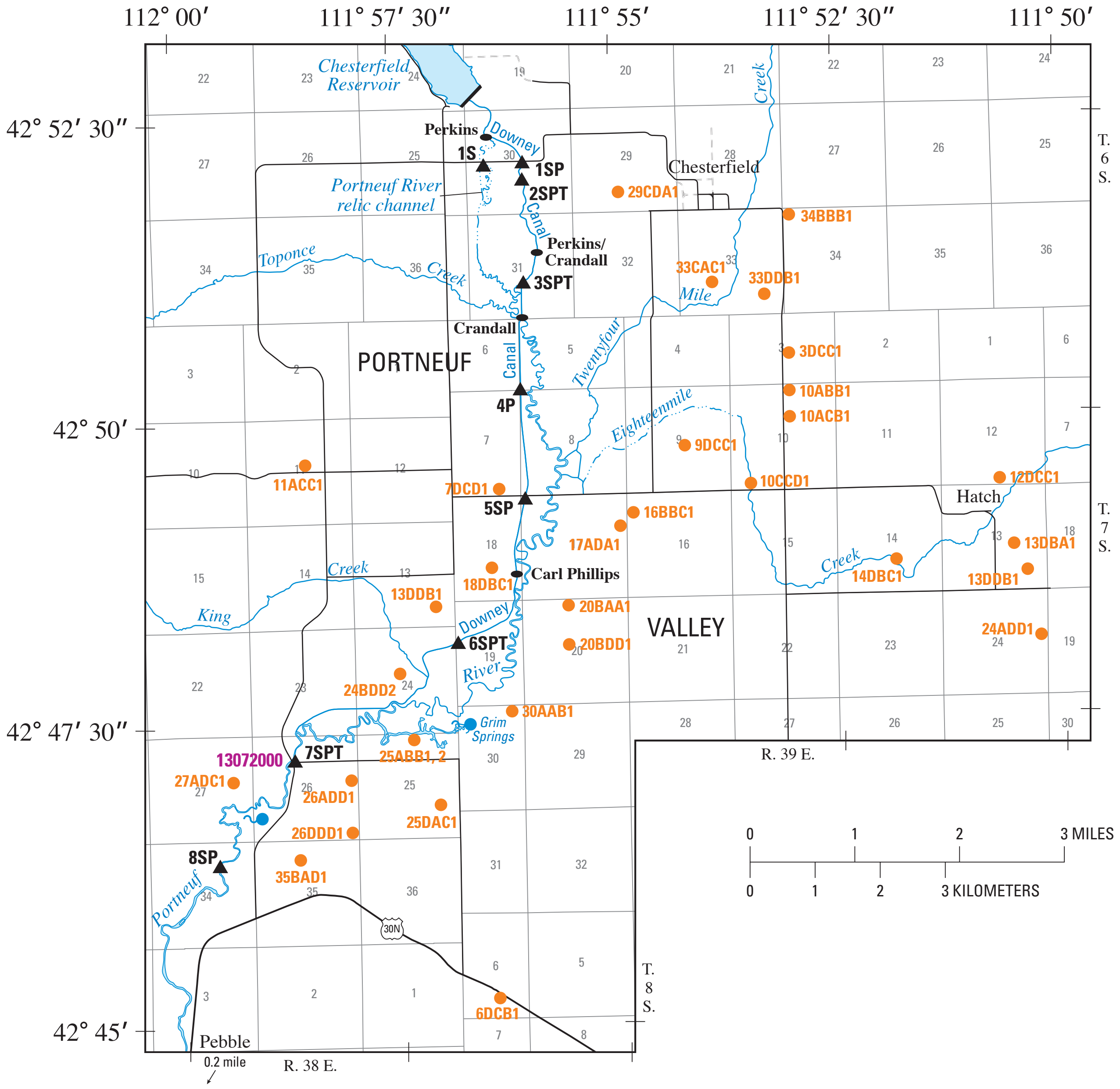
Description of Study Area

The study area encompasses about 65 mi^2 of the broad Portneuf Valley and includes 7.8 mi of channelized river downstream from Chesterfield Reservoir, the Portneuf Marsh Valley Canal, and a 2.4-mi reach of the Portneuf River downstream from the Portneuf Marsh Valley Canal (figs. 1–3). The Portneuf Marsh Valley Canal is referred to locally as the Downey Canal. Water released from the Chesterfield Reservoir regulates flow in the total 10.2-mi reach. The reservoir has a capacity of 24,000 acre-ft. When the river was channelized (during 1908–12), about 2 mi of the relic Portneuf River remained directly downstream from the Chesterfield Reservoir but was separated from the Portneuf Marsh Valley Canal. Water in the relic stream channel is a fraction of its previous flow and is diverted primarily for irrigation during the growing season; hence, the relic river is dry part of the year.

For the purpose of this report, the Portneuf River in the Portneuf Valley is defined to include the Portneuf Marsh Valley Canal and is referred to as the Portneuf River Valley reach. The study area also includes a 20-mi reach of the Portneuf River that is located downstream from the Portneuf River Valley reach and upstream from Topaz (figs. 1 and 3). This 20-mi reach cuts through the Portneuf Range and forms a narrow valley. The channel gradient is appreciably greater downstream from the Portneuf River Valley reach. For the purpose of this report, the 20-mi reach is referred to as the Pebble-Topaz reach.

Physiographically, the study area is located in the northeastern-most extension of the Basin and Range province of the Intermontane Plateau (Fenneman, 1931, pl. 1). The study area is in the Great Basin section of the province and is characterized by isolated mountain ranges separated by aggraded desert plains. Sediments in the Portneuf Valley consist of loess, silty alluvial deposits, and volcanic ash, which form a broad, alluvial plain. The agricultural area lies within this plain and consists of dryland farming, pasture, and grazing. The Portneuf Valley is bounded on the east by the Chesterfield Range and on the west by the Portneuf Range.

Norvitch and Larson (1970) described climatic conditions in the Portneuf Valley as variable, primarily because of the large topographic relief (altitudes of 5,200 to 9,271 ft above sea level) within the valley. Annual average precipitation ranges from less than 10 in. on the valley floor to more than 30 in. near the summit of Haystack Mountain (altitude 9,033 ft) in the Portneuf Range. Summer precipitation is generally low and afternoon temperatures are high; arid conditions can exist seasonally in the lower valley areas.



EXPLANATION

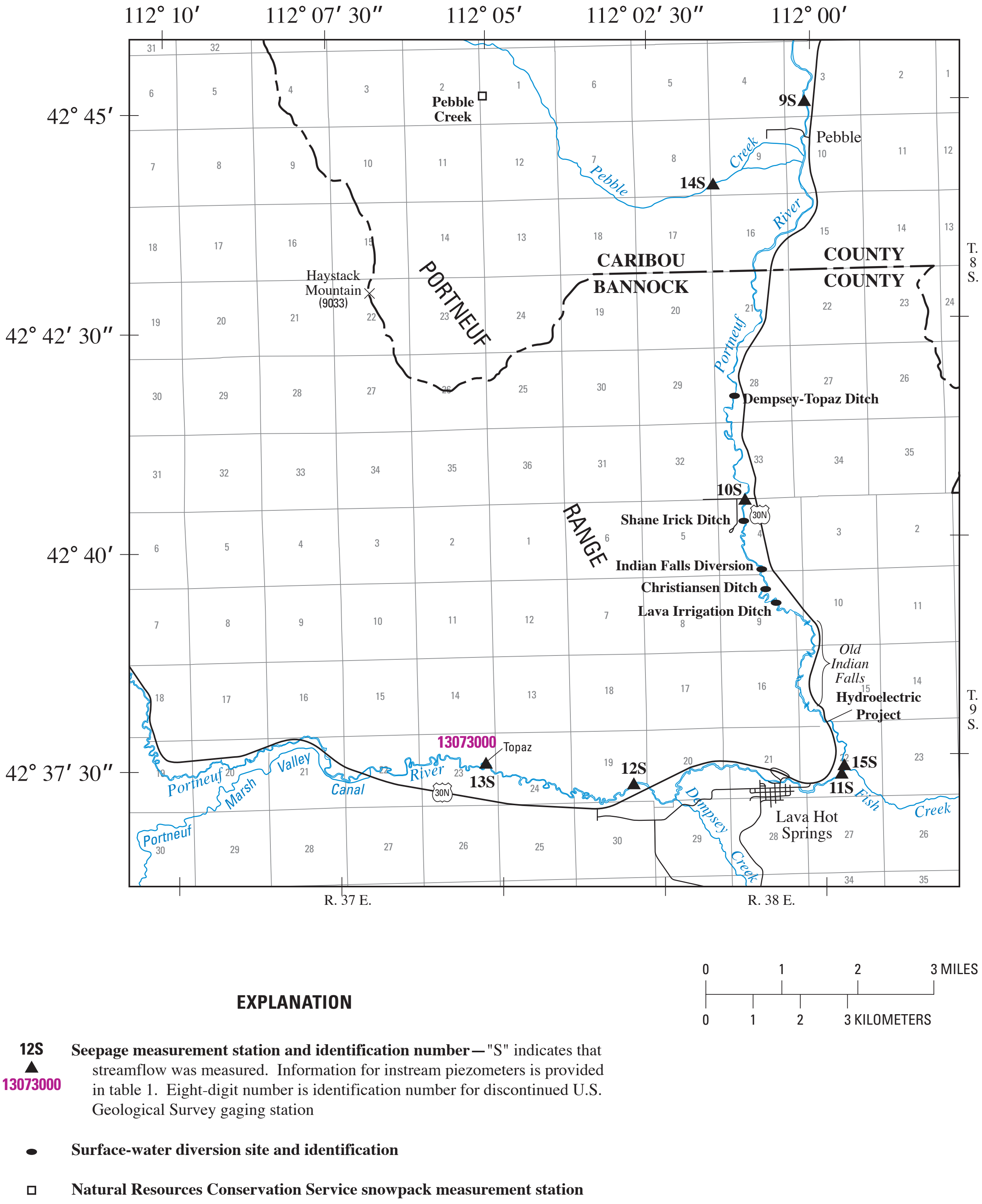
● 11ACC1 **Ground-water-level measurement station and identification number**—Water levels were measured in wells during approximately eight visits per site. Graphs of water levels provided in appendix 1. Water levels have been monitored quarterly and sometimes weekly in well 10CCD1 since 1968

7SPT ▲ 13072000 **Seepage measurement station and identification number**—"S" indicates that streamflow was measured; "P" indicates that an instream piezometer was installed in riverbed and the hydraulic head between river stage and the ground-water level was measured with a manometer board and field water-quality parameters were measured; "T" indicates that a second instream piezometer equipped with thermistors that monitor stream temperature and ground-water temperature at 20 and 40 inches below the riverbed was installed. Information for instream piezometers is provided in table 1. Eight-digit number is identification number for discontinued U.S. Geological Survey gaging station

● **Surface-water diversion site and identification**

∿● **Spring**—Tail indicates direction of flow

Figure 2. Location of measurement stations and surface-water diversions on the Portneuf River between Chesterfield Reservoir and Pebble, Idaho.



EXPLANATION

12S ▲ 13073000 **Seepage measurement station and identification number**—"S" indicates that streamflow was measured. Information for instream piezometers is provided in table 1. Eight-digit number is identification number for discontinued U.S. Geological Survey gaging station

● **Surface-water diversion site and identification**

□ **Natural Resources Conservation Service snowpack measurement station**

Figure 3. Location of measurement stations and surface-water diversions on the Portneuf River between Pebble and Topaz, Idaho.

Surface-Water Conditions

The Portneuf Marsh Valley Canal was constructed in conjunction with the Chesterfield Reservoir during 1908–12 to provide a dependable source of water to areas downstream from Lava Hot Springs. This unlined canal carries nearly all the water formerly carried by the Portneuf River (U.S. Department of Agriculture, 1993). Water rights decree the cessation of all streamflow releases from the Chesterfield Reservoir during September 15 to April 15 on an annual basis for the purpose of reservoir refilling. The water in storage is released the following spring and summer and the water rights decree that this water shall suffer no conveyance losses. During April 15 to September 15, water rights decree that the natural streamflow entering the Chesterfield Reservoir be diverted downstream. This natural streamflow can be diverted for irrigation in the Portneuf Valley.

During 1912–13 and 1968–77, the period of record for USGS stream-gaging station 13072000 near Pebble, Idaho, which measures drainage from 260 mi^2 (fig. 2), the Portneuf River typically flowed between 200 and 400 ft^3/s during the April through June snowmelt-runoff period (fig. 4). Following snowmelt runoff and prior to September 15, streamflow generally ranged from about 80 to 150 ft^3/s. After the annual cessation of all streamflow from the reservoir to the Portneuf River on September 15, flows in the river declined to a base flow of about 45 to 75 ft^3/s during the fall, winter, and early spring months. The minimum daily mean flow during the period of record was 21 ft^3/s on December 30, 1968. The maximum daily mean flows during the period of record were 537 ft^3/s on April 1, 1913, and 536 ft^3/s on April 9, 1976. Farther downstream at USGS stream-gaging station 13073000 at Topaz (fig. 3, measures drainage from 570 mi^2), the Portneuf River during 1968–2001 typically flowed between 500 and 800 ft^3/s during the April through June snowmelt-runoff period (fig. 4). During the rest of the year, streamflow generally ranged from about 110 to 180 ft^3/s. The minimum daily mean flow during the period of record was 63 ft^3/s on September 23, 2002. The maximum daily mean flow during the period of record was 1,320 ft^3/s on May 22, 1984.

Prior to large-scale dryland farming in the Portneuf Valley, mountain tributaries Twentyfour Mile Creek, Eighteenmile Creek, King Creek, and Toponce Creek provided significant discharge to the Portneuf River. These creeks are now diverted for other uses and do not provide flow to the Portneuf River. During the post-irrigation season, water from Toponce Creek is diverted into the Chesterfield Reservoir for storage. It is estimated that Toponce Creek supplies at least half the water in storage in the Chesterfield Reservoir (Steve Hebdon, District Watermaster for the Portneuf River Marsh Valley Canal, Idaho, oral commun., 2002).

During this study, releases from the Chesterfield Reservoir to the Portneuf River were stopped prematurely on July 22 during the 2001 irrigation season and on July 20 during the 2002 irrigation season because of a lack of water in storage in the reservoir. Prior to the drought that began in 1999 and continues to the present (2002), there were many years when Chesterfield Reservoir would completely refill prior to the irrigation season, and releases from the dam would continue throughout the growing season into mid-September. The premature cessation of releases from the Chesterfield Reservoir to the Portneuf River during the middle of summer

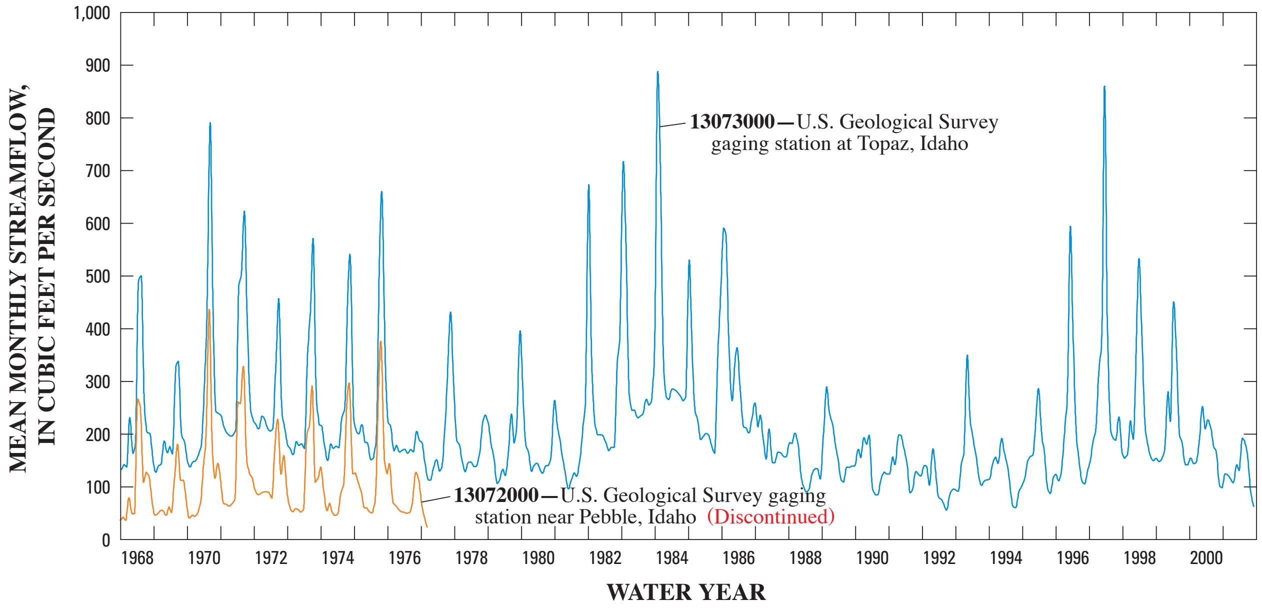


Figure 4. Mean monthly streamflow in the Portneuf River near Pebble and at Topaz, Idaho, 1968–2001.

has been more frequent since the early 1990s as a result of drought conditions (Steve Hebdon, District Watermaster for the Portneuf River Marsh Valley Canal, oral commun., 2002). Between the end of streamflow releases and September 15, 2001, streamflow (1 to 3 ft^3/s) entering Chesterfield Reservoir was passed on downstream.

Ground-Water Conditions

In general, ground-water movement in the Portneuf Valley is from the uplands to the center of the valley, then southward downgradient in the direction of streamflow in the Portneuf River. Some ground water moves vertically upward through leaky confining strata where water-table aquifers are underlain by artesian aquifers (Norvitch and Larson, 1970). The water table is at or near the land surface near Grim Springs (fig. 2) in the south-central part of the valley. Numerous springs are located about 2 mi upstream from Pebble in the southwestern part of the Portneuf Valley (fig. 5). Supply wells and irrigation wells in the study area are completed principally in alluvial and colluvial deposits of Quaternary age. These deposits are composed of soil, clay, silt, sand, gravel, and boulders. A few irrigation wells are completed in basalt of Quaternary age (Norvitch and Larson, 1970; Lewis and Peterson, 1921).

The water-table aquifer is recharged by (1) snowmelt runoff from the adjacent mountains, (2) streams that flow out of the mountains onto the alluvial plain and lose their entire discharge to the water-table aquifer or are diverted for irrigation, (3) precipitation that falls on the valley floor and percolates to the water table, (4) leakage from irrigation canals and ditches, (5) recharge from irrigated fields, and (6) possibly leakage from the southern part of the Chesterfield Reservoir (Norvitch and Larson, 1970). During periods of increased mountain snowpack, water levels in irrigation well 07S 39E 10CCD1 (period of record is 1968 to present) tend to rise (fig. 6). During periods of decreased mountain snowpack, water levels in this well tend to decline. Hence, aquifer recharge from snowmelt runoff from the adjacent mountains is significant and perhaps the dominant source of water to the valley aquifer system. Ground water discharges from the water-table aquifer by (1) seepage up through the riverbed of the Portneuf River, (2) spring flow or seeps along the banks of the stream channels, (3) evapotranspiration at places where the water

Figure 5. Spring located about 0.3 mile upstream from measurement station 8SP and 200 feet east of the Portneuf River in the southwestern part of the Portneuf Valley, Idaho, July 2001.

table is near land surface and within reach of phreatophytes, and (4) withdrawals from irrigation wells (Norvitch and Larson, 1970).

Ground-water allocations for irrigation increased more than a thousandfold in the valley from 1951 to 1978 when dryland farming expanded considerably. However, because ground-water withdrawals are not measured in the valley, the amount of water pumped on an annual basis since the 1950s is not known. Water-rights (decreed, statutory claim, and licensed) data are used as surrogate data to provide some generalizations about ground-water usage. Between 1951 and 1978, the number of ground-water withdrawal rights in the valley increased from 12 to 157. The allocated amount of withdrawals for all wells combined increased at nearly a constant rate (fig. 7). A moratorium has been placed on new water rights, with a few minor exceptions, since the late 1970s. Beginning in the 1980s to present, the combined water rights for ground-water withdrawals in the valley have been constant at about 46,000 acre-ft per year.

Methods of Investigations

Fieldwork was conducted during July 2001 through July 2002. Seepage studies provided the foundation of the field approach and were used to understand the relations between streamflow and adjacent ground-water movement. Seepage studies in the Portneuf River Valley reach consisted of measurements of (1) streamflow; (2) differences in hydraulic head between the surface-water stages and ground-water levels measured at instream piezometers; (3) water quality measured at instream piezometers and at selected springs; and (4) continuous water temperature. Seepage studies in the Pebble-Topaz reach consisted of direct measurements of streamflow. Each of these methods is described in following sections of the report.

Numbering and Location of Measurement Stations

Eight measurement stations, 1S through 8SP, were located along the 10.2-mi-long Portneuf River Valley reach (fig. 2), and six measurement stations, 9S through 13S, were located along the 20-mi-long Pebble-Topaz reach (fig. 3). Station 8SP is on the border shared by both the Portneuf River Valley and Pebble-Topaz reaches. Locations of the measurement stations were selected on the basis of accessibility, safety, ease of measurement, and availability of a bridge from which to measure streamflow. An attempt was made to establish measurement stations downstream from known seeps.

