USGS
science for a changing world

Prepared in cooperation with Meagher County Conservation District

Hydrologic Data for an Investigation of the Smith River Watershed, Montana, through Water Year 2010

Open-File Report 2012–1134

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

Front cover. Upper right: USGS streamflow-gaging station installation at the Smith River near Eden, Mont., October 2005.

Center right: Instream monitoring well near USGS streamflow-gaging station at the Smith River below Newlan Creek, Mont., October 2007.

Lower right: Exploration well drilling near White Sulphur Springs, Mont., September 2008.

All photographs by Rodney R. Caldwell, U. S. Geological Survey

Prepared in cooperation with Meagher County Conservation District

Hydrologic Data for an Investigation of the Smith River Watershed, Montana, through Water Year 2010

Open-File Report 2012–1134

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

Hydrologic Data for an Investigation of the Smith River Watershed, Montana, through Water Year 2010

By Hannah L. Nilges and Rodney R. Caldwell

Prepared in cooperation with Meagher County Conservation District

Open-File Report 2012–1134

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

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

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Nilges, H.L., and Caldwell, R.R., 2012, Hydrologic data for an investigation of the Smith River Watershed through water year 2010: U.S. Geological Survey Open-File Report 2012–1134, 41 p.

Contents

Figures

Tables

Conversion Factors, Datum, Abbreviated Water-Quality Units, and Acronyms

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min, gpm)	0.06309	liter per second (L/s)
	Mass	
ounce (oz)	28.35	gram (g)
pound (lb)	0.4536	kilogram (kg)

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

$$°F=(1.8×°C)+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).
Altitude, as used in this report, refers to distance above specified vertical datum.
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).
Concentrations of chemical constituents in groundwater are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Water-year definition:

Water year is the 12-month period from October 1 through September 30 of the following calendar year. The water year is designated by the calendar year in which it ends. For example, water year 2007 is the period from October 1, 2006 through September 30, 2007.

Abbreviated water-quality units used in this report:

mg/L	milligram per liter
µS/cm	microsiemens per centimeter
per mil	parts per thousand
µS/cm	microsiemens per centimeter
pg/kg	picograms per kilogram
pCi/L	picocuries per liter
fmol/L	femtomol per liter

Acronyms used in this report:

CFC-11	trichlorofluoromethane
CFC-12	dichlorodifluoromethane
CFC-113	1,1,2-Trichloro-1,2,2-trifluoroethane
GPS	global positioning system
GWIC	Groundwater Information Center
ITL	USGS Isotopes Tracers Laboratory
lsd	land surface datum
MBMG	Montana Bureau of Mines and Geology
MCCD	Meagher County Conservation District
MDNRC	Montana Department of Resources and Conservation
mp	measuring point
NED	national elevation dataset
NWIS	National Water Information System
NWQL	USGS National Water Quality Laboratory
R	Radiochemical value below sample-specific critical level
RCL	USGS Reston Chlorofluorocarbon Laboratory
RPD	relative percent difference
RTK	real-time kinematic
USGS	U.S. Geological Survey

Hydrologic Data for an Investigation of the Smith River Watershed, Montana, through Water Year 2010

By Hannah L. Nilges and Rodney R. Caldwell

Abstract

Hydrologic data collected through water year 2010 and compiled as part of a U.S. Geological Survey study of the water resources of the Smith River watershed in west-central Montana are presented in this report. Tabulated data presented in this report were collected at 173 wells and 65 surface-water sites. Figures include location maps of data-collection sites and hydrographs of streamflow. Digital data files used to construct the figures, hydrographs, and data tables are included in the report. Data collected by the USGS are also stored in the USGS National Water Information System database and are available through the USGS National Water Information System Water Data for Montana Web page at *http://waterdata.usgs.gov/mt/nwis/*.

Introduction

The Smith River watershed is an important agricultural and recreational area in Meagher and Cascade Counties in west-central Montana (fig. 1). In 2005, the U.S. Geological Survey (USGS), in cooperation with the Meagher County Conservation District (MCCD), initiated a multi-year study of the Smith River watershed. This study was designed to expand the knowledge of the hydrologic system through a systematic program of data collection and compilation, research, and analysis. Selected hydrologic data collected in the watershed by several entities (including the USGS, MCCD, Montana Department of Natural Resources and Conservation (MDNRC), and the Montana Bureau of Mines and Geology (MBMG)) were utilized for this study.