Measurement stations were numbered using a 15-digit site identifier (SID) consisting of the latitude and longitude, followed by a two-digit sequence number beginning “01,” and

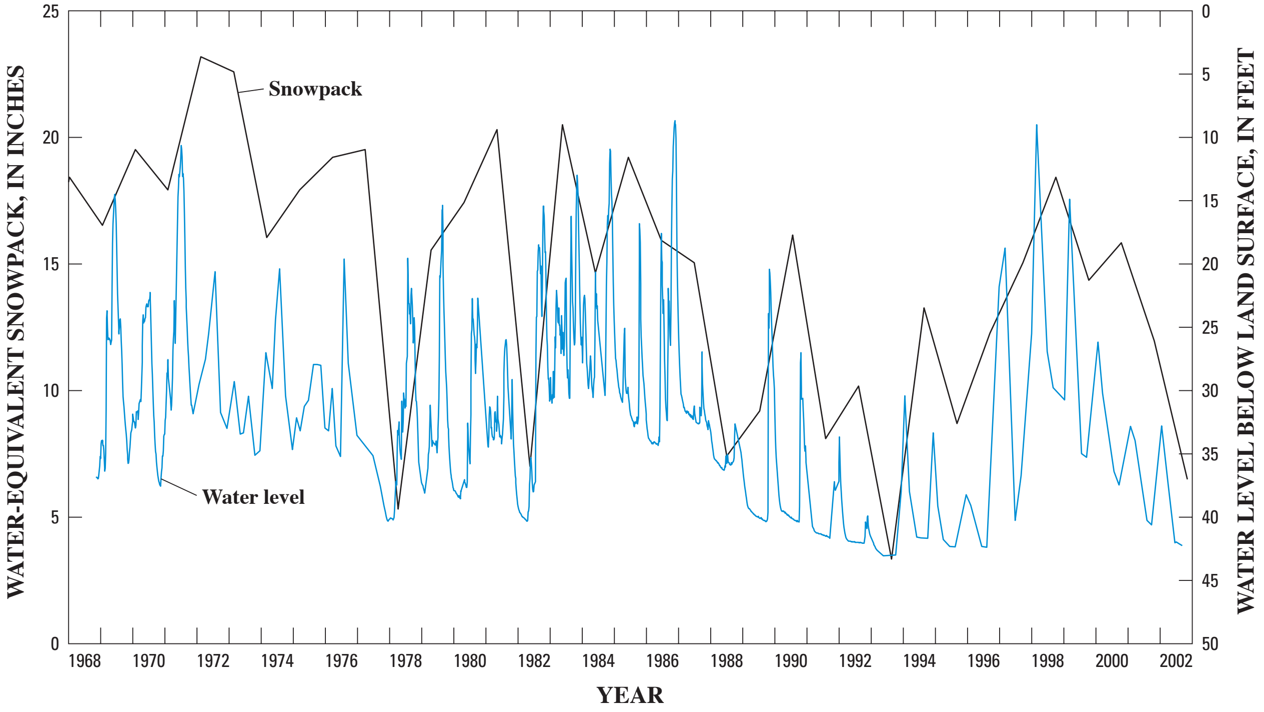


Figure 6. Water levels in irrigation well 07S-39E-10CCD1 and water-equivalent snowpack during April at Pebble Creek station, 1968–2002. (Water-equivalent snowpack data from Natural Resources Conservation Service, 1993)

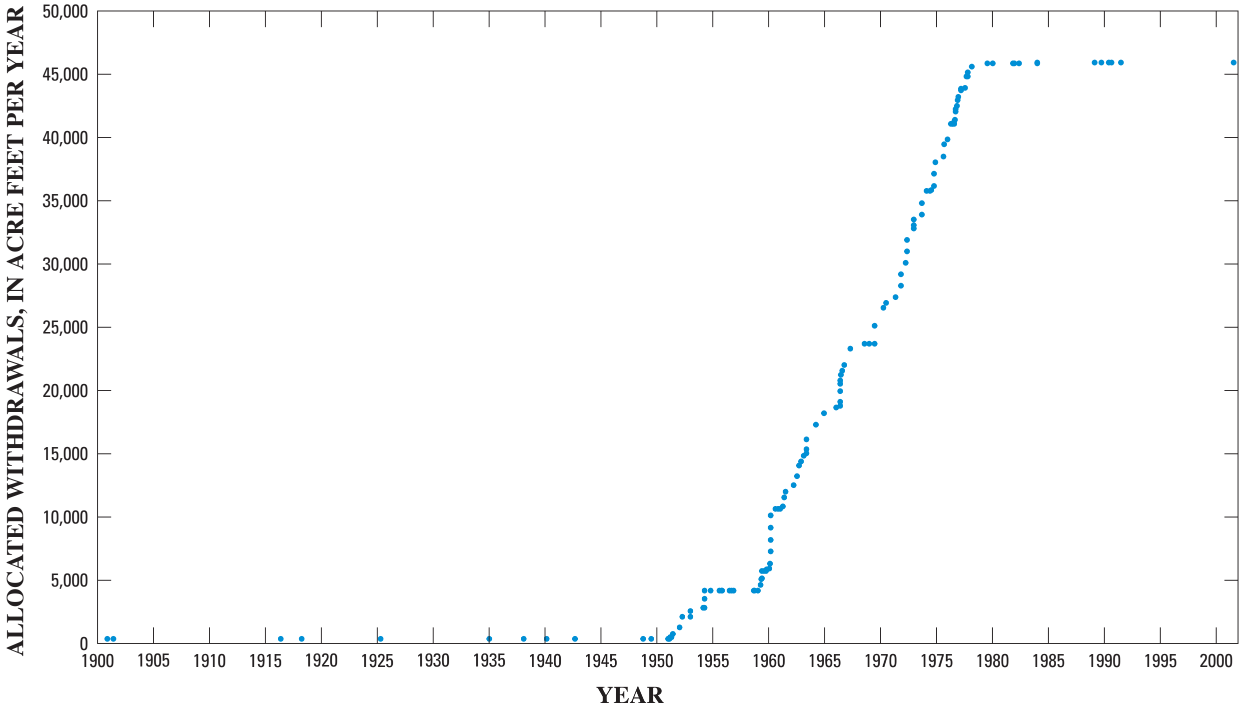


Figure 7. Growth in allocated ground-water withdrawals in the Portneuf Valley, Idaho, 1900–2000. (Data from Idaho Department of Water Resources, 1993)

were assigned a measurement station name. Information for each measurement station is stored under the SID and station name in the USGS National Water Information System data base. A local identifier was established for measurement stations, consisting of a single number increasing in the downstream direction. The suffix "S" on the local identifier indicates that streamflow was measured, "P" indicates that an instream piezometer was installed, and "T" indicates that a second instream piezometer equipped with thermistors was installed.

Timing of Seepage Studies

Seepage studies in the Portneuf River Valley reach were conducted over a range of hydrologic conditions to characterize the seasonality of surface- and ground-water relations: (1) spring regulated high flows at the start of the irrigation season on May 29, 2002; (2) mid-summer regulated high flows during the irrigation season during July 16–17, 2001; (3) late-summer base flows during the irrigation season on August 13, 2001; (4) early-fall regulated low flows at the end of the irrigation season on September 17, 2001; and (5) mid-fall regulated low flows during the post-irrigation season on October 18, 2001. Seepage studies in the Pebble-Topaz reach were conducted only during hydrologic conditions (1), (4), and (5).

High-flow conditions during seepage studies (1) and (2) on the Portneuf River are controlled by the release of water from storage in the Chesterfield Reservoir and herein are referred to as regulated high-flow conditions. Seepage study (3) was conducted when only the natural streamflow entering the Chesterfield Reservoir was diverted downstream and herein is referred to as base-flow conditions. Seepage studies (4) and (5) were conducted when the release of all flow from Chesterfield Dam was stopped and herein are referred to as regulated low-flow conditions.

During seepage study (2), consecutive streamflow measurements were averaged and used as the mid-summer regulated high-flow measurements. During July 10–12, 2001, a few days prior to the streamflow measurements, instream piezometers were installed at eight measurement stations (fig. 8). Immediately after the installation of an instream piezometer, hydraulic head and water-quality properties were measured. During the same period, water quality was measured at mid-depth across the river at station 8SP and at nearby springs. During this period, four instream piezometers equipped with multiple thermistors were installed and began monitoring the temperature of the streamflow and riverbed.

Daily precipitation data were used to indicate the stability of streamflow conditions during each seepage study. The most complete record of daily precipitation near the study area was obtained at the weather station at the Pocatello (39 mi west of the study area) regional airport (National Oceanic and Atmospheric Administration, http://lwf.ncdc.noaa.gov/oa/ncdc.html). These data (fig. 9) provide a general indication of

Figure 8. Instream piezometer used to continuously monitor the temperature of the Portneuf River and of ground water and to measure hydraulic head of surface and ground water at measurement station 3SPT in the Portneuf River Valley reach, Idaho, July 2001.

precipitation in the study area because precipitation in intermontane basins is highly dependent upon altitude and general topography. Apparently, no significant precipitation fell prior to the seepage studies except during the May 29, 2002, study. During these studies, the dry soils could readily absorb the small amount of precipitation that fell and any effect on streamflow would be negligible. However, 6 days prior to the May 29, 2002, study, about 1 in. of rain fell during a 48-hour period. Because of the 6-day lapse between the rainfall and the seepage run, storm-related inflows downstream from Chesterfield Reservoir would have receded and streamflow in the Portneuf River would have stabilized.

Measuring Differences in Hydraulic Head Between Surface-Water Stages and Ground-Water Levels

The differences in hydraulic head were measured at instream piezometers by means of a manometer board. Piezometers consisted of a $^1/_2$-in. (inside diameter) steel pipe with a pointed bottom. Twenty-four $^1/_8$-in.-diameter openings in the lower 6 in. of the piezometer served as a well screen (fig. 10). The piezometers were driven into the riverbed with a portable safety hammer to depths ranging from 2.0 to 7.7 ft below the riverbed. To ensure that the piezometers were in good hydraulic connection with the surrounding aquifer, a portable peristaltic pump was used to inject water into or withdraw water from the piezometers. This pumping forced water through the $^1/_8$-in. openings of the piezometers and removed the fine-grained sediments that clogged the openings during installation. Piezometer installations were considered complete when the pumping action was halted and water levels inside the piezometer equilibrated rapidly with water levels in the surrounding aquifer. Location and construction information for piezometers is given in table 1.

A calibrated manometer board was used to measure the difference in hydraulic head between the surface-water stage in the river outside the piezometer and the ground-water level in the piezometer. The manometer's accuracy was 1 mm (0.04 in.). Measurement precision—consecutive water-level measurements over a brief period—varied depending on the extent of wave action on the river surface. Typically, measurement precision was roughly 3 mm (0.12 in.). To mute the effects of waves and flowing water on measurement precision, the manometer's surface-water line was inserted through a small opening in a 2-in.-diameter cylinder (stilling well) that was attached to the piezometer. Detailed descriptions of the use of manometers and instream piezometers are provided in a report by Winter and others (1983) and, in relation to work in Idaho, are described in a report by Barton (2002).

Manometer measurements were used to identify zones of upward gradient (ground-water levels higher than river stage), downward gradient (river stage higher than ground-water levels), and no gradient (ground-water levels equal to river stage). Water moves from zones of high hydraulic head to zones of low hydraulic head; thus, an upward gradient indicates potential seepage of ground water to the river (gaining river reach); a downward gradient indicates potential seepage of river water to ground water (losing river reach); no gradient indicates no movement of water across the riverbed (Winter and others, 1983). Because the piezometers completed in the sandy riverbed of the Portneuf River easily yielded water, there is a good hydraulic connection between the river and the underlying aquifer, and an upward or downward hydraulic head gradient will readily force water through the riverbed.

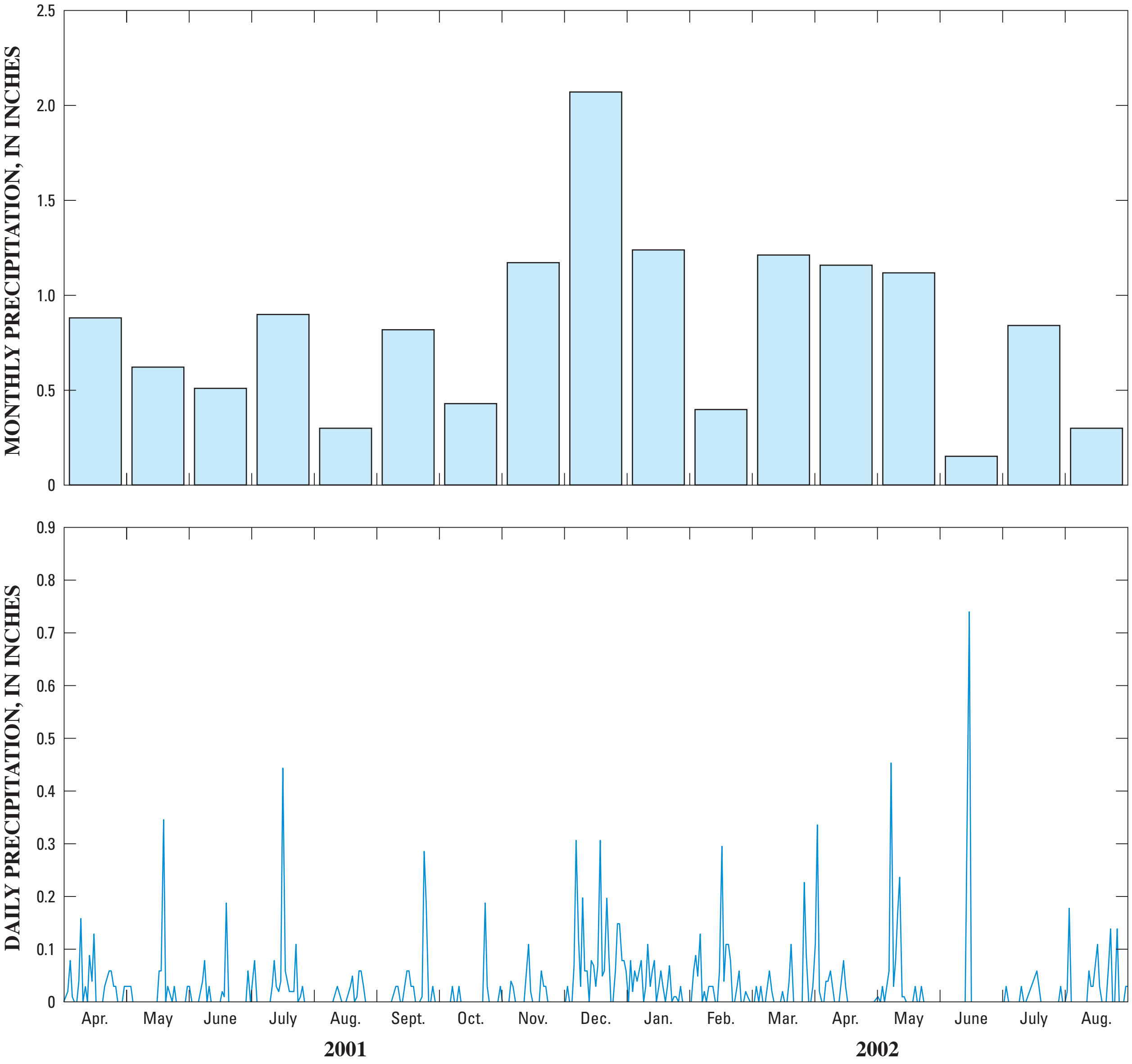


Figure 9. Daily and monthly precipitation at Pocatello regional airport, Idaho, 2001–02. (Data from National Oceanic and Atmospheric Administration, National Climatic Data Center, 1993)

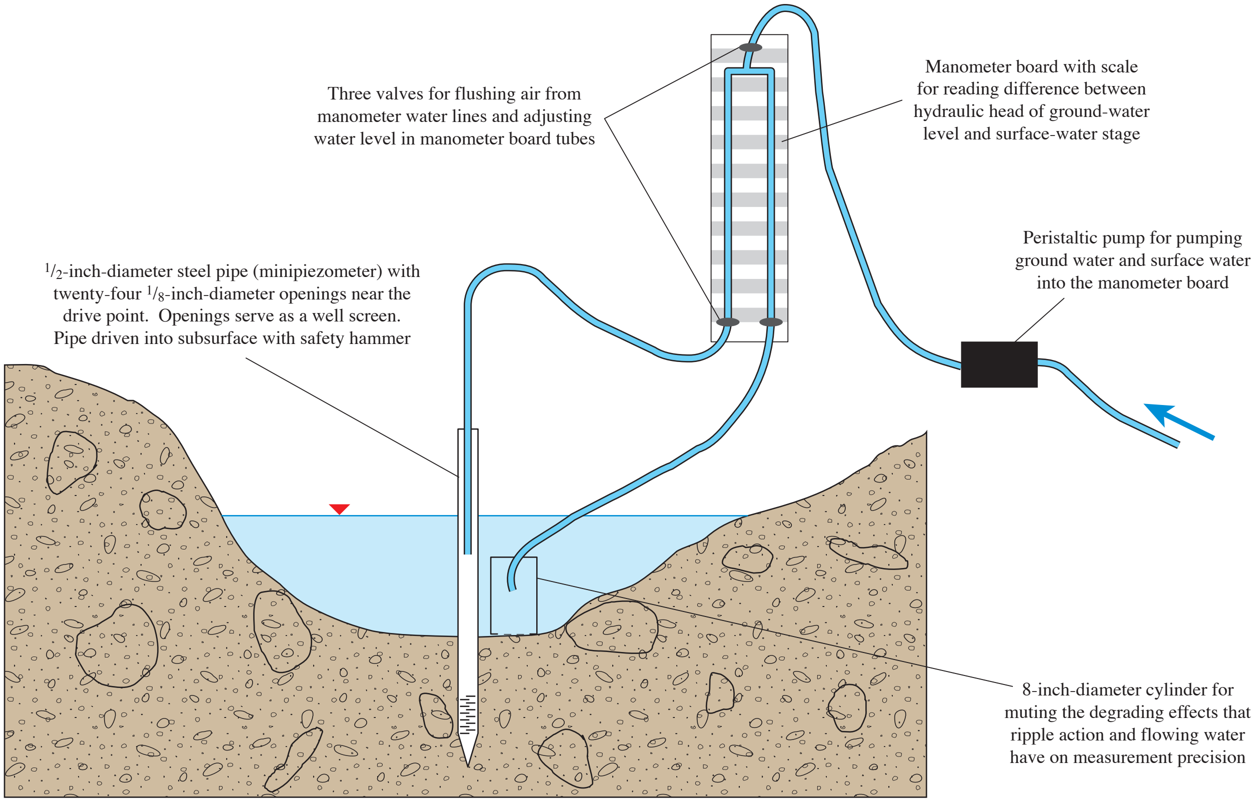


Figure 10. Schematic of instream piezometer and manometer board.

Measuring Water Quality

During July 10–12, 2001, pH, dissolved oxygen, specific conductance, and temperature of surface and ground water were measured onsite using a Hydrolab Minisonde 4-A multiparameter probe. For ground-water measurements, piezometers were purged until water-quality properties were stable prior to recording a measurement. For surface-water measurements, the Hydrolab Minisonde was dipped into the river to mid-depth and measurements were made in a flow-through chamber attached to the Minisonde. To ensure accurate measurements, the Minisonde was calibrated at the beginning of each day. Probes were submerged in a standard solution prior to all measurements, and the meters were recalibrated on an as-needed basis.

Using Heat as a Tracer to Monitor Surface- and Ground-Water Relations

Concepts

Temperature gradients between a stream and adjacent ground water are controlled by the movement of water through the riverbed. Heat flows continuously between surface water and adjacent ground water and, hence, can be used as a tracer of water movement between the surface and subsurface. The use of heat as a tracer relies on the measurement of temperature fluctuations in the surface water and within the upper several feet of the riverbed sediments. Heat is transferred down into and up through the riverbed as a result of several mechanisms. Heat conduction occurs as solar radiation is absorbed by the riverbed surface and surface water. This is the dominant mechanism for heating a dry riverbed but is only a small component of heat transfer to the riverbed beneath a flowing stream. Conductive heat transfer occurs by the diffusive molecular transfer of heat by direct contact between two materials of dissimilar temperatures. Convective heat transfer occurs by the movement of water as it flows over riverbed sediments of dissimilar temperature. Similarly, advective heat transport occurs as water infiltrates in a downward or upward direction through the riverbed sediments. More detailed descriptions of these processes are given in a report by Constantz and Stonestrom (2003).

The idealized hydraulic and thermal responses within a cross section of a gaining stream and a losing stream are shown in figure 11. The thermal response depicts conditions during the summer and early fall when the surface water is relatively warmer than ground water.

Table 1. Description of measurement stations and construction information for instream piezometers at measurement stations on the Portneuf River, Idaho

[Locations shown in figures 2 and 3; S, streamflow measured; P, instream piezometer installed; T, second instream piezometer equipped with thermistors installed; —, not applicable]

Measurement station local identifier	USGS Ground Water Site Inventory data base		USGS Surface Water Data System		Latitude	Longitude	Depth below river, in feet		Diameter, in inches
	Site identifier	Station name	Site identifier	Station name			Top of open interval	Bottom of open interval	
1S	—	Portneuf River #8 in relic channel	13071010	Downey Canal Portneuf River #8 in relic channel					
1SP[1]	425209111555901	Portneuf River Piezo D-LB	13070505	Downey Canal Portneuf River #7 at site D	42°52’08.9”	111°55’58.5”	5.5	6.0	0.5
2SPT	425205111560101	Portneuf River Piezo G-LB	13070505	Downey Canal Portneuf River #7 at site G	42°52’04.8”	111°56’01.1”	4.4	4.9	0.5
2SPT[2]	425205111560102	Portneuf River Piezo GT-LB			42°52’04.8”	111°56’01.1”	4.0	4.5	1.5
3SPT	425109111560101	Portneuf River Piezo E-LB	13071600	Portneuf River #6 at site E	42°51’09.2”	111°56’00.5”	5.5	6.0	0.5
3SPT[2]	425108111555901	Portneuf River Piezo ET-LB			42°51’08.2”	111°52’59.0”	4.0	4.5	1.5
4P	425016111560301	Portneuf River Piezo H-LB			42°50’15.9”	111°56’03.2”	5.9	6.4	0.5
5SP	424921111560201	Portneuf River Piezo C-LB	13071700	Portneuf River #5 at site C	42°49’21.4”	111°56’02.3”	5.9	6.4	0.5
6SPT	424809111565501	Portneuf River Piezo B-LB	13071800	Portneuf River #4 at site B	42°48’09.0”	111°56’54.7”	7.1	7.7	0.5
6SPT[2,3]	424809111565401	Portneuf River Piezo BT-RB			42°48’09.4”	111°56’54.3”	3.7	4.2	1.5
7SPT	424714111584401	Portneuf River Piezo A-LB	13072000	Portneuf River #3 at site A	42°47’13.6”	111°58’44.2”	3.0	3.5	0.5
7SPT[2]	424715111584201	Portneuf River Piezo AT-RB			42°47’14.8”	111°58’42.3”	3.1	3.7	1.5
8SP	424623111592901	Portneuf River Piezo F-LB	13072040	Portneuf River #2 at site F	42°46’23.3”	111°59’28.6”	1.5	2.0	0.5
9S			13072400	Portneuf River #1 at Mike’s Place					
10S			13072550	Portneuf River at Symmons Road					
11S			13072600	Portneuf River above Lava Hot Springs					
12S			13072810	Portneuf River below Lava Hot Springs					
13S			13073000	Portneuf River at Topaz					
14S			13072500	Pebble Creek near Pebble					
15S			13072790	Fish Creek above Lava Hot Springs					

[1] Instream piezometer located near the left bank of the Portneuf River when facing downstream.

[2] Thermistors suspended inside piezometer at depths of 20 and 40 inches below riverbed. A thermistor also strapped to outside of piezometer near the river bottom.

[3] Instream piezometer located near the right bank of the Portneuf River when facing downstream.