Purpose and Scope

The purpose of this report is to present hydrologic data collected and compiled for the USGS Smith River watershed hydrologic study through 2010. This compilation provides a central location for collected data that will be available for subsequent USGS interpretive reports and hydrologic models. Types of data presented in this report include groundwater levels, lithologic and yield information from drillers' logs, stream stage, streamflow, water temperature, and water quality. The frequency of data collected at a site varied from single miscellaneous field measurements to continuous data collected using data loggers. Summary tables and graphs of data are included in the body of the report and data are included as digital files in appendixes. Data collected by the USGS are also stored in the USGS National Water Information System (NWIS) database and are available through the USGS NWIS Water Data for Montana Web page at *http://waterdata.usgs.gov/mt/nwis/*.

Description of the Study Area

The Smith River watershed encompasses approximately 2,000 square miles (mi^2) of the upper Missouri River Basin in Meagher and Cascade counties of west-central Montana. Although study efforts included the collection and analysis of information throughout the entire watershed, the majority of data-collection efforts took place in the approximately 1,200 mi^2 drainage area above the USGS streamflow-gaging station on the Smith River below Eagle Creek near Fort Logan (06077200) (fig. 1).

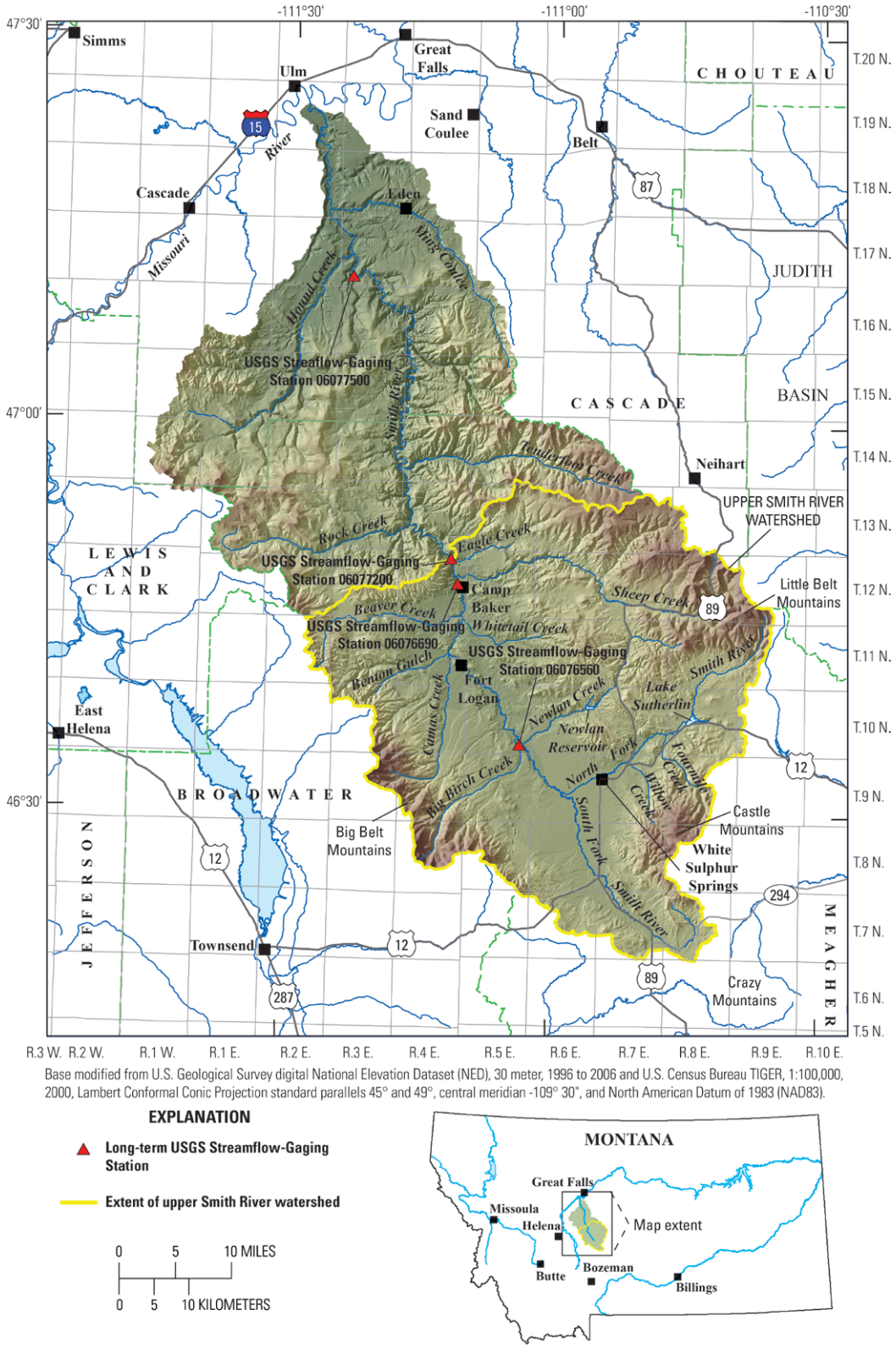

Figure 1. Location of Smith River watershed, Montana.

The Smith River watershed lies within the Northern Rocky Mountains Physiographic Division described by Fenneman and Johnson (1946) and is characterized by somewhat rugged mountains and relatively flat river valleys, particularly in the upper Smith River watershed. Surrounding mountain ranges include the Castle Mountains to the east, the Little Belt Mountains to the north and east, the Big Belt Mountains to the west, and the Crazy Mountains to the south. Elevations in the watershed range from about 9,500 feet (ft) at Edith Mountain in the Big Belt Mountains to about 3,320 ft at the mouth of the Smith River near Ulm, Montana.

The watershed has a low-density rural population and the majority (about 48 percent) of the total area land cover in the watershed is grass rangeland (U.S. Geological Survey, 2000). Conifer forests are located at the higher elevations in the watershed and account for 39 percent of the total area. The more arid, lower elevation portions of the watershed are dominated by grasslands with riparian vegetation near the streams. Cultivated farm lands are also present in the lower elevations, adjacent to the Smith River and its tributaries.