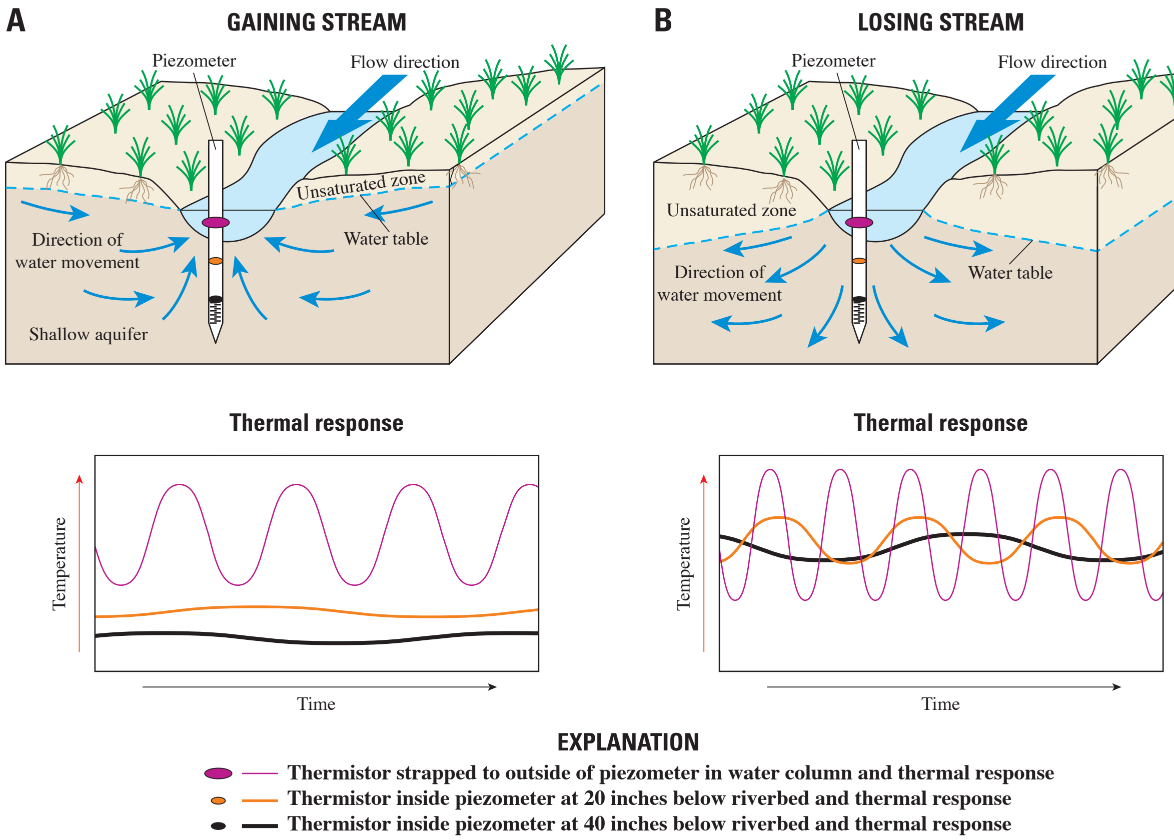


Figure 11. Surface- and ground-water relations and thermal response during summer and early fall in streams with (A) gaining reaches and (B) losing reaches. (Modified from Winter and others, 1998, figs. 8 and 9)

In a gaining stream reach, the hydraulic gradient of water through the riverbed is upward as indicated by the flow lines in the riverbed on figure 11A. The thermal response graph shows a large diurnal variation in stream water temperature but only a slight diurnal variation in riverbed temperature resulting from the continuous inflow of ground water to the stream. Ground water is generally of constant temperature throughout the day. Furthermore, ground water seeping into a stream can reduce temperature fluctuations in the river if the volume of seepage is sufficient. During the summer and early fall, surface water is relatively warmer than ground water. Hence, the temperature of the riverbed in a gaining reach is a reflection of advective heat transport as ground water moves up through the riverbed and discharges into the stream. Under these conditions, the riverbed temperature will be lower than that of surface water.

In a losing stream reach, the hydraulic gradient of water through the riverbed is downward, as indicated by the flow lines in figure 11B. Thus, the downward flow transports heat from the stream into the riverbed. The combined convective and advective heat transport causes diurnal fluctuations in the riverbed temperature. Furthermore, since ground water is not flowing into the stream, stream temperature variations in losing streams are generally larger than those in gaining streams (Constantz and Stonestrom, 2003). The magnitude of diurnal temperature fluctuations in the shallow sediments of the riverbed is affected by the rate of downward flow, the thermal conductivity of the sediment, and other factors.

Instrumentation

At measurement stations 2SPT, 3SPT, 6SPT, and 7SPT (table 1), an array of three thermistors was used to monitor the temperature of the stream and riverbed. At these stations, a 1.25-in.-diameter steel piezometer was hand driven and developed by using a surge block and pumping with a peristaltic pump. Onset Optic StowAway thermistors were suspended on a nylon line at 20 and 40 in. below the riverbed inside the piezometer. An Onset StowAway Tidbit thermistor was strapped to the outside of the piezometer casing near the riverbed to monitor surface-water temperature. The data-recording interval was 30 or 60 minutes. The accuracy of Optic StowAway and StowAway Tidbit thermistors is ±0.8º and ±0.9ºF at 70ºF (±17.2º and ±17.3ºC at 21ºC), respectively. The temperature measurement ranges of the Optic StowAway and StowAway Tidbit thermistors are -4º to +122ºF (-15.6º to +50ºC) and -32º to +167ºF (-36º to +75ºC), respectively.

Measuring Streamflow

Streamflow was measured at seven measurement stations in the Portneuf River Valley reach during a single day, referred to as a seepage run. In addition, streamflow was measured at seven measurement stations in the Pebble-Topaz reach (table 2) during a single day. Seepage runs were used to delineate gaining or losing river reaches and indicate areas of streamflow depletion. Streamflow was measured using Price-AA current meters. All measurements were rated subjectively for accuracy on the basis of flow and cross-section conditions (within 2 percent, excellent; 5 percent, good; 8 percent, fair; greater than 8 percent, poor). The amount of nonmeasurable flow (for example, nonchannelized overland flow) was estimated visually. The variance in fluctuating streamflow within each study reach was monitored during repeat seepage runs over a 2-day period in July 2001.

Diversion of surface water for irrigation during seepage runs was monitored and reported by the District Watermaster of the Portneuf River Marsh Valley Canal (table 2). A headgate, located between measurement stations 2SPT and 3SPT on the Portneuf River, operated by a landowner, provided some level of control over streamflow and could have caused some variance in streamflow. No inflows, besides springs, were observed in the Portneuf River Valley reach.

Measuring Ground-Water Levels

To determine the temporal changes in ground-water levels in the Portneuf Valley since 1968, a monitoring well network was established for measuring ground-water levels. For this study, all wells in the area with previous water-level data were inventoried and water levels were measured.

The Portneuf Valley ground-water-level monitoring network consisted of 33 wells; 5 were unused observation wells and 28 were irrigation wells (fig. 2). These wells were also part of the monitoring network used in the previous USGS study (Norvitch and Larson, 1970). The network included wells located near the Portneuf River and in areas of large ground-water withdrawals. Well depths ranged from 31.9 to 367 ft below land surface, and the median well depth was 131 ft below land surface. Each well's top of open interval ranged from 0 to 90 ft below land surface, and the bottom of the open interval ranged from 34 to 272 ft below land surface. Eight wells lacked this construction information. Water levels were measured several times between July 2001 and July 2002. Hydrographs showing water-level measurements are provided in appendix 1 (back of report).

Quality Assurance

Good quality-assurance practices help to maintain the accuracy and precision of measurements, ensure that field

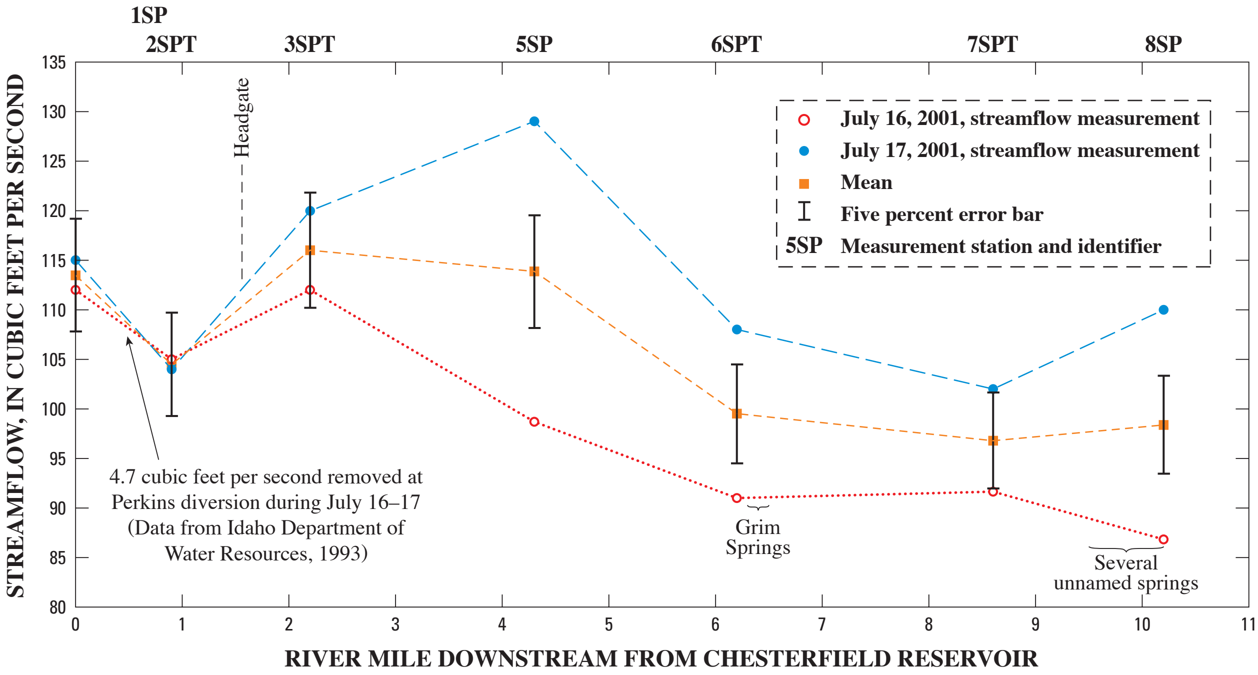


Figure 12. Variability in streamflow at measurement stations in the Portneuf River Valley reach, Idaho, July 16–17, 2001. (Headgate is privately operated and provides some level of control over streamflow, resulting in variability between consecutive seepage runs)

Table 2. Streamflow, surface-water diversions, and calculated gains and losses in streamflow between measurement stations on the Portneuf River, Idaho, 2001–02

[Station locations shown in figures 2 and 3; station descriptions shown in table 1; ft^3/s, cubic feet per second; —, no data]

Measurement stations, diversions[1], and tributaries	River miles downstream from Chesterfield Dam	7/16-17/2001[2] Irrigating fields, mid-summer regulated high flows				8/13/2001 Irrigating fields, late-summer base flows				9/17-18/2001 Irrigating fields, early-fall regulated base flows[3]				10/17-18/2001 No irrigation, mid-fall regulated flows3				5/29-30/2002 Irrigating fields, spring regulated high flows[3]			
			Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage		
		Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss4, in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss4, in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss4, in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss4, in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss4, in ft^3/s
Chesterfield Dam[5]	0	115	—	—	—	5	—	—	—	0	—	—	—	0	—	—	—	99	—	—	—
Perkins diversion[6]		4.7	—	—	—	3	—	—	—	0	—	—	—	0	—	—	—	4.3	—	—	—
1S (relic river below dam)	0.6	—	—	—	—	4	—	—	—	1.0	—	—	—	—	—	—	—	—	—	—	—
2SPT[5]	0.9	105	dam	2SPT	-5.8	4	1SP	2SPT	2	1.0	dam	2SPT	0	0.8	dam	2SPT	—	92.7	dam	2SPT	-2.0
Perkins-Crandall diversion	2.1	0	—	—	—	0	—	—	—	0	—	—	—	0	—	—	—	7.5	—	—	—
3SPT	2.2	116	2SPT	3SPT	11.5	3	2SPT	3SPT	-1	0	—	—	—	0.9	2SPT	3SPT	0.1	93	2SPT	3SPT	7.8
Crandall diversion	2.5	0	—	—	—	0	—	—	—	0	—	—	—	0	—	—	—	0	—	—	—
5SP	4.3	114	3SPT	5SP	-2.1	1.5	3SPT	5SP	-1.5	0.8	2SPT	5SPT	-0.2	1.7	3SPT	5SP	0.8	99.5	3SPT	5SP	6.5
Carl Phillips diversion	5.2	0	—	—	—	0	—	—	—	0	—	—	—	0	—	—	—	1.5	—	—	—
6SPT	6.2	99.9	5SP	6SPT	-14.8	2.0	5SP	6SPT	0.5	—	—	—	—	0.9	5SP	6SPT	-0.8	93.7	5SP	6SPT	-4.3
7SPT	8.6	96.8	6SPT	7SPT	-3.1	2.5	6SPT	7SPT	0.46	0.6	5SPT	7SPT	-0.2	3.2	6SPT	7SPT	2.3	106	6SPT	7SPT	12.3
8SP	10.2	98.4	7SPT	8SP	1.6	2.9	7SPT	8SP	0.42	1.3	7SPT	8SP	0.7	5.7	7SPT	8SP	2.5	116	7SPT	8SP	10.0
9S	12.2	—	—	—	—	—	—	—	—	48.1	8SP	9S	46.8	44.7	8SP	9S	39.0	157	8SP	9S	41.0
Pebble Creek	13	—	—	—	—	—	—	—	—	5.6	—	—	—	5.5	—	—	—	88.6	—	—	—
Dempsey-Topaz Ditch	17	—	—	—	—	—	—	—	—	0	—	—	—	0	—	—	—	25.4	—	—	—
10S	19.0	—	—	—	—	—	—	—	—	72.8	9S	10S	19.1	65.0	9S	10S	14.8	315	9S	10S	94.8
Shane Irick Ditch	19.3	—	—	—	—	—	—	—	—	0	—	—	—	0	—	—	—	0.9	—	—	—
Indian Falls diversion	20.7	—	—	—	—	—	—	—	—	0	—	—	—	0	—	—	—	0.8	—	—	—
Christiansen Ditch	21	—	—	—	—	—	—	—	—	0	—	—	—	0	—	—	—	1.2	—	—	—
Lava Irrigation Ditch	21.2	—	—	—	—	—	—	—	—	0	—	—	—	0	—	—	—	13.9	—	—	—

Table 2. Streamflow, surface-water diversions, and calculated gains and losses in streamflow between measurement stations on the Portneuf River, Idaho, 2001–02—Continued

[Station locations shown in figures 2 and 3; station descriptions shown in table 1; ft^3/s, cubic feet per second; —, no data]

Measurement stations, diversions[1], and tributaries	River miles downstream from Chesterfield Dam	7/16–17/2001[2] Irrigating fields, mid-summer regulated high flows				8/13/2001 Irrigating fields, late-summer base flows				9/17–18/2001 Irrigating fields, early-fall regulated base flows[3]				10/17–18/2001 No irrigation, mid-fall regulated flows[3]				5/29–30/2002 Irrigating fields, spring regulated high flows[3]			
			Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage				Reach quantified for gains and losses resulting from seepage		
		Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss[4], in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss[4], in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss[4], in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss[4], in ft^3/s	Streamflow, in ft^3/s	Upstream station	Downstream station	Gain or loss[4], in ft^3/s
Fish Creek	24.1	—	—	—	—	—	—	—	—	0.14	—	—	—	1.0	—	—	—	2.5	—	—	—
11S	24.2	—	—	—	—	—	—	—	—	16.2	10S	11S	-56.7	45.7	10S	11S	-20.3	19	10S	11S	-282.6
12S	27.0	—	—	—	—	—	—	—	—	52.3	11S	12S	36.1	58.4	11S	12S	12.7	226	11S	12S	207.0
13S	30.2	—	—	—	—	—	—	—	—	72.1	12S	13S	19.8	62.4	12S	13S	4.0	245	12S	13S	19.0
Streamflow depletion in the Portneuf River Valley reach resulting from surface water seeping down through the riverbed, excluding reach between dam and station 2SPT, in ft^3/s					-19.2				-2.5				-0.4				-0.8				-4.3
Streamflow depletion in the Pebble-Topaz reach resulting from surface water seeping down through the riverbed, in ft^3/s[7]					—				—				—				—				—

[1] Approximate river miles downstream from Chesterfield Dam.

[2] Mean streamflow for July 16-17, 2001.

[3] Streamflow measurements on September 18, 2001, October 17, 2001, and May 30, 2002, conducted in the Pebble-Topaz reach. Streamflow measurements on September 17, 2001, October 18, 2001, and May 29, 2002, conducted in the Portneuf River Valley reach.

[4] Gains and losses in streamflow between measurement stations resulting from water seeping through the riverbed, calculated as streamflow minus tributary inflow plus surface-water diversions.

[5] Idaho Department of Water Resources reported flow from Chesterfield Reservoir to be 115 and 112 ft^3/s during July 16–17, 2001, respectively. These measurements may be biased high because the reach between the dam and station 2SPT appeared to be losing 5.8 ft^3/s, adjusted for diversions, on July 16, 2001. During May 29–30, 2002, flow from the dam may be biased high, resulting in a calculated loss of 2.0 ft^3/s. All other field data collected indicate this is a gaining reach; for example, manometer measurements at instream piezometers at stations 1SP and 2SPT showed that ground-water levels were higher than the surface-water stages. The loss in streamflow cannot be explained with the existing data.

[6] Streamflow measurementmade by the U.S. Geological Survey; the Idaho Department of Water Resources reported a flow of 3.5 ft^3/s on July 16, 2001.

[7] Streamflow depletion could not be computed between measurement stations 10S and 12S because flow data for the hydroelectric project located within this reach were not provided to the U.S. Geological Survey.

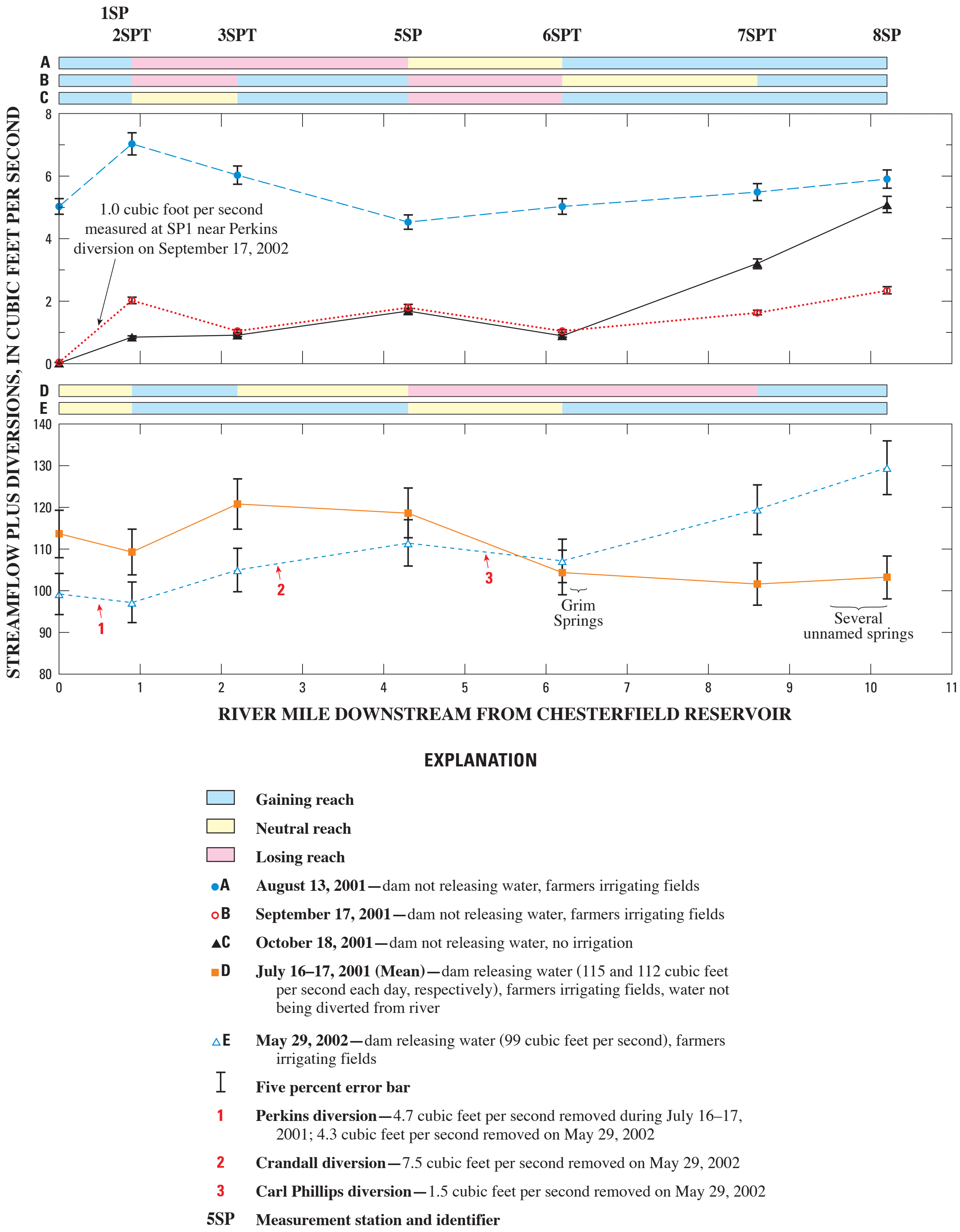


Figure 13. Streamflow adjusted for diversions at measurement stations and location of gaining and losing reaches in the Portneuf River Valley reach, Idaho, 2001–02. (Diversion data from Idaho Department of Water Resources, 1993)

measurements reflect actual conditions being monitored, and provide reliable data for many uses. During seepage runs, the streamflow measurements, computation of streamflow, and quality-assurance procedures followed standardized USGS methods described by Rantz and others (1982). Manometer operation and quality-assurance procedures followed methods described by Barton (2002). Ground-water-level measurements and quality-assurance procedures followed standardized methods outlined in the USGS Idaho District's Ground Water Quality Assurance Plan.

The principal source of error in characterizing and delineating gaining and losing river reaches during regulated high-flow conditions is associated with the variability in streamflow and diversions during seepage runs. The variability in streamflow at measurement stations was documented during consecutive seepage runs during July 16–17, 2001 (fig. 12). Releases from Chesterfield Reservoir during consecutive seepage runs were constant as measured at station 2SPT, less than 1 mi downstream from the reservoir. However, streamflow during consecutive seepage runs at measurement station 5SP increased from 98.7 ft^3/s on July 16 to 129 ft^3/s on July 17. This variability is in excess of measurement error and is the result of changes at a headgate located between measurement stations 2SPT and 3SPT on the Portneuf River, which provides some level of control over streamflow.