The climate in the Smith River watershed is generally semi-arid with some semi-humid areas in the higher mountains. Summer temperatures are mild in the valleys with cooler temperatures in the higher mountains. Winters are cold with a thick snowpack that accumulates in the mountains. Monthly mean temperatures during the period of study (2006-2010) near White Sulphur Springs ranged from 24.3ºF (-4.3ºC) in January to 67.3ºF (19.6ºC) in July (National Climatic Data Center, 2011). Precipitation varies both spatially and temporally. Average annual precipitation (1971–2000) ranges from less than 12 inches (in.) per year in the lower elevations of the watershed to the west and northwest of White Sulphur Springs to over 40 in. per year in the Castle, Little Belt, and Big Belt mountains (Oregon State University PRISM Group, 2006; Phil Farnes, written commun., 2007).

The Smith River is the primary stream that drains the watershed. The Smith River originates about 3 miles (mi) southwest of White Sulphur Springs at the confluence of the North Fork and South Fork Smith Rivers. The North Fork Smith River begins in the Little Belt Mountains to the northeast of White Sulphur Springs and flows for nearly 40 mi to the southwest as it gains tributary inflow from both the Little Belt and the Castle Mountains before joining the South Fork Smith River. The South Fork Smith River begins in the Castle Mountains and flows to the west and northwest for about 38 mi. The South Fork Smith River gains tributary inflow from both the Castle and Big Belt Mountains and from an unsealed artesian well before meeting the North Fork Smith River. Together, the North Fork and South Fork Smith Rivers form the Smith River which flows roughly northwest for about 125 mi until it ultimately joins the Missouri River near Ulm, Montana. In addition to North and South Forks of the Smith River, major tributaries include Big Birch Creek, Camas Creek, Rock Creek, and Hound Creek from the Big Belt Mountains and Newlan Creek, Sheep Creek, Eagle Creek, and Tenderfoot Creek from the Little Belt Mountains. Numerous reservoirs, canals, and irrigation ditches are also located in the upper watershed.

The most productive and developed aquifers in the Smith River watershed generally occur in the alluvium and basin-fill sediments of the valley lowlands and tributary drainages. The alluvial aquifers are generally composed of sand and gravel with some clay layers. The basin-fill aquifers are generally fine grained with lower permeability. However, some of the most productive irrigation wells produce water from the basin-fill aquifers. Wells completed in the older sedimentary and igneous rocks in the watershed typically yield low volumes of water and are used for domestic and stock purposes.