Seasonality of Surface- and Ground-Water Relations on the Portneuf River

During the 10-month-long seepage studies on the Portneuf River, surface- and ground-water relations were dynamic. Significant elements of surface- and ground-water relations in the Portneuf River are a losing reach in the middle of the Portneuf River Valley reach and a gaining reach in the southern part of the valley extending downstream to station 10S. Results of the seepage studies from a seasonal perspective, beginning with spring and ending with mid-fall, are presented in the following paragraphs.

Gaining and losing river reaches in the Portneuf River Valley reach were delineated using analyses of streamflow measurements (fig. 13) and manometer measurements of hydraulic heads at instream piezometers (fig. 14). These delineations showed spatial variability between analyses based on streamflow measurements and analyses based on manometer measurements. Some of the variability is caused by the scale of investigation; a seepage run measurement integrates the suface- and ground-water relations between measurement stations, whereas a manometer measurement represents the surface- and ground-water relations at a specific location in the river. The ±5-percent error rating for streamflow measurements made during the seepage studies is a source of uncertainty in the analysis of surface- and ground-water relations. Because of the spatial variability inherent in the two field methods, and because of the ±5-percent error, delineation of gaining and losing reaches in the Portneuf River Valley reach was based on an integrated analysis (hereafter referred to as integrated measurements) of streamflow, hydraulic head, specific conductance, and temperature (fig. 15).

Spring Regulated High Flows at the Start of the Irrigation Season

A seepage run was conducted in the Portneuf River Valley reach (fig. 2) on May 29, 2002, during regulated high flows at the start of the irrigation season. Streamflow ranged from 92.7 to 116 ft^3/s at seven measurement stations (table 2). During the spring high flows in the Portneuf River, a large percentage of flow in the river is water released from storage in the Chesterfield Reservoir (fig. 13). The Chesterfield Reservoir was releasing about 99 ft^3/s at the time of this seepage study (Steve Hebdon, Watermaster for the Portneuf River Marsh Valley Canal, oral commun., 2002). A 6.3-ft^3/s loss in streamflow was measured between the dam and measurement station 2SPT; 4.3 ft^3/s of this loss is attributed to surface-water diversion, and the remaining 2.0 ft^3/s of loss may be attributed to measurement error. Manometer measurements at stations 1SP and 2SPT showed that the hydraulic head of ground water was greater than surface-water stage, which indicates that ground water was seeping up through the riverbed.

Integrated measurements of streamflow and hydraulic head in the Portneuf River Valley reach showed (1) a 4.9-mi-long gaining reach that extended from the dam to about 0.8 mi downstream from measurement station 6SPT; (2) a 2.6-mi-long losing reach in the middle of the valley (fig. 15), the center of which was near station 6SPT; and (3) a 2.8-mi-long gaining reach in the southern part of the valley. Manometer measurements at station 6SPT showed that the hydraulic head of ground water beneath the streambed was 105 mm (4 in.) below the surface-water stage (fig. 14), indicating that surface water was seeping down through the riverbed. Manometer measurements at all other stations showed that the hydraulic head of ground water beneath the streambed was greater than the surface-water stage, indicating that ground water was seeping up through the riverbed. Between stations 6SPT and 7SPT and between 7SPT and 8SP, ground water was seeping into the Portneuf River at about 12 and 10 ft^3/s, respectively. Portneuf River streamflow not originating from the Chesterfield Reservoir is principally from springs and ground water seeping into the river between stations 6SPT and 8SP.

A seepage run was conducted in the Pebble-Topaz reach (fig. 3) on May 30, 2002. Streamflow in the Portneuf River ranged from 19 to 315 ft^3/s at six measurement stations (fig. 16), and the total diversion of streamflow was 42.2 ft^3/s. Tributary inflows from Pebble and Fish Creeks were about 89 and 2.5 ft^3/s, respectively. A 136-ft^3/s gain in streamflow along the 8.8-mi reach between stations 8SP and 10S is attributed to ground water seeping up through the riverbed. A 283-ft^3/s loss in streamflow along the 5.2-mi reach between stations 10S and 11S (table 2) may be the result of a hydro-

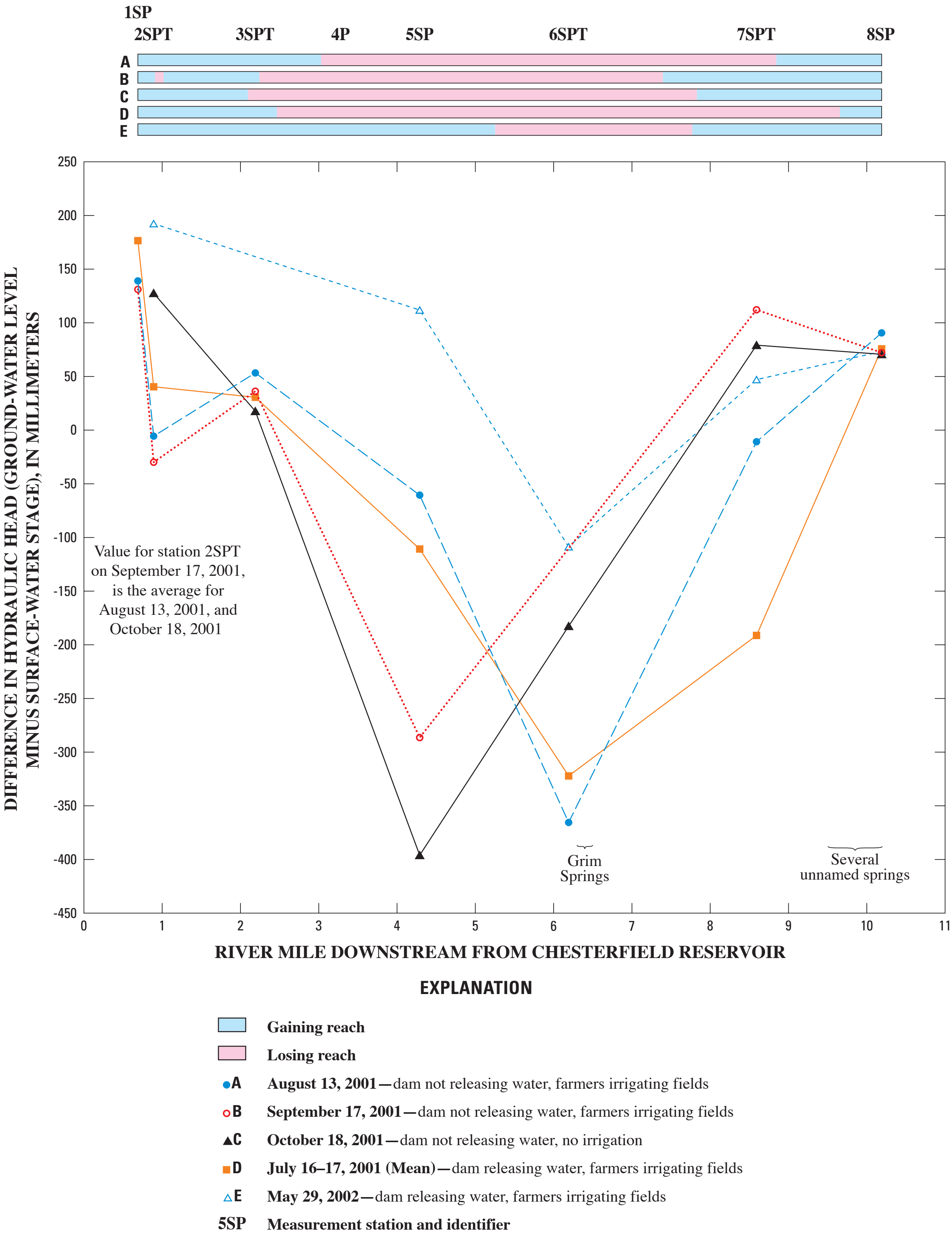
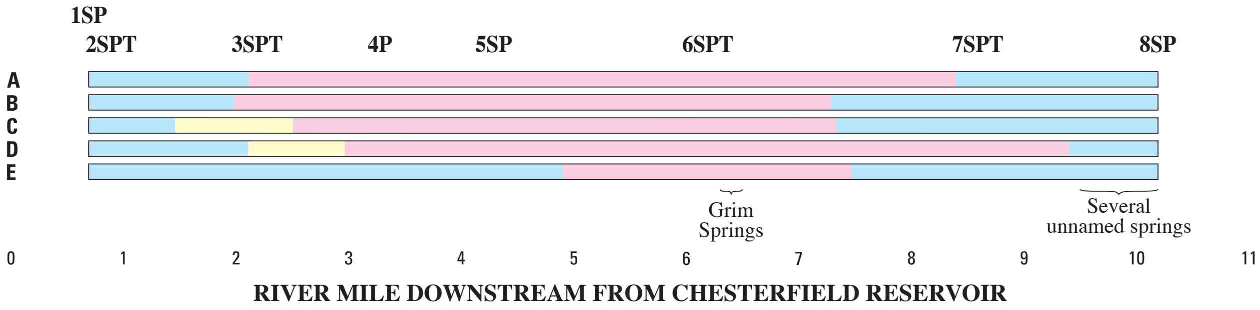


Figure 14. Differences in hydraulic head between river stages and ground-water levels at measurement stations and location of potential gaining and losing reaches in the Portneuf River Valley reach, Idaho, 2001–02.



EXPLANATION

🟦	**Gaining reach**
🟨	**Neutral reach**
🟥	**Losing reach**
A	**August 13, 2001—**dam not releasing water, farmers irrigating fields
B	**September 17, 2001—**dam not releasing water, farmers irrigating fields
C	**October 18, 2001—**dam not releasing water, no irrigation
D	**July 16–17, 2001 (Mean)—**dam releasing water, farmers irrigating fields
E	**May 29, 2002—**dam releasing water, farmers irrigating fields
5SP	**Measurement station and identifier**

Figure 15. Location of gaining, neutral, and losing reaches in the Portneuf River Valley reach, Idaho, based on integrated analysis of streamflow, hydraulic head, specific conductance, and temperature, 2001–02.

electric project located between these stations that stores water behind a cement impoundment structure. A 207-ft^3/s gain in streamflow was measured along the 2.8-mi reach between stations 11S and 12S. This gain may be a result of the hydroelectric project returning water to the river between those stations during power generation. Flow data for this hydroelectric project during the seepage run was not available to the USGS; therefore, any withdrawal or release of water by this hydroelectric project could not be quantified. Because of this data gap, the surface- and ground-water relations between stations 10S and 12S could not be quantified. A 19-ft^3/s gain in streamflow was measured along the 3.2-mi reach between stations 12S and 13S. Up to 2 ft^3/s of this gain may be attributable to unmeasured tributary inflow; the remainder is attributed to ground water seeping up through the riverbed.

Mid-Summer Regulated High Flows During the Irrigation Season

Seepage runs were conducted in the Portneuf River Valley reach (fig. 2) during July 16–17, 2001, during regulated high flows in the middle of the irrigation season. The Chesterfield Reservoir was releasing about 115 and 112 ft^3/s on July 16 and 17, respectively (Tim Luke, Idaho Department of Water Resources, written commun., 2003). Streamflow ranged from 97 to 116 ft^3/s (2-day average) at seven measurement stations (fig. 12, table 2). During the summer high flows, a large percentage of flow in the river is water released from storage in the Chesterfield Reservoir. A 5.8-ft^3/s loss in streamflow was measured between the dam and station 2SPT; 4.7 ft^3/s of this loss is attributed to surface-water diversion, and the remaining 1.1 ft^3/s of loss cannot be explained. All other field data indicate that this is a gaining reach; for example, the manometer measurements at stations 1SP and 2SPT showed that the hydraulic head of ground water beneath the streambed was greater than the surface-water stage, indicating that ground water was seeping up through the riverbed (fig. 14).

The losing reach identified in the middle of the Portneuf River Valley reach near station 6SPT during the spring seepage study increased in length from 2.6 mi to nearly 6 mi during the mid-summer seepage study (fig. 15). Manometer measurements showed that the losing reach expanded to include stations 5SP and 7SPT. Manometer measurements at stations 5SP, 6SPT, and 7SPT showed that ground-water heads ranged from 110 to 320 mm (4 to 13 in.) below the surface-water stages (fig. 14), indicating that surface water is infiltrating down through the riverbed.

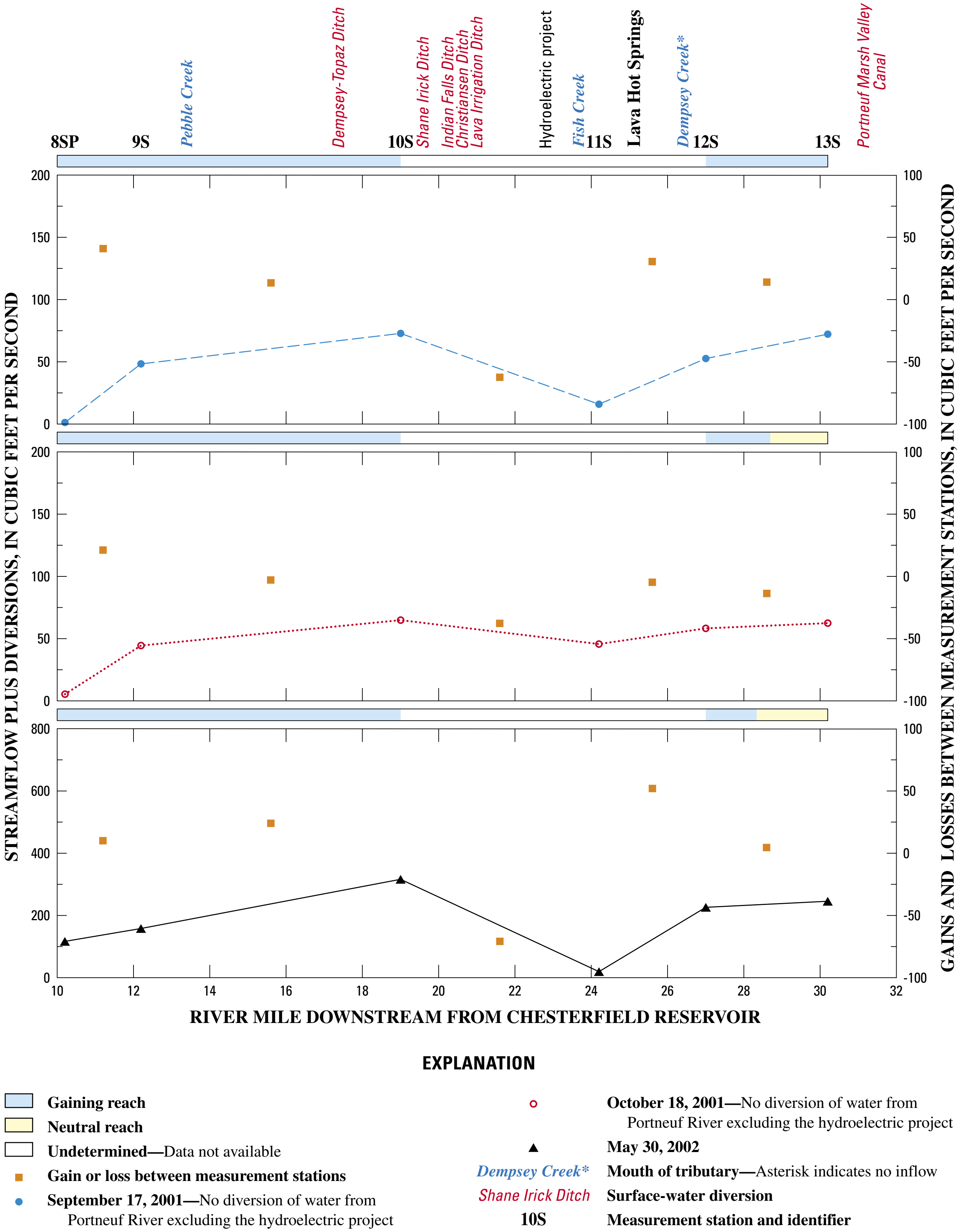


Figure 16. Streamflow and location of gaining and losing reaches in the Pebble-Topaz reach, Idaho, 2001–02.

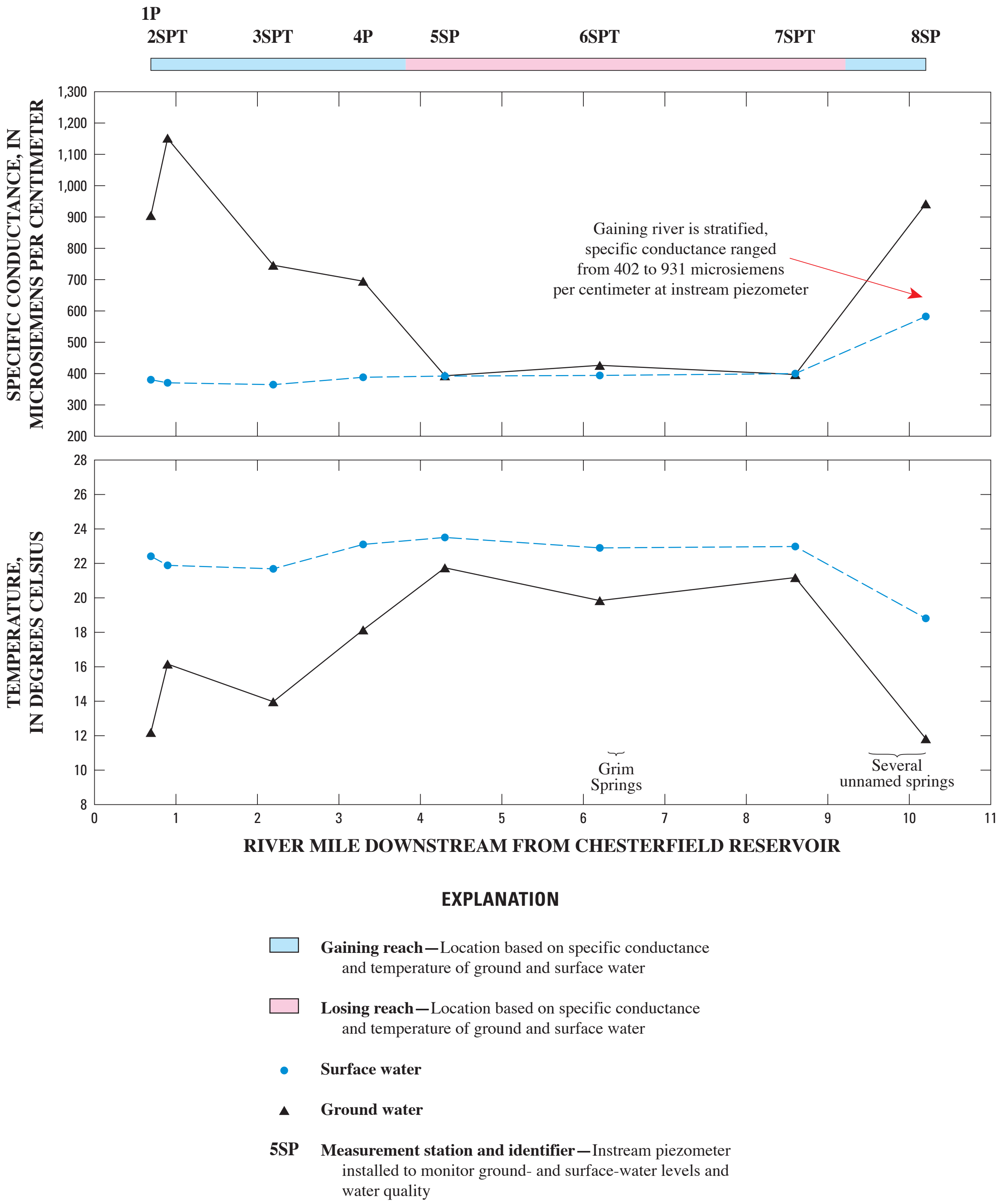


Figure 17. Specific conductance and temperature at measurement stations in the Portneuf River Valley reach, Idaho, July 10–12, 2001. (Mid-summer regulated high flows and farmers irrigating fields)

Surface- and Ground-Water Relations Based on Specific Conductance and Temperature

A perspective on surface- and ground-water relations in the Portneuf River Valley reach was obtained from an analysis of specific conductance and temperature measured at instream piezometers during July 10–12, 2001. Specific conductance and temperature data showed that ground water was seeping into the river just downstream from Chesterfield Reservoir at stations 1SP, 2SPT, 3SPT, and 4P, and at station 8SP where the valley narrows upstream from the Pebble-Topaz reach. Specific conductance was about twice that of the river water, and ground water was several degrees cooler than river water in the gaining reach between stations 1SP and 4P (fig. 17). More dilute and warmer surface water infiltrated the riverbed in the losing reach between stations 5SP and 7SPT. Infiltration of relatively dilute surface water through the riverbed lowered the specific conductance of the ground water so that surface- and ground-water specific conductance were nearly equivalent. Infiltration of the warm surface water through the riverbed also increased ground-water temperatures to the extent that surface- and ground-water temperatures were nearly equivalent.

Stratification of specific conductance and temperature across the Portneuf River at measurement station 8SP is also an indicator of ground water seeping into the river. On July 11, 2001, the water column of the Portneuf River was highly stratified from bank to bank (fig. 18). Instream water-quality measurements showed a ground-water signature near the left bank (facing downstream) and a surface-water signature between the river's mid-section and the right bank. The specific conductance and temperature profile across the river—left bank to right bank—ranged from 931 to 402 µS/cm and from 10.6° to 22.8°C, respectively (fig. 18). As a point of reference, at station 7SPT upstream from station 8SP, specific conductance of the surface water was 400 µS/cm. Sources of ground-water input at station 8SP are springs near the river's left bank and ground water seeping through the riverbed. Specific conductance at a spring about 1,000 ft upstream from station 7SPT was 1,000 µS/cm and temperature was 9.6°C. The gaining reach at station 8SP most likely extends less than 2,100 ft

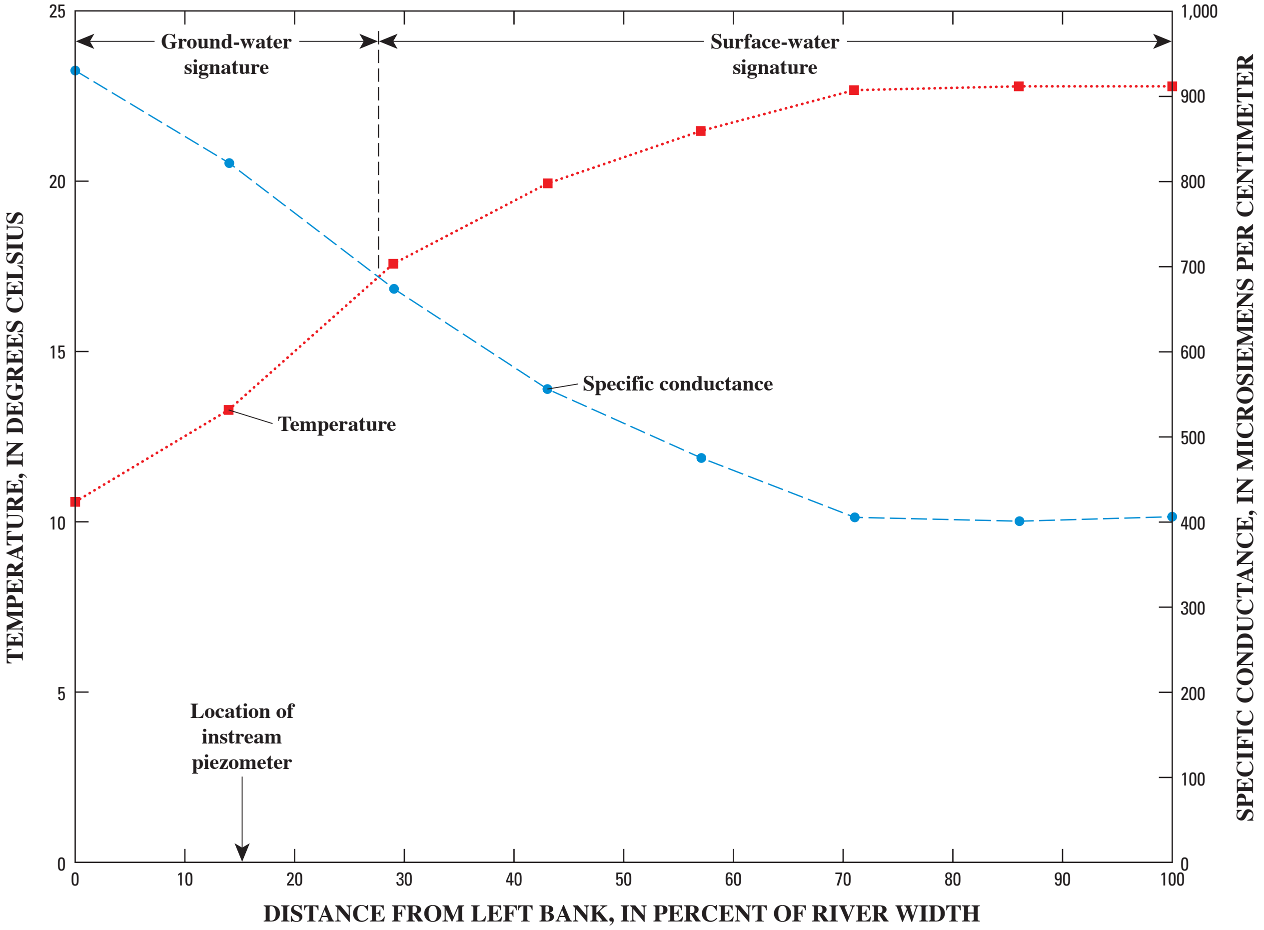


Figure 18. Specific conductance and temperature profiles across the Portneuf River, Idaho, at measurement station 8SP, July 11, 2001.

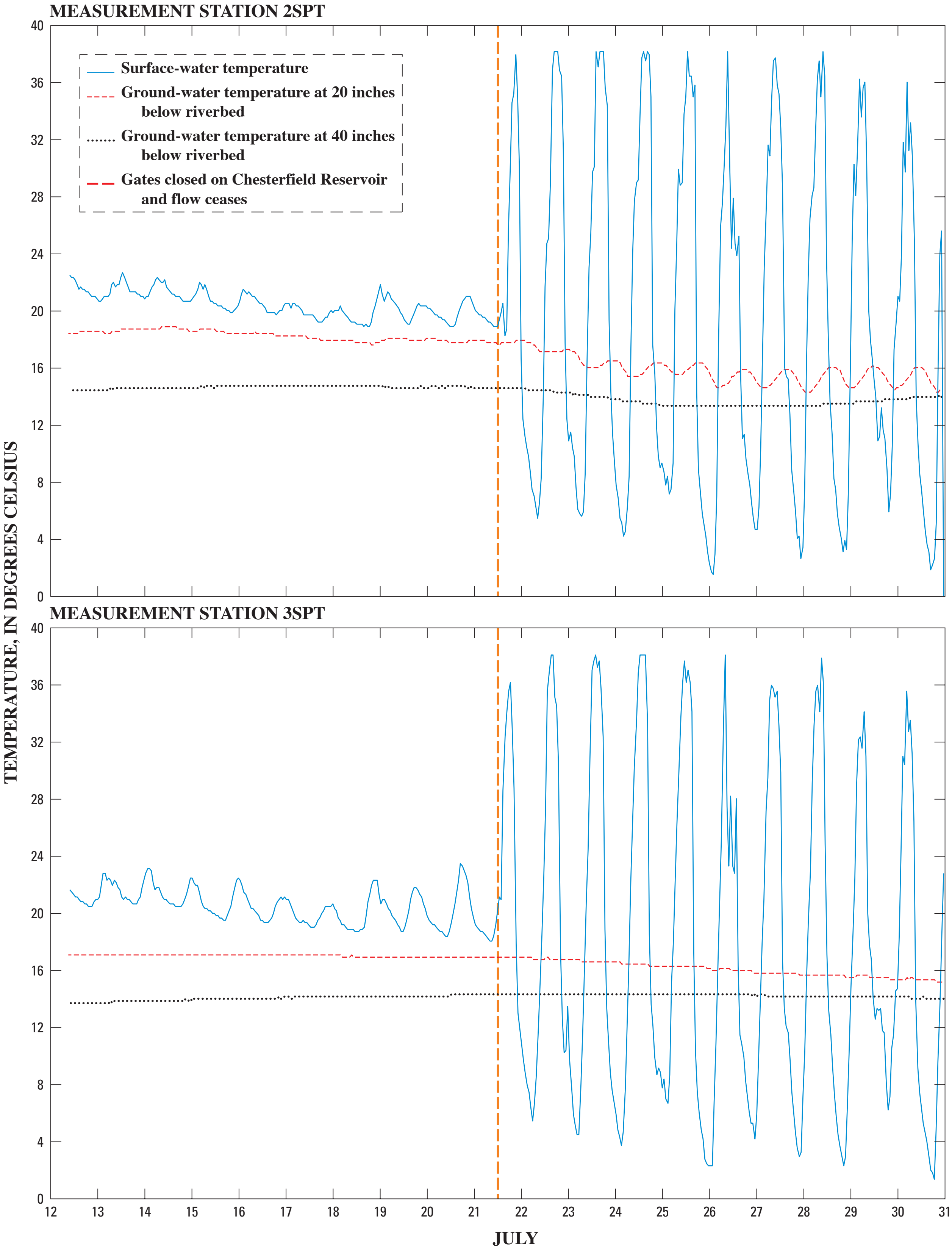


Figure 19. Continuous record of surface- and ground-water temperatures at measurement stations 2SPT and 3SPT showing cool ground water discharging to the Portneuf River, Idaho, July 2001.

upstream from the station, because there are no springs, which are an indication of a gaining reach, located more than 2,100 ft upstream from this station. A "dry" piezometer 2,100 ft upstream from station 8SP could not produce water because it encountered a very dense clay layer at 2 ft below the riverbed and was abandoned. The lateral extent of this nearly impermeable clay layer is not known but, where present, it would behave as a boundary to ground-water seepage through the riverbed.

Surface- and Ground-Water Relations Based on Continuous Temperature Data From Thermistor Arrays

During July 2001, continuous temperature data were collected by thermistor arrays at instream piezometers at stations 2SPT and 3SPT. Thermographs for stations 2SPT and 3SPT (fig. 19) showed that (1) the riverbed was 2° to 6°C cooler than the surface water, and (2) no diurnal ground-water temperature fluctuations mimicking the diurnal surface-water temperature fluctuations were discernible. Conditions (1) and (2) indicate this is a gaining river reach where cooler ground water is seeping up through the riverbed. After Chesterfield Reservoir ceased releasing water on July 22, 2001, the surface-water temperature at stations 2SPT and 3SPT increased dramatically because the thermistors were exposed.

Thermographs for stations 6SPT and 7SPT (fig. 20) showed that (1) the riverbed and surface water were nearly the same temperature, and (2) the shallowest thermistor at 20 in. below the riverbed recorded small diurnal fluctuations that mimicked the diurnal surface-water temperature fluctuations. The similarity between surface- and ground-water temperatures and diurnal fluctuations in the ground water is a result of surface water infiltrating the riverbed in this losing reach. After Chesterfield Reservoir ceased releasing water from storage on July 22, 2001, the surface-water temperature at station 6SPT increased dramatically because the thermistor was exposed. During the same period, diurnal fluctuations in surface-water temperatures at station 7SPT decreased. This decrease occurred because a small amount of ground water began seeping into the river, resulting in streamflow at station 7SPT, which kept the thermistor submerged in flowing water. The source of this ground-water seepage may have been Grim Springs, upstream from station 7SPT.

Late-Summer Base Flows During the Irrigation Season

A seepage run was conducted in the Portneuf River Valley reach (fig. 2) on August 13 during late-summer base flow in the irrigation season. The Chesterfield Reservoir was releasing about 5 ft^3/s on August 13, 2001 (Tim Luke, Idaho Department of Water Resources, written commun., 2003). At this time, the small amount of water in storage in the reservoir was not being released. The natural flow of water through the Chesterfield Reservoir provided flow to the Portneuf River (Steve Hebdon, Watermaster for the Portneuf River Marsh Valley Canal, oral commun., 2002). Flows in the Portneuf River during this seepage study (table 2) ranged from none to 4 ft^3/s. Ground-water seepage in the reach between the reservoir and station 2SPT contributed about 2 ft^3/s of flow. However, the streamflow measured farther downstream at station 5SP was less than 50 percent of that measured at the upstream station 2SPT. This streamflow loss indicates a losing river reach where surface water infiltrates down through the riverbed into the water-table aquifer because no surface water is diverted between these two stations. The losing reach in the middle of the Portneuf Valley near measurement station 6SPT is about 6 mi long and similar in length to that measured during the mid-summer seepage study (fig. 15). Streamflow increased by about 1.4 ft^3/s between stations 5SP and 8SP. Manometer measurements showed a losing reach between stations 4P and 7SPT (fig. 14). Manometer measurements at stations 5SP and 6SPT showed that the hydraulic heads of ground-water levels were 284 to 240 mm (11 to 9 in.) below the surface-water stages, respectively, indicating that surface water is seeping down through the riverbed.

Early-Fall Regulated Low Flows at the End of the Irrigation Season

A seepage run was conducted in the Portneuf River Valley reach (fig. 2) on September 17, 2001, during early-fall regulated low flows at the end of the irrigation season. No water was being released from the Chesterfield Reservoir to the Portneuf River. The lowest streamflows during this study were measured during the September seepage run. September streamflows at all stations (table 2) ranged from none to 1.3 ft^3/s. These minimum streamflows reflect conditions at the end of the irrigation season when climate and ground-water withdrawals can have the greatest impact on ground-water-level declines. These conditions are reflected strongly by manometer measurements (fig. 14) at station 5SP, where hydraulic heads declined substantially. The gaining reach upstream from station 8SP contributed about 0.7 ft^3/s of water, which corresponds to manometer measurements at stations 7SPT and 8SP, where hydraulic heads were rising.

A seepage run was conducted in the Pebble-Topaz reach (fig. 3) on September 18, 2001. Streamflow ranged from 1.3 to 72.8 ft^3/s at six stations (fig. 16, table 2), and no streamflow was being diverted. Tributary inflows from Pebble and Fish Creeks were 5.6 and 0.14 ft^3/s, respectively. A 65.9-ft^3/s gain in streamflow along the 8.8-mi reach between stations 8SP and 10S is attributed to ground water seeping up through the riverbed; about two-thirds of the gain occurred between stations 8S and 9S. Along the 5.2-mi reach between stations 10S and 11S, the Portneuf River lost about 57 ft^3/s of streamflow. This loss of streamflow may be the result of the hydroelectric project located between these stations. A 36-ft^3/s gain in streamflow

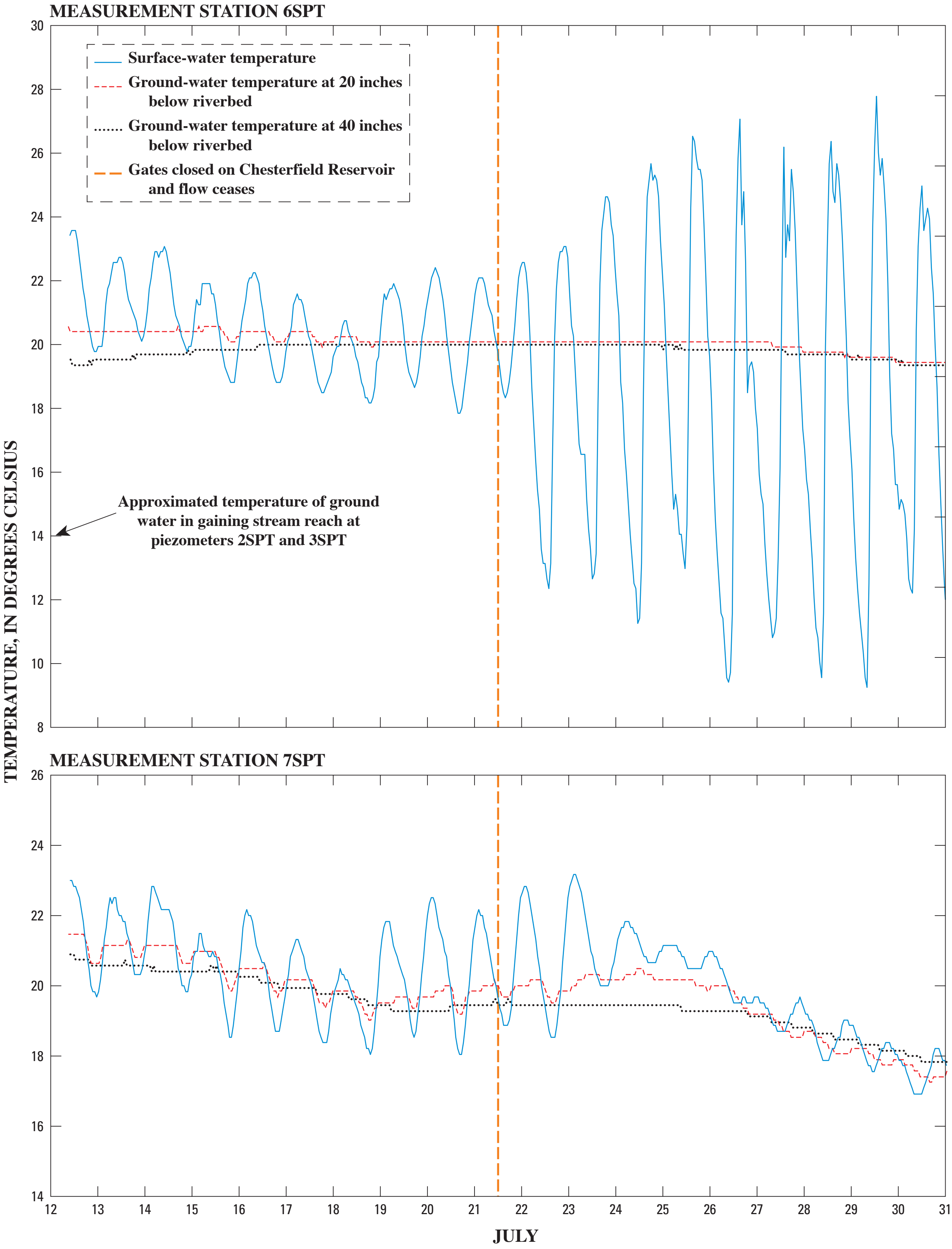


Figure 20. Continuous record of surface- and ground-water temperatures at measurement stations 6SPT and 7SPT showing warm stream water infiltrating down through the streambed in the Portneuf River, Idaho, July 2001.

was measured along the 2.8-mi reach between stations 11S and 12S. This gain may be a result of the hydroelectric project returning water to the river between those stations during power generation. Flow data for this hydroelectric project during the seepage run were not available to the USGS; therefore, any withdrawal or release of water by this hydroelectric project could not be quantified. Because of this data gap, the surface- and ground-water relations between stations 10S and 12S could not be quantified. A 20-ft^3/s gain in streamflow was measured along the 3.2-mi reach between stations 12S and 13S. About 1 ft^3/s of this gain may be attributable to unmeasured tributary inflow; the remainder is attributed to ground water seeping up through the riverbed.

Mid-Fall Regulated Low Flows During the Post-Irrigation Season

A seepage run was conducted in the Portneuf River Valley reach (fig. 2) on October 18, 2001, during regulated low flows after the irrigation season. No water was being released from the Chesterfield Reservoir. During the October seepage run, water was flowing at all measurement stations, in contrast to no-flow conditions observed at some measurement stations during the prior September seepage run (table 2). October flow decreased between stations 5SP and 6SPT, and manometer measurements at these stations showed that hydraulic heads of ground water were below the surface-water stages (fig. 14), indicating a losing reach about 5 mi in length (fig. 15). Between stations 6SPT and 8SP, streamflow increased about sixfold to 5 ft^3/s as a result of ground-water seepage up through the riverbed and spring discharge. Ground-water seepage measured during the early fall seepage run probably increased in response to the cessation of withdrawals by irrigation wells. During this period there was no measurable precipitation to cause such a response (fig. 9). Manometer measurements at station 7SPT showed that the hydraulic heads of ground water were greater than the surface-water stages (fig. 14), indicating gaining stream conditions in this area. Manometer measurements at station 6SPT showed that the hydraulic heads of ground-water levels were well below the surface-water stages, indicating losing stream conditions in this area. These manometer measurements indicate that the gaining reach may have extended about 0.7 mi upstream from station 7SPT.

During the seepage run in the Pebble-Topaz reach (fig. 3) on October 17, 2001, streamflow ranged from 46 to 65 ft^3/s at six stations (fig. 16, table 2), and no streamflow was being diverted. Tributary inflows from Pebble and Fish Creeks were 5.5 and 1.0 ft^3/s, respectively. The lowest streamflows in the Pebble-Topaz reach during this study were measured during the October seepage run. A 54-ft^3/s gain in streamflow along the 8.8-mi reach between stations 8SP and 10S is attributed to ground water seeping up through the riverbed; about two-thirds of the gain occurred between stations 8S and 9S. Along the 5.2-mi reach between stations 10S and 11S, the Portneuf River lost 20 ft^3/s of streamflow. This loss of streamflow may be the result of the hydroelectric project located between these stations. A 13-ft^3/s gain in streamflow was measured along the 2.8-mi reach between measurement stations 11S and 12S. This gain may be a result of the hydroelectric project returning water to the river between those stations during power generation. Flow data for this hydroelectric project during the seepage run were not available to the USGS; therefore, any withdrawal or release of water by this hydroelectric project could not be quantified. Because of this data gap, the surface- and ground-water relations between stations 10S and 12S could not be quantified. A 4-ft^3/s gain in streamflow was measured along the 3.2-mi reach between stations 12S and 13S. This gain is attributed to ground water seeping up through the riverbed.

Streamflow Depletion

Streamflow depletion in the Portneuf River is related to the seasonality of water regulation, climatic conditions, and water usage. The two primary elements of streamflow depletion are: (1) losses resulting from surface water seeping down into the riverbed, and (2) losses resulting from surface-water diversions.

The river is hydraulically connected to the water-table aquifer, which is replenished partially by spring snowmelt runoff. Water in the aquifer attains its maximum level in the spring prior to the irrigation season, then declines during the summer and fall when recharge to the aquifer is minimal and ground-water withdrawals are maximum. Declines in water levels in the aquifer can, over a period of time, cause gaining river reaches to become losing reaches as surface water seeps down into the riverbed. It is not known whether the Portneuf River Valley reach had a losing reach prior to development of the Portneuf Valley. However, ground-water withdrawals for irrigation, evapotranspiration, and drought conditions increase the rate of water-level declines in the aquifer. Withdrawals of ground water for irrigation lengthen losing reaches and intensify the magnitude of streamflow depletion in losing reaches. No data are available to determine whether the Pebble-Topaz reach had a losing reach prior to regulation of streamflow; however, given the magnitude of the measured losses between stations 10S and 11S, existence of a losing reach in the Pebble-Topaz reach is probable.

Seepage studies indicated that streamflow depletion from surface water seeping down through the riverbed in the losing reach of the Portneuf River Valley reach ranged from 4.3 to 20 ft^3/s during the period of regulated high flows (table 2). This calculation does not include surface water seeping down through the riverbed between Chesterfield Dam and station 2SPT. Measured streamflow at station 2SPT is less than flow at Chesterfield Dam minus the Perkins diversion. These measurements erroneously indicate that surface water is seeping down through the riverbed between the dam and station 2SPT; however, this indication of a losing reach is attributed to inaccurate flow data for the Perkins diversion and the Chesterfield Dam. Manometer measurements at stations 1SP and 2SPT actually identify this as a gaining reach during regulated high flows.

During the July 16–17, 2001, seepage study, there were no streamflow losses in the Portneuf River Valley reach associated with pumped surface-water diversions because irrigators participated in a power buyback program, except between Chesterfield Dam and measurement station 1SP. During the May 29, 2002, seepage study, a 13.3-ft^3/s streamflow loss from pumped surface-water diversions was measured between Chesterfield Dam and station 6SPT (Steve Luke, Idaho Department of Water Resources, written commun., 2002). The length of the losing river reach was nearly 3 times longer during July 16–17, 2001, in the middle of the irrigation season, than on May 29, 2002, early in the irrigation season (fig. 15). The seepage run on May 29, 2002, several days after the beginning of regulated high flows and the start of the irrigation season, showed that surface water was seeping through the riverbed in the losing reach between stations 6SPT and 7SPT at a rate of 4.3 ft^3/s (table 2). This loss is less than the ±5-percent accuracy for streamflow measurements; thus, the reach between 5SP and 6SPT is reported as a neutral reach (fig. 13). Integrated analysis of streamflow and manometer measurements at instream piezometers report a losing reach between 5SP and 6SPT (fig. 15.) The loss from surface water seeping through the riverbed was much larger at the end of the regulated high flows, about 19 ft^3/s during July 16–17, 2001, between stations 3SPT and 7SPT.

Manometer measurements at instream piezometers in the Portneuf River Valley reach indicate streamflow depletion. Manometer measurements at station 6SPT, near the center of the losing reach, showed a continually negative hydraulic head between the surface-water stages and ground-water levels during 2001–02. At this station, surface water infiltrating through the riverbed probably is common. Infiltration is dependent on the hydraulic head and on the riverbed hydraulic conductivity. Manometer measurements at station 6SPT showed that the hydraulic head was −100 mm (−4 in.) during May 2002 early in the irrigation season and −325 mm (−14.6 in.) during July 2001 later in the irrigation season. These hydraulic head declines show that ground-water levels were declining relative to the surface-water stage and that additional surface water was being induced to flow through the riverbed and into the aquifer. These ground-water-level declines and the resulting streamflow losses probably result from withdrawal of ground water by irrigation wells. These negative hydraulic heads could not be produced by increases in surface-water diversions.