Site-Identification System

Groundwater sites (wells) are assigned a 15-digit site identification number; these numbers represent the approximate latitude and longitude of the site (first 13 digits) plus a sequence number

(last 2 digits). Wells used for this study were also assigned a station name based on their geographic position within the rectangular grid system used for the subdivision of public lands (fig. 2). The station name consists of 14 characters. The first three characters specify the township and its position north (N) of the baseline in Montana (for example, 09N). The next three characters specify the range and its position east (E) of the principal meridian in Montana (for example, 05E). The next two numbers represent the section number. The next four characters sequentially designate the quarter (160-acre tract), quarter-quarter (40-acre tract), quarter-quarter-quarter (10-acre tract), and the quarter-quarter-quarter-quarter (2 ½-acre tract) of the section in which the well lies. The quarter subdivisions within a section are designated A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. The final two characters of the station name are a sequence number assigned to differentiate multiple wells within a single quarter-quarter-quarter-quarter section. For example, as shown in figure 2, 09N05E18BBAC01 was the first well inventoried in the SW1/4 of the NE1/4 of the NW1/4 of the NW1/4 of sec. 18, T. 09N., R. 05E.

Streamflow-gaging stations are typically assigned an eight digit station identification number that represents the standard USGS numbering system for streamflow-gaging stations. Miscellaneous surface-water measurement sites are assigned a 15-digit station identification number similar to the site identification number of the groundwater sites. These numbers represent the approximate latitude and longitude of the site (first 13 digits), plus a sequence number (last 2 digits). Streamflow-gaging stations and miscellaneous surface-water measurement sites were also assigned a station name based on their geographic position relative to landmarks.

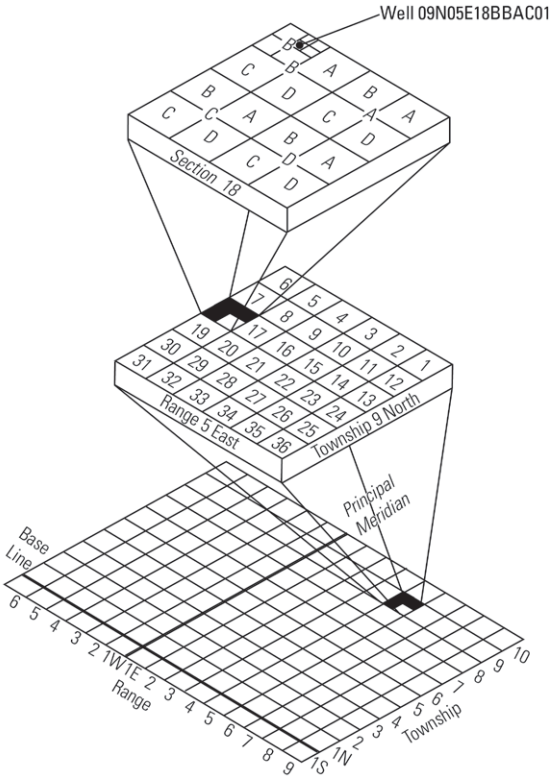

Figure 2. Identification system for wells.

Acknowledgments

We gratefully acknowledge the landowners who provided access to their property for the acquisition of data. Without their involvement, very little information could have been collected. We also thank members of the Meagher County Conservation District that have supported this project. Special thanks to Otto Olson for his local knowledge and submission of groundwater-level and Newlan Creek Reservoir data. Kathy Hochstrat provided streamflow and diversion information for the North Fork Smith River. Several scientists with the Montana Department of Natural Resources and Conservation including Larry Dolan, Russell Levens, Mike Roberts, and Bill Uthman provided background information including access to hydrologic data collected in the area.

This work was completed through the combined effort and expertise of several USGS colleagues, including Fred Bailey, Craig Bowers, Tom Cleasby, Phil Karper, Sean Lawlor, Steve Lynn, Peter McCarthy, Steve Nichols, David Nimick, Kevin Sattler, Todd Schmidt, William Stotts, Andy Skerda, and Andrea Stanley during the collection, compilation, and analysis of hydrologic data including streamflow measurements, surveys, well installation, and groundwater levels. DeAnn Dutton provided field time and was the primary Geographic Information System specialist and illustrator for this project. Mitchell Reynolds (USGS, retired) graciously volunteered his time and knowledge with discussions of area geology and analysis of drill cuttings from exploration wells. A special thanks to Michael Cannon (USGS, retired) who was involved in the early phases of study design, field work, and data interpretation. Ron Shields (USGS, retired) volunteered several days in the field, verified data, and provided guidance on many aspects of this study.