Seepage studies indicated a possibility of large streamflow losses from surface water seeping through the riverbed in the Pebble-Topaz reach between stations 10S and 11S. The 283-ft^3/s loss in streamflow between these stations on May 29, 2002, may be a result of the hydroelectric project located between these stations. Flow data for this hydroelectric project during the seepage run was not available to the USGS; therefore, any withdrawal or release of water by this hydroelectric project could not be quantified. Because of this data gap, the surface- and ground-water relations between stations 10S and 11S could not be quantified.

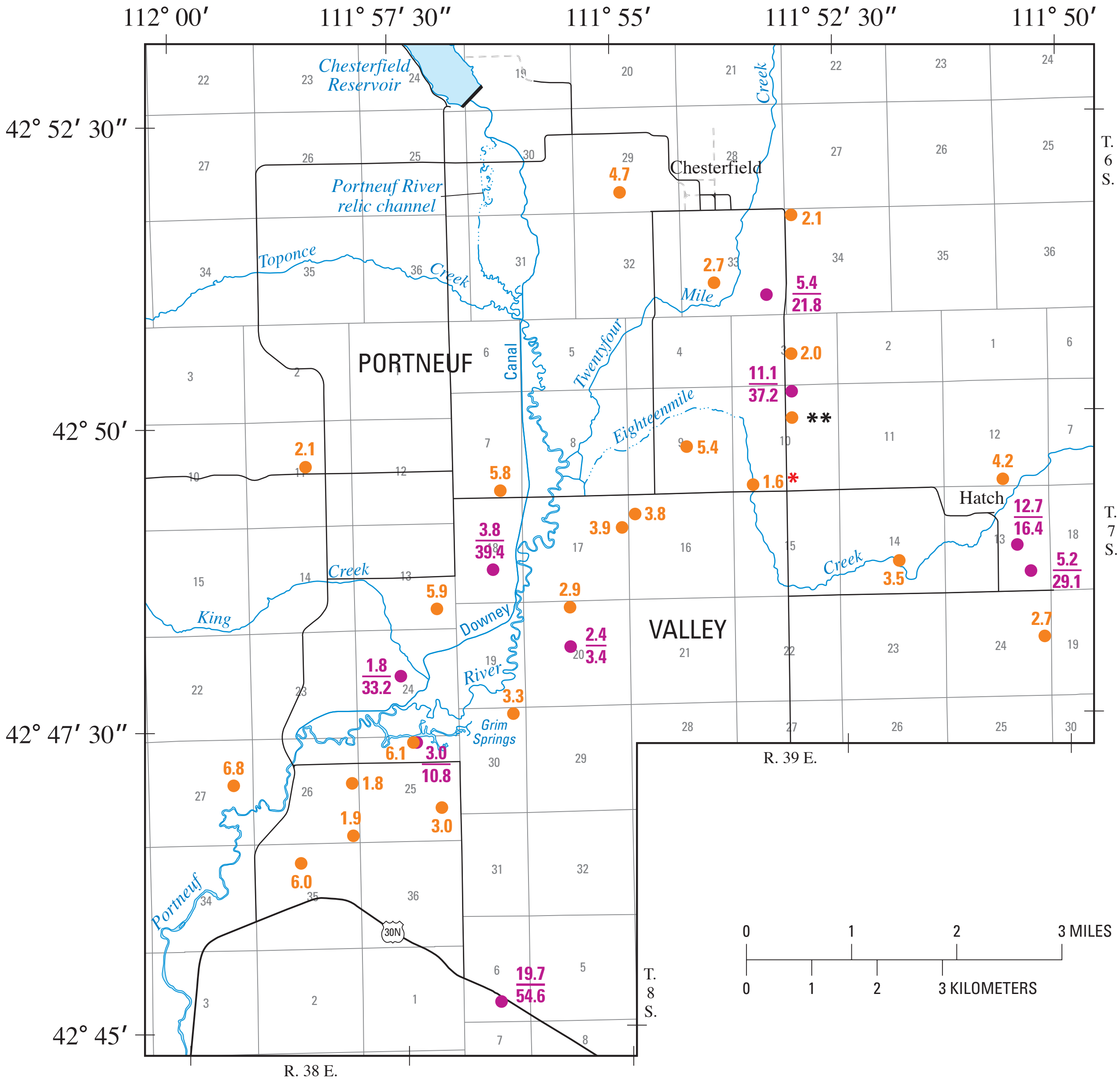
Conclusions about streamflow conveyance losses in the Portneuf River Valley reach and the Pebble-Topaz reach resulting from infiltration during regulated high-flow conditions in the irrigation season are based on two seepage runs. Conveyance losses in the Portneuf River Valley reach (about 19 ft^3/s) were greatest during the mid-summer regulated high flows. Conveyance losses in the Pebble-Topaz reach were about 283 ft^3/s during the spring regulated high flows. The percentage of this loss that is associated with the nearby hydroelectric project is not known. Although these measurements provide a rough estimate of the magnitude of conveyance losses resulting from infiltration, additional seepage studies, along with monitoring of streamflow diversions and ground-water pumping, are needed to quantify streamflow depletion more accurately. These additional data also can help quantify streamflow depletion associated with (1) diversion of surface water for irrigation and (2) pumping irrigation wells that lower the water table and induce surface-water seepage through the riverbed. Ground-water-flow modeling would provide a more thorough evaluation of the effects of ground-water withdrawals on streamflow depletion.

Temporal Changes in Ground-Water Levels in the Portneuf Valley

Hydrologic Conditions

Drought conditions prevailed along the Portneuf River before and during this study. Hydrologic conditions are based on (1) records of local maximum water-equivalent snowpack measurements from 1945, (2) records of discrete water-level measurements for well 07S 39E 10CCD1 dating from 1968 (fig. 6), and (3) daily precipitation data measured at the Pocatello regional airport. The maximum water-equivalent snowpack data based on April snowpack measurements were obtained from the Natural Resources Conservation Service (NRCS) station at Pebble Creek, located about 1,000 ft above the floor of the Portneuf Valley (fig. 3). The average annual maximum water-equivalent snowpack for the period 1945–2002 was 15.0 in. and ranged from 3.2 in. in 1992 to 27.3 in. in 1952. For the sake of brevity, the average annual maximum water-equivalent snowpack hereafter is referred to as annual snowpack.

The annual minimum water level in well 07S-39E-10CCD1 (period of record 1968 to present) declined steeply during drought conditions in 1987–93 and 1998–2002 (fig. 6). During March 1, 1987, to May 15, 1993, ground-water levels declined at a rate of 2.7 ft per year; concomitantly, the annual snowpack at the Pebble Creek station was 6.3 in. below average. By 1997, the annual minimum ground-water



EXPLANATION

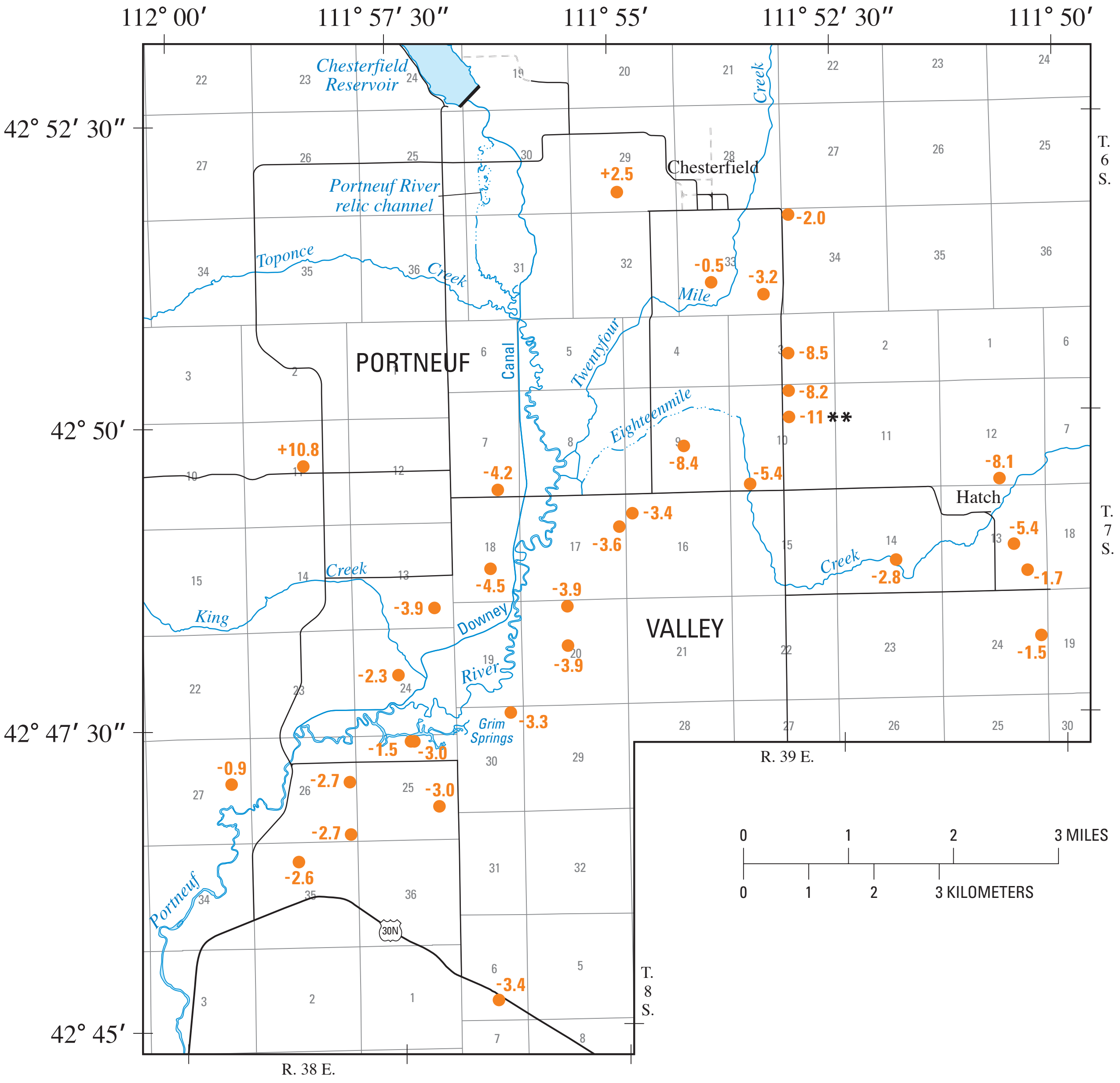
● 6.0 **Nonpumping well—**Number is water-level fluctuation, in feet. Well identification number provided in figure 2

● 3.8/39.4 **Nonpumping well/pumping well—**Numbers are water-level fluctuation, in feet. Well identification number provided in figure 2

* **Water levels have been monitored since 1968—**Monitored on at least a quarterly basis, sometimes on a weekly basis. Annual water-level fluctuations frequently exceeded 20 feet

** **Dry during eight site visits in 2001-02—**Contained water during 1968

Figure 21. Annual fluctuations in ground-water levels in the Portneuf Valley, Idaho, July 2001 through July 2002.



EXPLANATION

● -3.6 **Nonpumping well—**Number is water-level fluctuation, in feet. Well identification number provided in figure 2. Negative number indicates decline; positive number indicates rise

** **Dry during eight site visits in 2001-02—**Contained water during 1968

Figure 22. Long-term fluctuations in ground-water levels in the Portneuf Valley, Idaho, September and October 1968 and 2001.

levels had recovered to their pre-1987 levels. This recovery also is reflected in increases in the annual snowpack. Between December 31, 1998, and July 25, 2002, ground-water levels declined at a rate of 3.4 ft per year; concomitantly, annual snowpack was 2.9 in. below average. At the end of the 1999–2001 period, the annual snowpack reached a minimum of 8.6 in. below average. Between July 25, 2001, and the final measurement for this study on July 26, 2002, ground-water levels appeared to have stopped declining, at least for this 1-year period, and were stable, perhaps owing, in part, to the 2002 snowpack, which was only 2.6 in. below average.

During this study, water levels in monitoring well 07S 39E 10CCD1 (fig. 6) were at their lowest since the 1987–93 drought. However, the rate of ground-water-level declines during the 1998–2002 drought was about 125 percent the rate of declines during the previous drought. Such an increase in rate of ground-water-level declines is the result of decreased precipitation and increased ground-water withdrawals. The annual snowpack in the mountains that border the Portneuf Valley has declined significantly; the 1945–85 annual snowpack was 16.1 in., whereas the 1986 to present annual snowpack was 11.6 in. Extended dry climatic conditions since 1987 are partially responsible for the 1998–2002 water-level declines. These declines also are attributed partially to increases in ground-water withdrawals since 1950 (fig. 7). Since the 1990s, there have been several years when the Chesterfield Reservoir has not completely refilled, and the water in storage behind the reservoir has been depleted by the middle of the irrigation season. In this situation, surface-water diversions for irrigation were terminated before the end of the irrigation season, and irrigators, who were relying in part on diversions from the Portneuf River, had to rely solely on ground water for an alternate supply. Although there are no water-use records, there is strong evidence that, in the dry 1990s, ground-water withdrawals increased and impacted ground-water levels. During the remainder of the irrigation season, flows from the reservoir were reduced to natural streamflow, which typically ranges from 1 to 4 ft^3/s (Steve Hebdon, District Watermaster for the Portneuf River Marsh Valley Canal, oral commun., 2002).

Annual Fluctuations, 2001–02

Annual ground-water-level fluctuations in the Portneuf Valley were based on measurements made about every 2 months during July 2001 through July 2002 in 32 wells composing the Portneuf Valley monitoring network (fig. 2). Water-level fluctuations in these wells ranged from 1.6 to 19.7 ft; the median fluctuation was 3.6 ft. Pumping water levels also were measured in 9 of the wells. Water-level fluctuations in these wells ranged from 3.4 to 54.6 ft; the median was 25.4 ft (fig. 21). Water levels rose during the fall and spring and declined during the summer. Wells with large annual water-level fluctuations appeared to be uniformly distributed throughout the Portneuf Valley. Wells with large water-level fluctuations and large declines can be the result of aquifer stress, poor aquifer water-yielding characteristics in some locations, proximity to flow-limiting boundaries, or poor well construction.

Long-Term Fluctuations, 1968–2001

Long-term fluctuations in ground-water levels in the Portneuf Valley were evaluated on the basis of measurements made during September and October 1968 and 2001 in 32 wells composing the monitoring network. September and October were selected for characterizing long-term fluctuations because declines associated with irrigation reach a maximum at the end of the irrigation season. Water levels declined in 30 of the 32 wells during the 34-year period 1968–2001; the median decline was 3.4 ft (fig. 22). The maximum decline was 11.0 ft in well 07S 39E 10ACB. This declining trend is concomitant with a long-term decrease in annual snowpack as measured at the NRCS Pebble Creek station. Water levels declined in all wells except 07S 38E 11ACC1 and 06S 39E 29CDA1; water levels in these wells rose 10.8 and 2.5 ft, respectively.

The 2001–02 median annual water-level fluctuation of 3.6 ft in wells in the Portneuf Valley monitoring network is nearly equal to the median long-term fluctuation of 3.4 ft in water levels over the past 34 years. Hence, annual water-level fluctuations conceivably could mask long-term fluctuations. However, the consistent water-level decline over the 34-year period suggests that the long-term declines are real. In addition, the discrete water-level measurements in well 07S 39E 10CCD1 indicate a long-term decline with intervening periods of higher water levels.

Long-term fluctuations in ground-water levels in the Portneuf Valley were investigated in relation to the history of ground-water withdrawal rights since 1900. Long-term water levels in well 07S 39E 10CCD1 declined substantially after 1986 and remained low through 1995 (fig. 6). Between 1968 and 1980, water rights for ground-water withdrawals nearly doubled from 23,500 to 46,000 acre-ft per year (fig. 7). However, during this period, ground-water levels were relatively constant and did not exhibit a declining trend (fig. 6) that could be related to the increased ground-water rights. During 1987–96, when the permitted amount of withdrawals for all ground-water rights combined remained constant, the median ground-water level was about 9 ft lower than during 1968–82. This decline in ground-water levels during a period of no increase in ground-water withdrawal rights could be accounted for by declining snowpack or by increased pumping from irrigation wells to help crops during the drier climatic conditions. If ground-water withdrawals increased during this dry period, this increase may have contributed to water-level declines.

Summary and Conclusions

The State of Idaho and local water users are concerned that streamflow depletion in the Portneuf River in Caribou and Bannock Counties is linked to ground-water withdrawals for irrigated agriculture. A year-long field study that focused on surface- and ground-water relations was conducted, in cooperation with the Idaho Department of Water Resources, to begin addressing some of the water-user concerns. The study area comprised a 30.2-mile reach of the Portneuf River downstream from the Chesterfield Reservoir. During the field study, the surface- and ground-water relations were dynamic. A losing reach was delineated in the middle of the Portneuf River Valley reach about 5.5 miles downstream from the Chesterfield Reservoir. Seepage studies indicated the possibility of large streamflow losses from surface water seeping through the riverbed in the Pebble-Topaz reach about 19 to 24.2 miles downstream from the Chesterfield Reservoir. However, streamflow data for the hydroelectric project in this reach were not available to the U.S. Geological Survey (USGS); because of this data gap, streamflow losses could not be quantified.

Thermistor arrays set up in four instream piezometers traced the movement of heat through the riverbed of the Portneuf River. These data provided continuous information about surface- and ground-water relations in a gaining reach and a losing reach. Broadening the use of heat as a tracer to monitor surface- and ground-water relations on the Portneuf River would greatly enhance the understanding of the evolution—timing, location, and magnitude—of losing and gaining reaches during the irrigation season. Instream piezometers with thermistor arrays are relatively inexpensive, require little maintenance, and continuously monitor conditions.

Manometer measurements of hydraulic head at instream piezometers in the losing reach in the Portneuf River Valley reach showed that the ground-water levels were as much as 393 millimeters (15.5 inches) below the surface-water stages, which indicated that surface water was infiltrating down through the riverbed of the Portneuf River. Manometer measurements in the gaining reach showed that the ground-water levels were 18 to 190 millimeters (0.7 to 7.5 inches) above the surface-water stages, which indicated that ground water was seeping up into the river. Installing instream piezometers in the Pebble-Topaz reach and measuring hydraulic heads, temperature, and specific conductance would improve the understanding of surface- and ground-water relations in this reach.

A regional perspective on surface- and ground-water relations in the Portneuf Valley was obtained from analysis of specific conductance and temperature in the Portneuf River Valley reach. Specific conductance and temperature data showed that ground water was seeping into the river just downstream from the Chesterfield Reservoir and where the valley narrows upstream from Pebble. Specific conductance was about two times higher and temperature was several degrees cooler in ground water than in the river in the gaining reach. The more dilute and warmer surface water infiltrated the riverbed in the losing reach in the middle of the study area. Infiltration of relatively dilute surface water through the riverbed lowered the specific conductance of the ground water so that surface- and ground-water specific conductance were nearly equivalent. Infiltration of the warm surface water through the riverbed also increased ground-water temperatures to the extent that surface- and ground-water temperatures were nearly equivalent. Stratification of water quality across the Portneuf River was another indicator of ground water seeping into the river.

Seepage studies indicated that streamflow losses from surface water seeping through the riverbed in the losing reach of the Portneuf River Valley reach ranged from 4.3 to 20 cubic feet per second (ft^3/s) during the period of regulated high flows. During the July 16–17, 2001, seepage studies, no streamflow losses in the Portneuf River Valley reach were associated with pumped surface-water diversions because irrigators participated in a power buyback program, except between Chesterfield Dam and measurement station 1SP. During the May 29, 2002, seepage study, streamflow losses from pumped surface-water diversions between Chesterfield Dam and measurement station 6SPT were 13.3 ft^3/s. The length of the losing river reach was nearly 3 times longer during July 16–17, 2001, in the middle of the irrigation season, than on May 29, 2002, early in the irrigation season. A seepage run conducted on May 29, 2002, several days after the beginning of regulated high flows and the start of the irrigation season, showed that surface water was seeping through the riverbed at a rate of 4.3 ft^3/s. The loss from surface water seeping through the riverbed was much larger at the end of the regulated high flows, about 19 ft^3/s during July 16–17, 2001. Even though apparent losses from surface water seeping through the riverbed were measured between Chesterfield Dam and station 2SPT during regulated high flows, these losses were attributed to inaccurate diversion data or inaccurate flow data for the dam.

Seepage studies indicated that streamflow losses along the Pebble-Topaz reach occurred between measurement stations 10S and 11S. During the May 30, 2002, regulated high flows, the streamflow losses were about 283 ft^3/s, compared with 57 and 20 ft^3/s during the September 18 and October 17, 2001, regulated low flows. During the September 18 and October 17, 2001, seepage runs, no streamflow was being diverted for irrigation. During the September, October, and May seepage runs, most of the streamflow losses between stations 10S and 11S were offset by gains of 55.9, 16.7, and 226 ft^3/s farther downstream between stations 11S and 13S. A hydroelectric project located between stations 10S and 11S stores water behind a cement impoundment structure. As much as 300 ft^3/s of water can be diverted from this project and returned to the river farther downstream between stations 11S and 12S. Flow data for this hydroelectric project during the seepage run were not available to the USGS; therefore, any withdrawal or release of water by this hydroelectric project could not be quantified. Because of this data gap, the surface- and ground-water relations between stations 10S and 12S could not be quantified.

Long-term fluctuations in ground-water levels in the Portneuf Valley were evaluated by comparing measurements during September and October 1968 and 2001 in 32 wells composing the monitoring network. During this 34-year period, water levels declined in all but two wells. The median water-level decline in 30 of the 32 wells was 3.4 feet. This temporal trend is concomitant with a long-term decrease in average annual snowpack. Long-term ground-water-level declines could not be related to a long-term increase in ground-water withdrawal rights. However, water-use data, rather than ground-water withdrawal rights, would provide a more accurate analysis of long-term trends in ground-water-level declines as they relate to ground-water withdrawals. A historical perspective of ground-water usage in the Portneuf Valley could be established by developing a relation between power consumption and irrigation well pumping rates, obtaining historical power consumption data for the various irrigators, and then using this information to compute historical water usage. This method of computing water usage also could be done on a yearly basis.

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APPENDIX 1. Water levels in selectd wells in the Portneuf Valley, Idaho, 1968–69 and 2001–02

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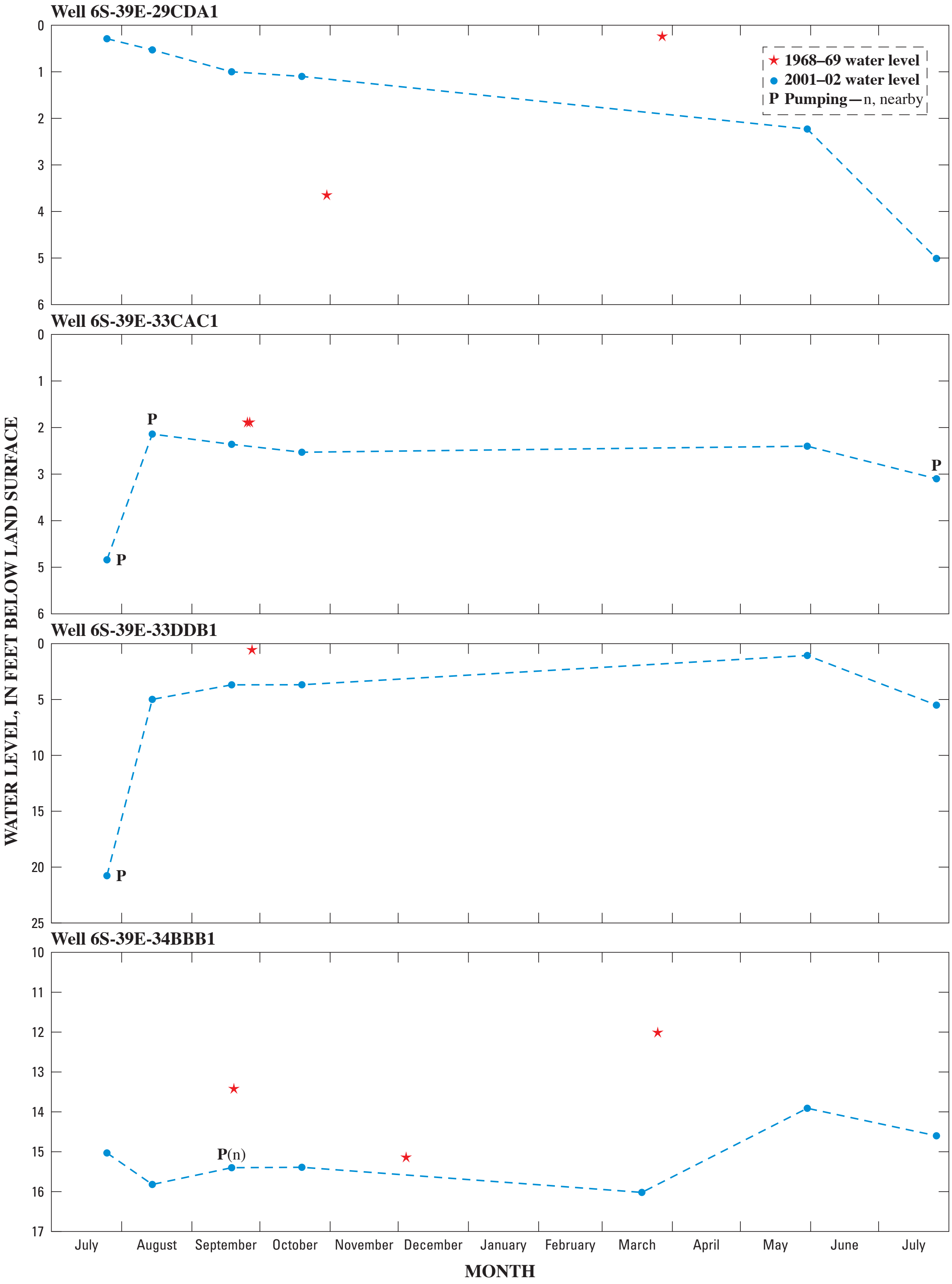

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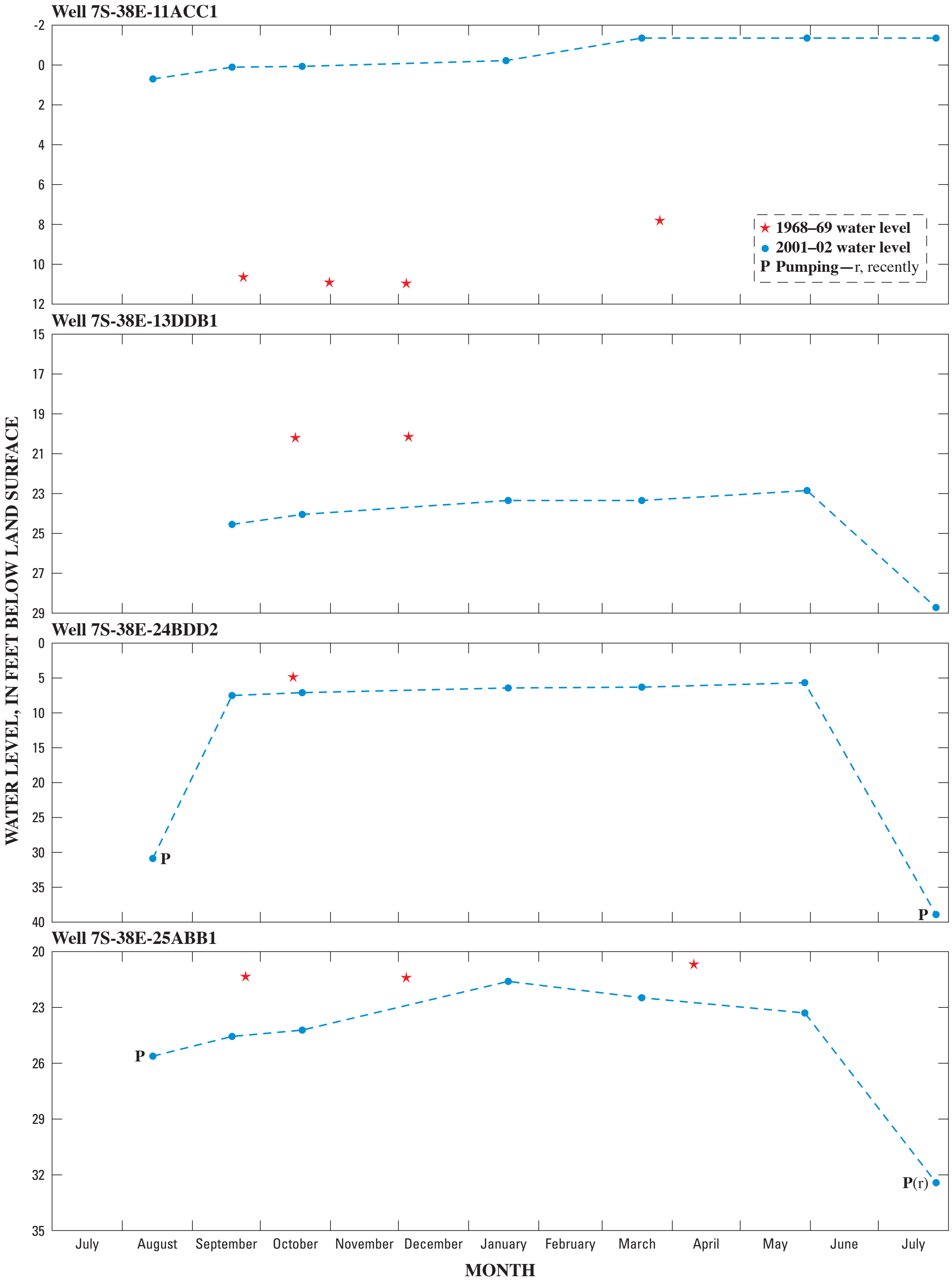

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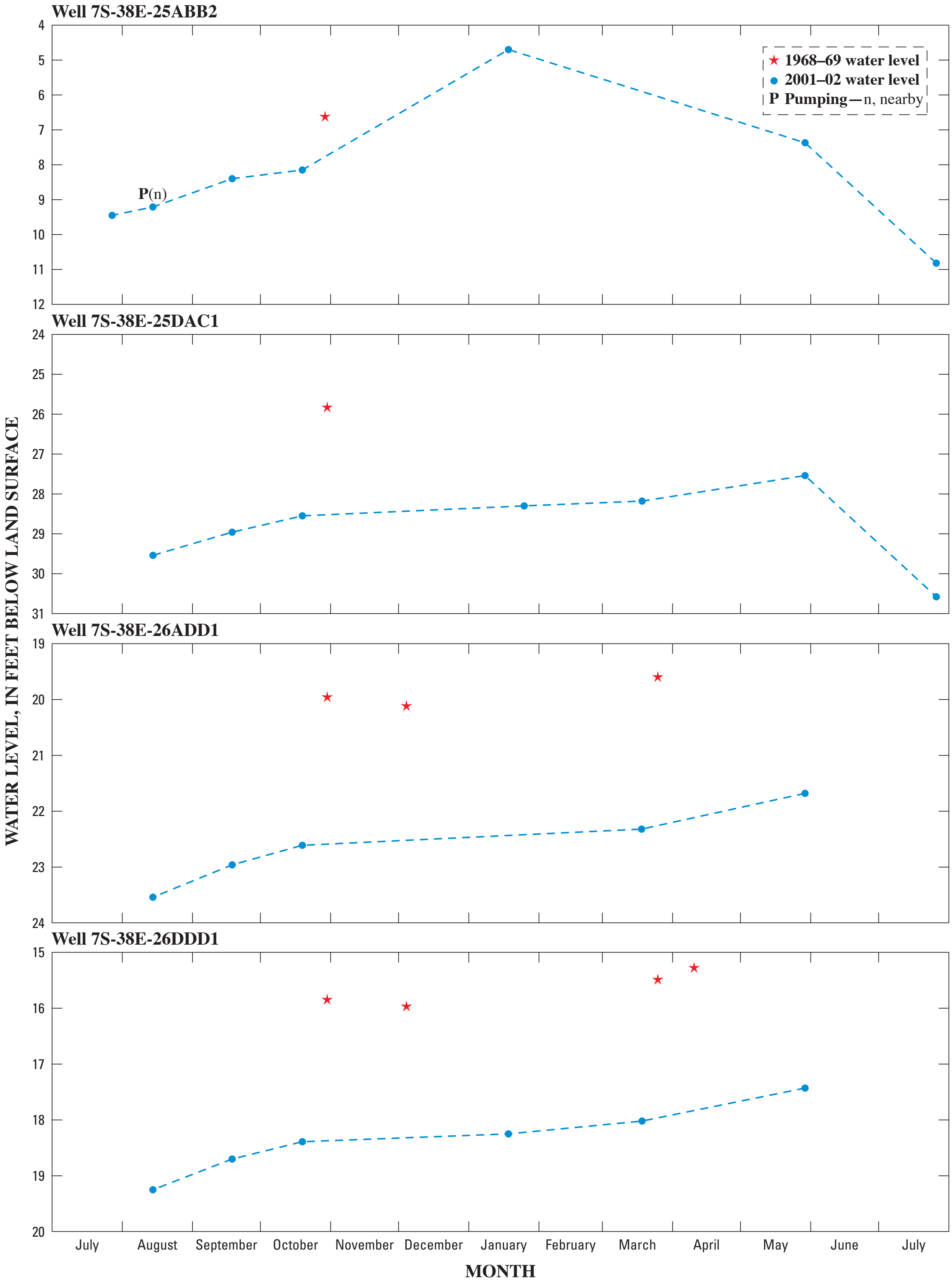

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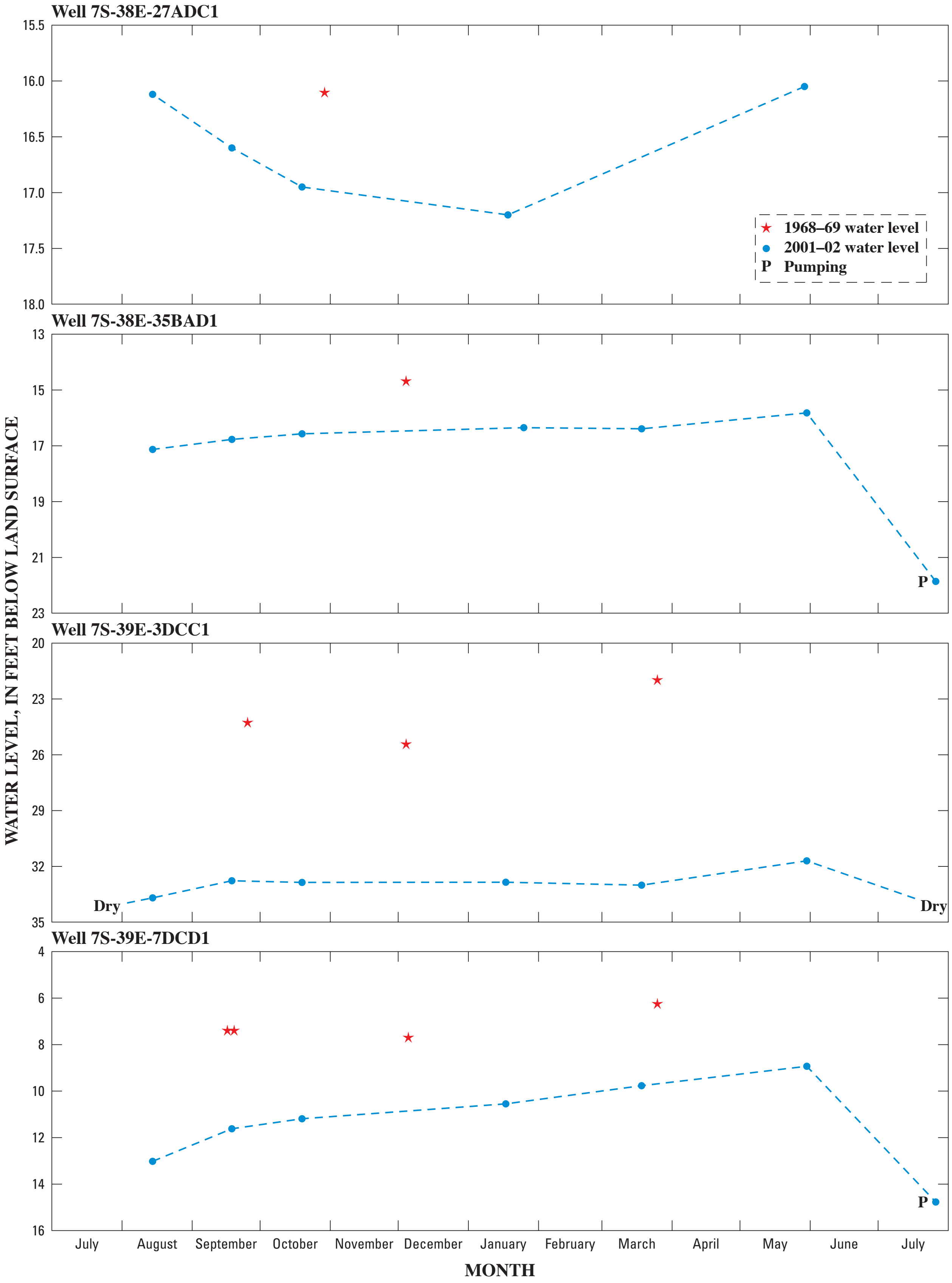

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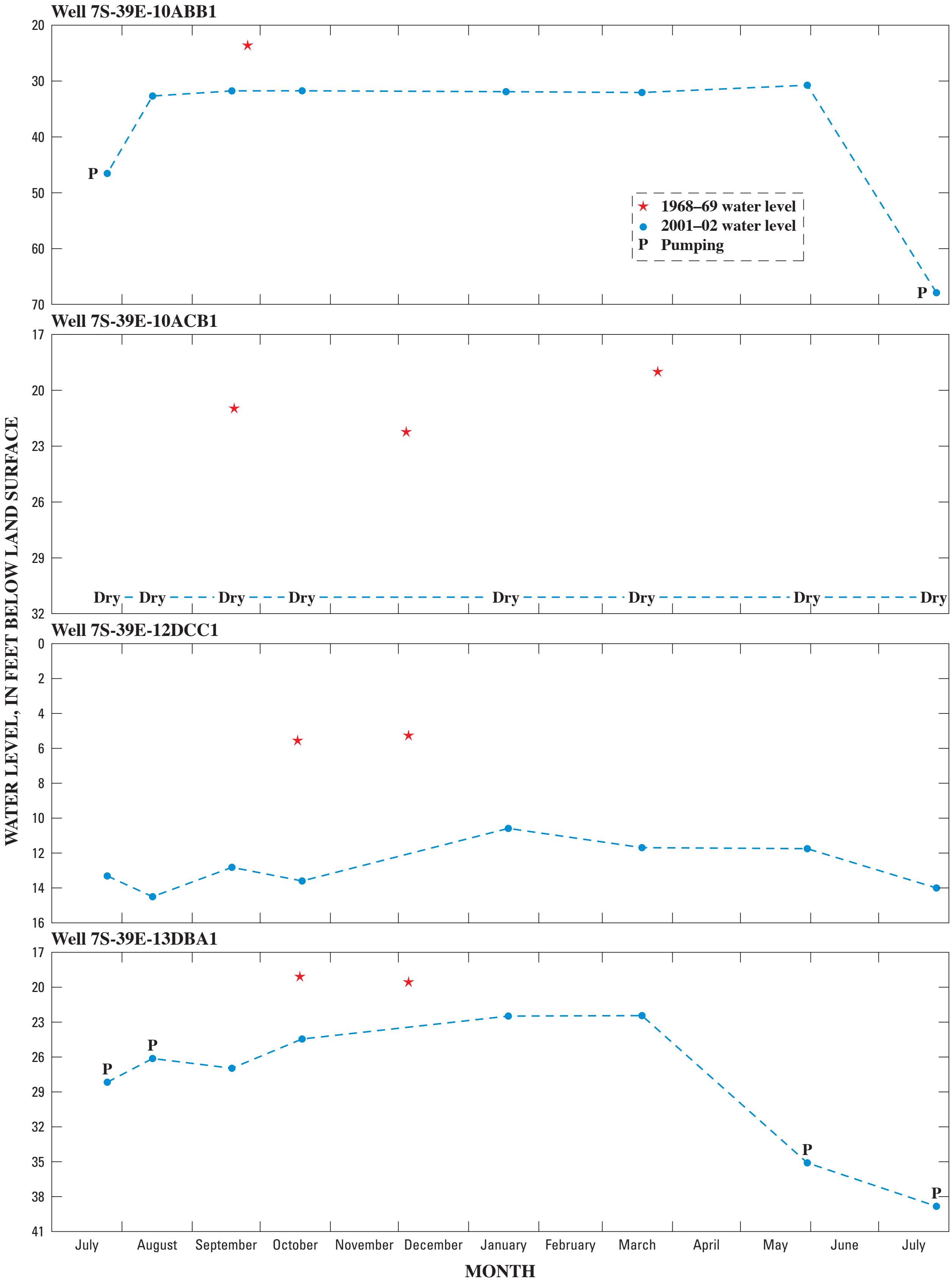

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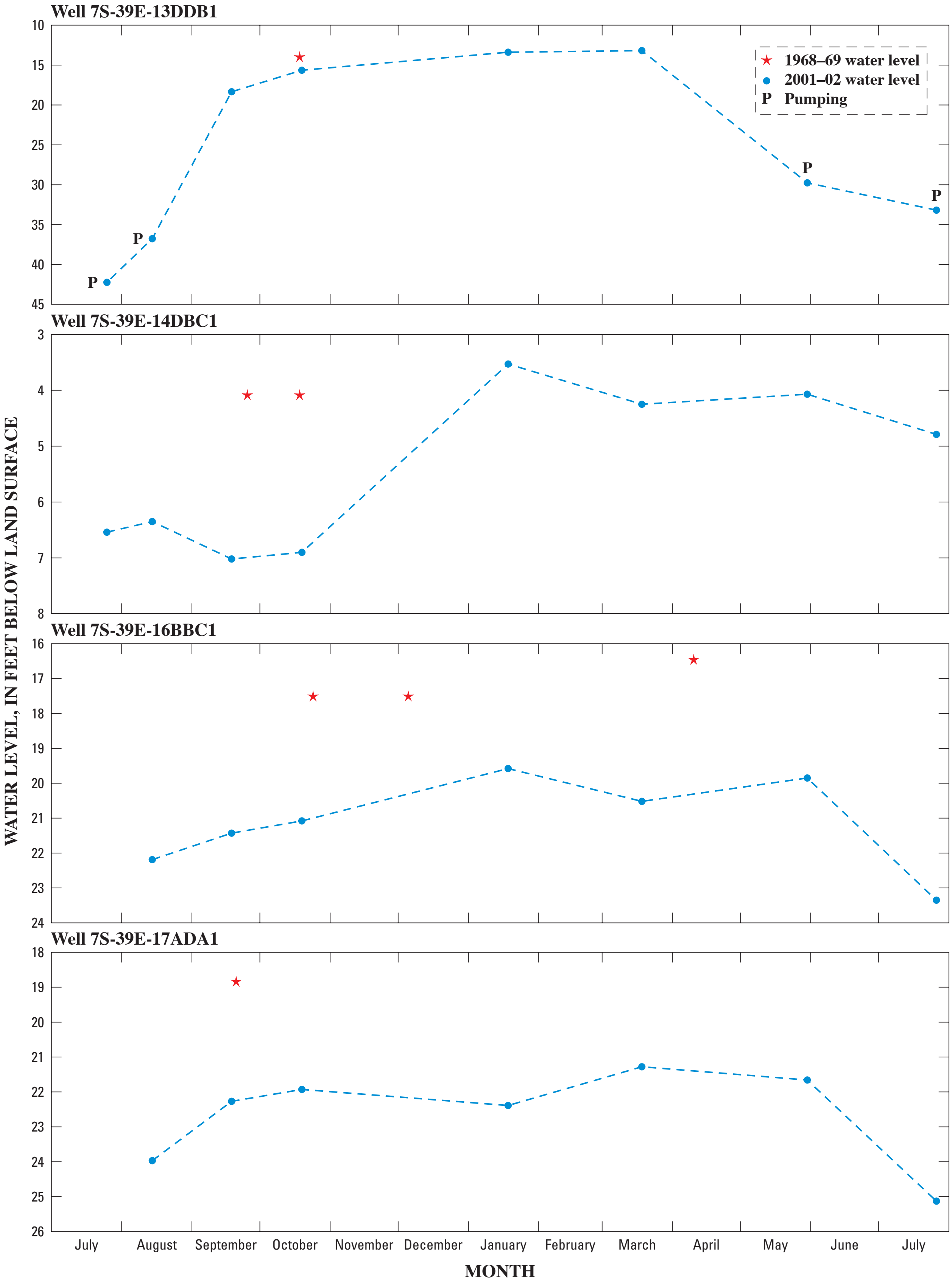