Methods of Data Collection

Data collection efforts included miscellaneous and continuous measurements of groundwater levels (depth to groundwater below land surface and altitude of groundwater level), stream stage, water temperature, and streamflow, altitude surveys of wells and staff gages, and water-quality sample collection. A hydrologic monitoring network was established for this study that included shallow monitoring wells, deeper exploration wells, long-term (operated 4 years or more) USGS streamflow-gaging stations and temporary USGS streamflow-gaging stations. Data were also collected at miscellaneous stream sites and domestic, stock, public supply, monitoring, and irrigation wells.

Groundwater

There are approximately 900 documented water wells in the Smith River watershed [Montana Bureau of Mines and Geology Groundwater Information Center (GWIC) database (accessed 2-15-2011 at *http://mbmggwic.mtech.edu/*)]. The wells are unevenly distributed over the study area, with the majority of the wells located in the more populated area near White Sulphur Springs and in the valley flats. Information from 173 wells was used for this study, including 139 existing wells inventoried in the field, historical information from 1 abandoned well, 2 deep (>400 ft) exploration wells drilled for the USGS, and 31 shallow monitoring wells installed by the USGS (appendix 1; figure 3). The existing wells were selected on the basis of location, geology, availability of well log, ease of access, and permission from the landowner. The geographic positions of the wells were determined using handheld or survey-grade GPS units. Altitudes of wellheads were surveyed using survey-grade GPS survey equipment and RTK positioning with estimated accuracy of plus or minus 0.1 ft or less.

Figure 3. Location of wells used in the study of the upper Smith River watershed, Montana.

Groundwater-levels were monitored for long-term trends and seasonal fluctuations in response to climate and water use. Available groundwater-level data collected by the USGS, MCCD, MDNRC, and MBMG were utilized for this study (appendixes 2 and 3). The USGS measured groundwater levels in approximately 170 wells during this study (calendar years 2006 – 2010) with measurement frequencies that ranged from single measurements during well inventories to hourly measurements with continuous recorders. The MDNRC, a contractor for the MCCD, and the MBMG have also measured groundwater levels monthly (March–November) in approximately 40 wells in the area since 2000 and in two wells since the early 1990s. Groundwater levels were synoptically measured in approximately 130 wells by the USGS and other agencies in March 2007, August 2007, October 2007, March 2008, and March 2010. These data were used to create synoptic potentiometric-surface maps.

Depth to water was measured to the nearest 0.01 ft with an electronic sounder or steel tape and referenced to land-surface datum. The altitude of the groundwater was calculated by subtracting the depth to groundwater from the land surface altitude which was referenced to the North American Vertical Datum of 1988. An attempt was made to measure groundwater levels during static conditions, which are water levels that are not affected by pumping in the measured or nearby wells. USGS personnel accompanied the MCCD contractor on two occasions (November 2005 and October 2006) and independently measured groundwater levels in the MCCD observation well network to verify procedures and accuracy.

The USGS contracted the drilling of two exploration wells in 2008 and 2009 for this study in an attempt to determine the thickness of basin-fill sediments within the central part of the upper Smith River watershed. Wells were drilled with either an air-rotary or mud-rotary drill rig. Both wells were completed as open holes with an upper 6-in. diameter steel casing to prevent the wells from collapsing. Drill cuttings were collected at 5-ft intervals or when the lithologic character of the material appeared to change. Mitchell Reynolds (scientist emeritus, USGS, Denver, Colorado) examined and described the cuttings (appendix 4). Estimates of yield (the volume of water discharged from the well in gallons per minute) were provided by the driller at various depths during well installation.

Surface Water

Since 1905, the USGS has operated several streamflow-gaging stations within the Smith River watershed. Streamflow and stage relationships were used at four long-term USGS streamflow-gaging stations and 13 temporary USGS streamflow-gaging stations to calculate continuous streamflow over a range of time periods (table 1, fig. 4). Additional miscellaneous measurements were collected at 67 sites during the course of this study (Appendix 5). Miscellaneous streamflow measurement frequency varied from single miscellaneous measurements to several measurements. All streamflow measurements collected during this study were made using standard USGS protocols (Rantz and others, 1982; Nolan and Shields, 2000; Turnipseed and Sauer, 2010). Cross-section locations were selected to maximize favorable flow conditions and minimize potential errors due to irregular velocity profiles, aquatic vegetation, and uneven streambeds.