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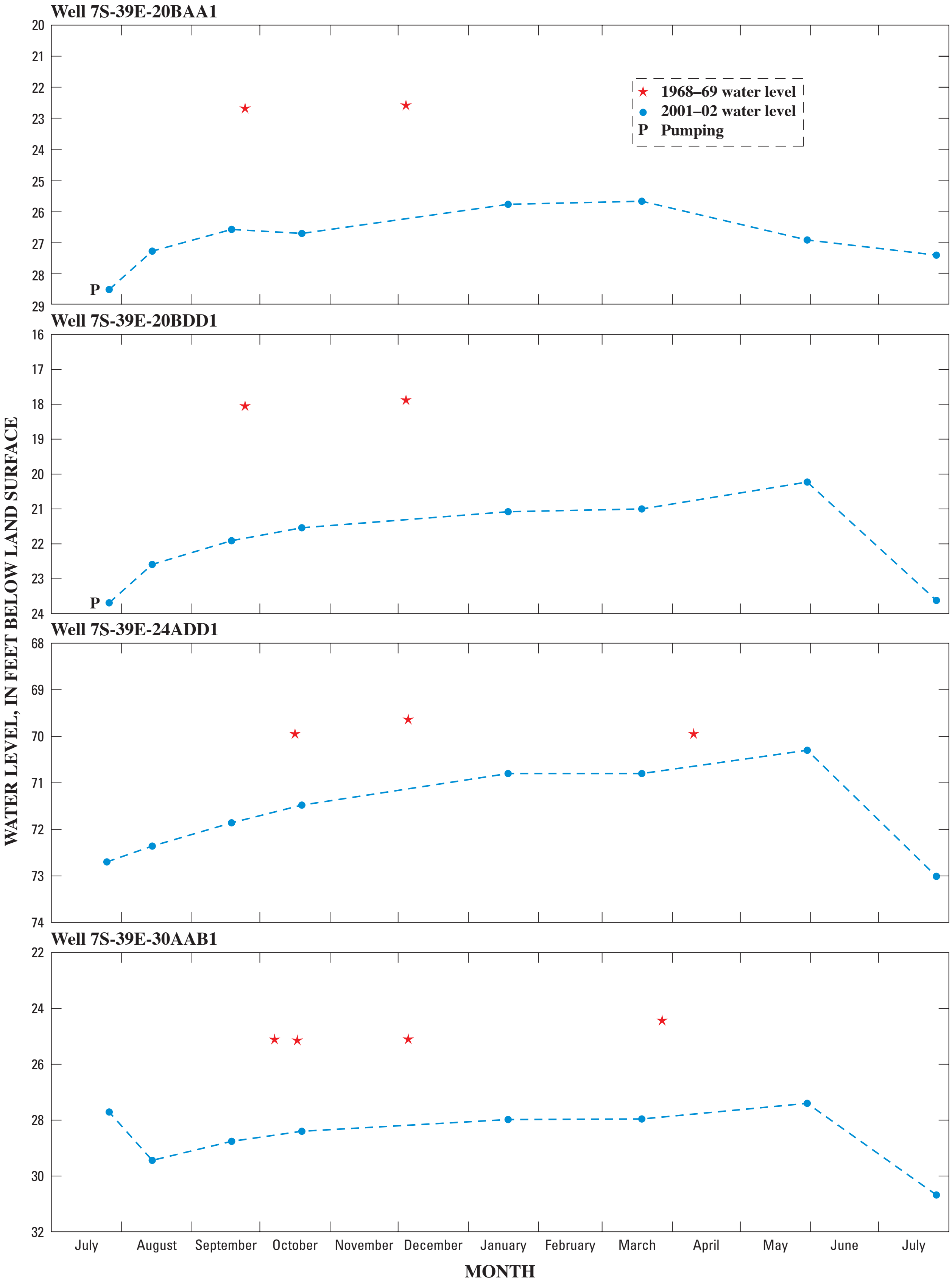

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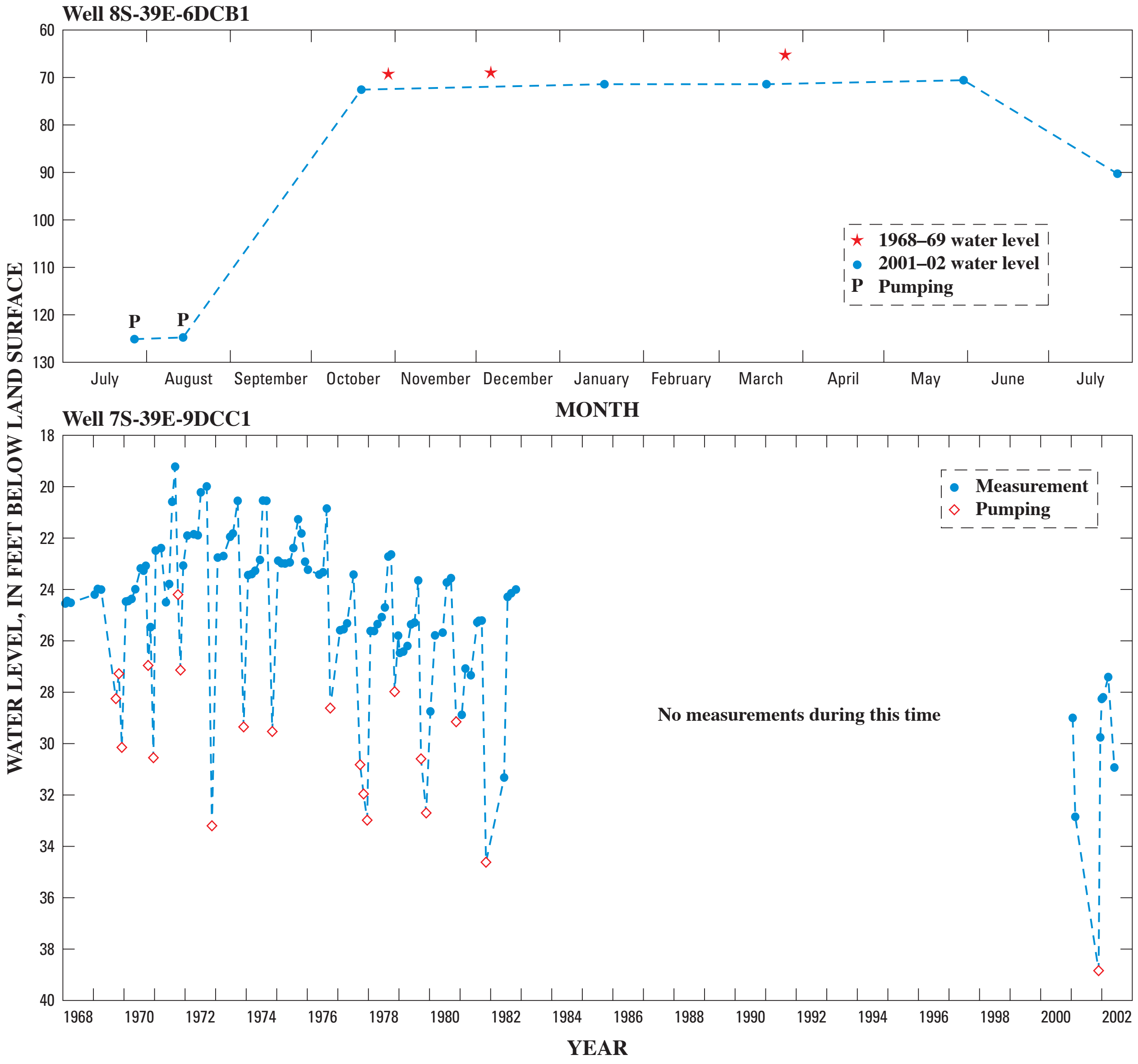

Water levels in selected wells in the Portneuf Valley, Idaho, 1968–69 and 2001–02.

APPENDIX 2. Continuous record of surface- and ground-water temperatures at measurement stations on the Portneuf River, Idaho, August 2001 through January 2002

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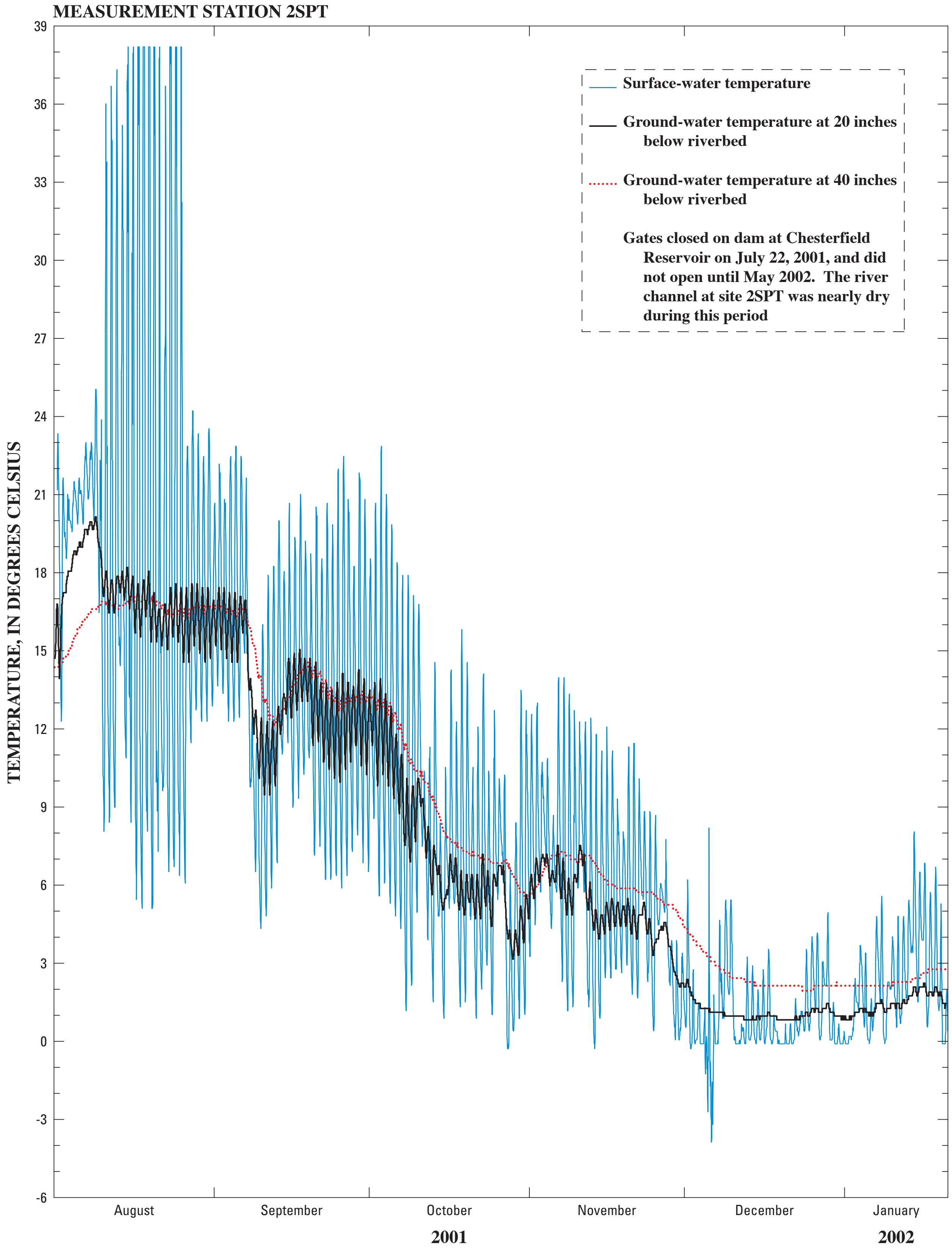

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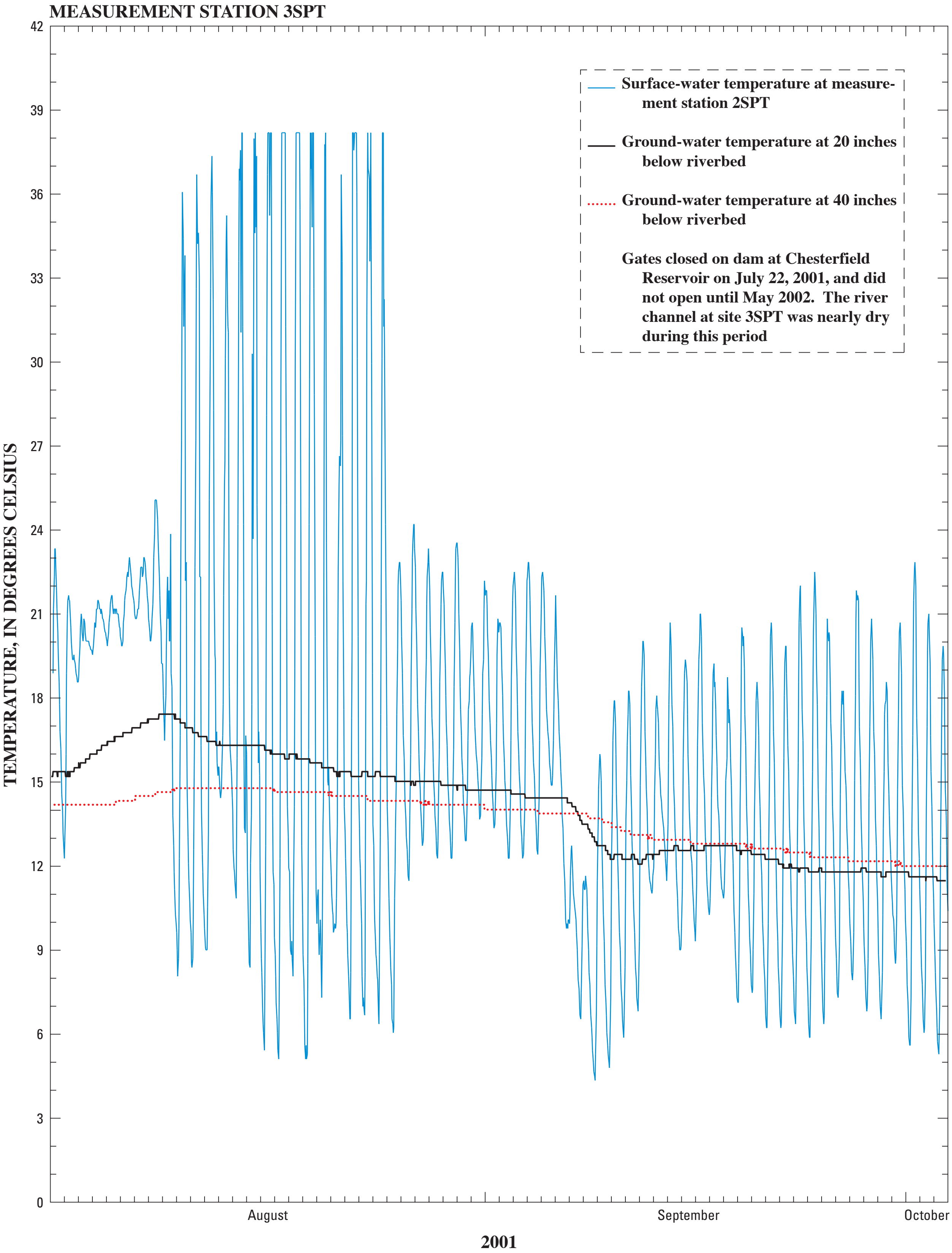
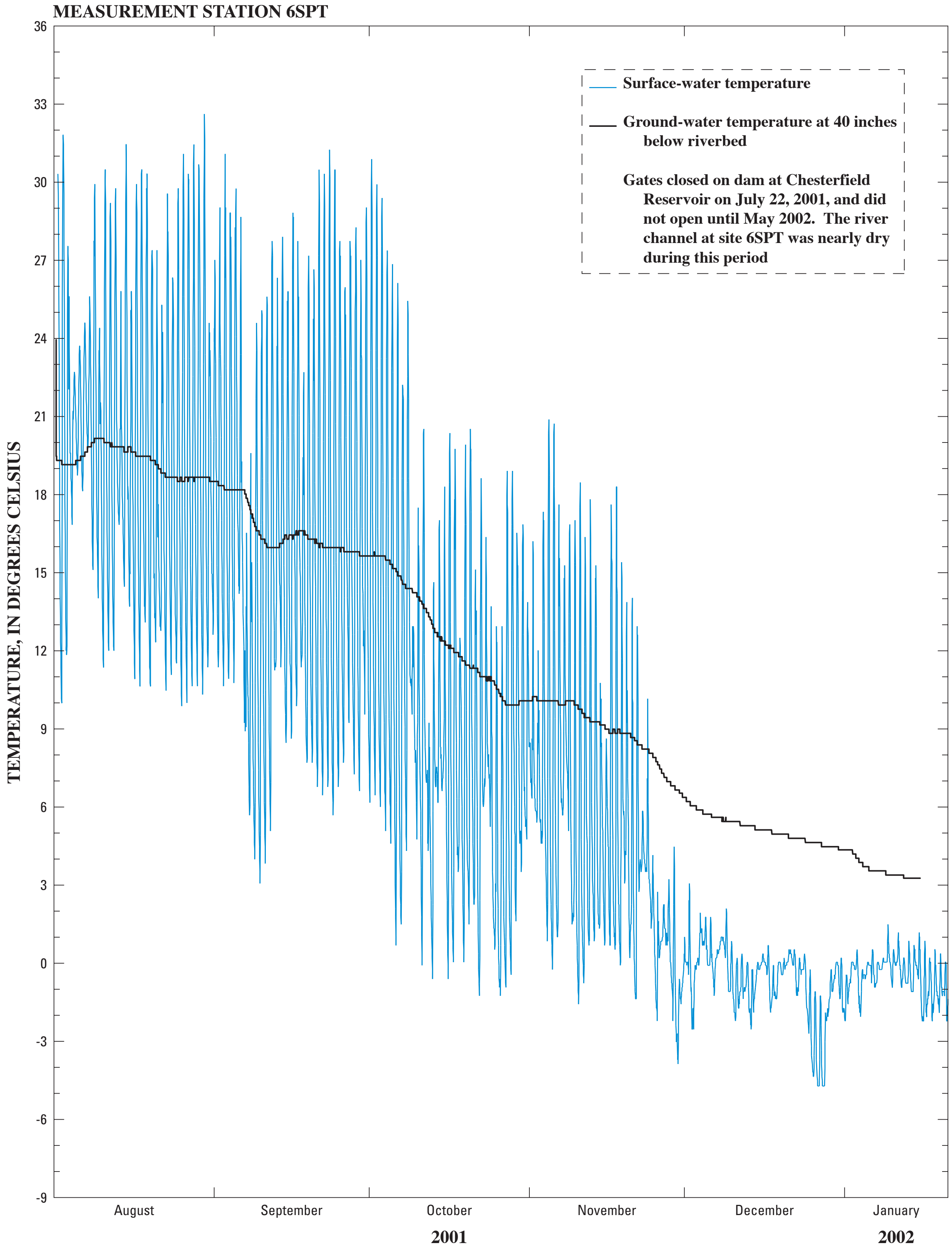


Continuous record of surface- and ground-water temperatures at measurement station 3SPT, Portneuf River, Idaho, during August 2001 through October 3, 2001. (Surface-water temperature at measurement station 2SPT is used because the surface-water thermistor failed at measurement station 3SPT)



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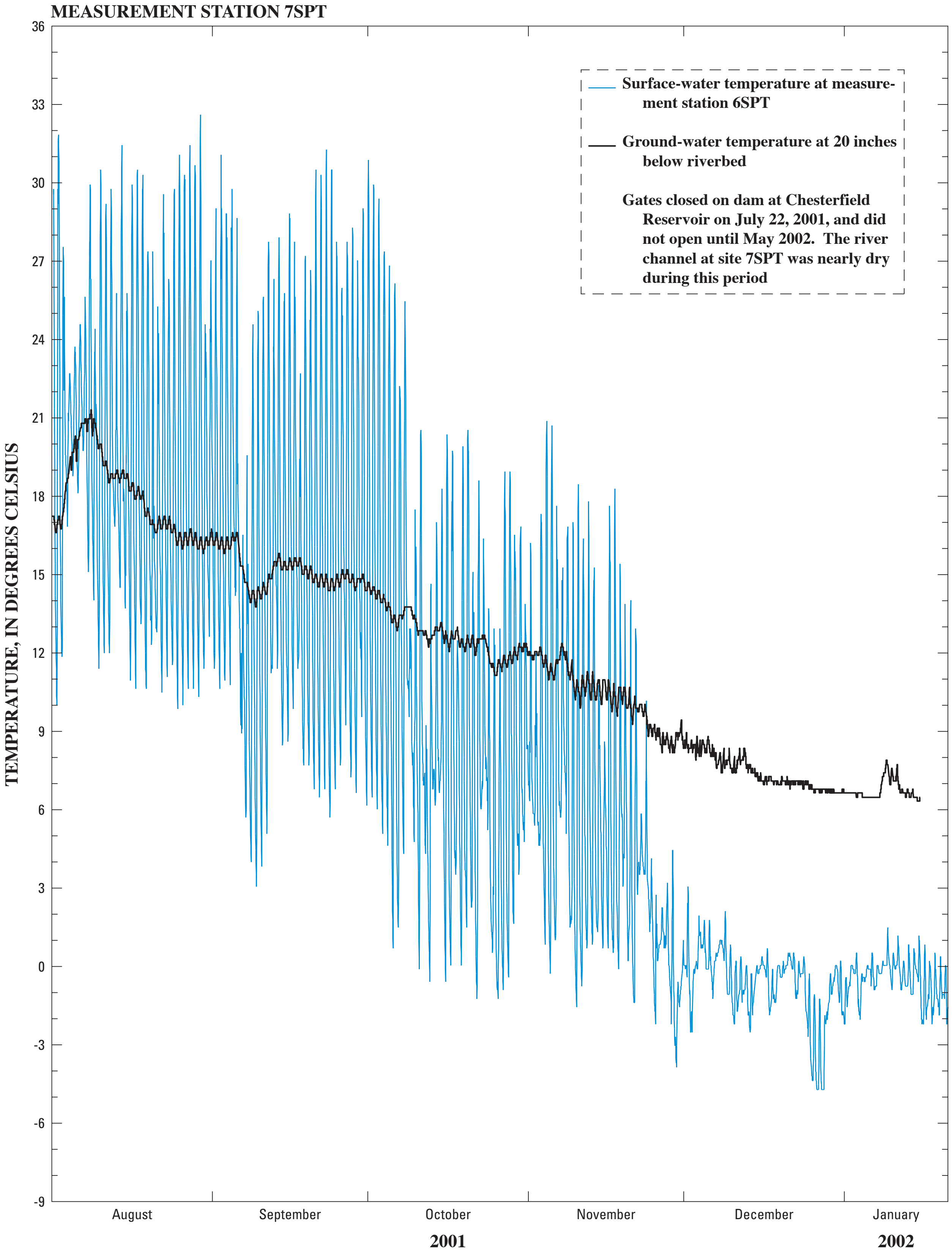

Continuous record of surface- and ground-water temperatures at measurement station 7SPT, Portneuf River, Idaho, during August 2001 through January 2002. (Surface-water temperature at measurement station 6SPT is used because the surface-water thermistor failed at measurement station 7SPT)

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