Table 1. U.S. Geological Survey streamflow-gaging stations in the Smith River watershed, Montana.

[Map number, used for cross reference for locations plotted on figure 4; Station identification number, see Site-Identification System section for explanation; Station name, see Site-Identification System section for explanation; Latitude and longitude reported in degrees, minutes, and seconds relative to North American Datum of 1983]

Map number (fig. 4)	Station identification number	Station name	Latitude	Longitude	Begin date	End date	Comments
1	06075775	South Fork Smith River at Birky Road, near White Sulphur Springs, Montana	46°26'48"	110°55'49"	3/22/2007	9/24/2010	Temporary streamflow-gaging station
2	06075780	South Fork Smith River at Skelton Ranch, near White Sulphur Springs, Montana	46°28'30"	110°56'47"	3/22/2007	10/22/2008	Temporary streamflow-gaging station
3	06075785	South Fork Smith River at McGuire Bridge near White Sulphur Springs, Montana	46°31'24"	110°57'23"	3/22/2007	9/24/2010	Temporary streamflow-gaging station
4	463638110460501	North Fork Smith River at Studhorse Road near White Sulphur Springs, Montana	46°36'38"	110°46'08"	3/19/2010	9/24/2010	Temporary streamflow-gaging station
5	463426110464801	Fourmile Creek near mouth near White Sulphur Springs, Montana	46°34'26"	110°46'51"	5/18/2010	9/24/2010	Temporary streamflow-gaging station
6	463438110512401	Trinity Spring at Pond outflow near White Sulphur Springs, Montana	46°34'38"	110°51'27"	3/16/2010	9/24/2010	Temporary streamflow-gaging station
7	463340110501401	Willow Creek at South Side Canal near White Sulphur Springs, Montana	46°33'40"	110°50'17"	3/23/2010	10/8/2010	Temporary streamflow-gaging station
8	463242110520101	South Side Canal at Willow Creek near White Sulphur Springs, Montana	46°32'42"	110°52'04"	6/29/2010	10/8/2010	Temporary streamflow-gaging station
9	06075700	North Fork Smith River near mouth near White Sulphur Springs, Montana	46°32'09"	110°56'52"	1/13/1993	7/30/2010	Temporary streamflow-gaging station
10	06075850	Smith River at Galt Ranch near White Sulphur Springs, Montana	46°34'14"	111°02'02"	3/22/2007	10/22/2008	Temporary streamflow-gaging station
11	463357111031801	Big Birch Creek below diversion at 1.7 miles near White Sulphur Springs, Montana	46°33'57"	111°03'21"	7/19/2007	10/5/2010	Temporary streamflow-gaging station
12	06076550	Newlan Creek at mouth near White Sulpher Springs, Montana	46°35'31"	111°02'57"	1/14/1993	10/1/2010	Temporary streamflow-gaging station
13	06076560	Smith River below Newlan Creek near White Sulphur Springs, Montana	46°35'27"	111°03'29"	9/23/2004	continued	Long-term streamflow-gaging station
14	06076580	Smith River at Bodell Ranch Bridge near White Sulphur Springs, Montana	46°37'57"	111°05'30"	9/14/2006	10/23/2008	Temporary streamflow-gaging station
15	06076690	Smith River near Fort Logan, Montana	46°47'45"	111°10'44"	9/23/1977	10/28/2010	Long-term streamflow-gaging station
16	06077200	Smith River below Eagle Creek near Fort Logan, Montana	46°49'41"	111°11'32"	8/1/1996	continued	Long-term streamflow-gaging station
See fig. 1.	06077500	Smith River near Eden, Montana	47°11'21"	111°23'11"	8/4/1988	continued	Long-term streamflow-gaging station

Streamflow-Gaging Stations

During this study, the USGS operated four long-term (operated 4 yr or more) streamflow-gaging stations on the Smith River (fig. 1): (1) Smith River below Newlan Creek near White Sulphur Springs (station number 06076560), (2) Smith River near Fort Logan (station number 06076690), (3) the Smith River below Eagle Creek near Fort Logan (station number 06077200), and (4) the Smith River near Eden (station number 06077500). These streamflow-gaging stations were ongoing, newly established, or reestablished during the course of the study.

The Smith River below Newlan Creek streamflow-gaging station (station number 06076560) was located downstream from the mouths of both Newlan and Birch Creeks before the Smith River flows through a narrowly incised canyon. The streamflow-gaging station was located at river mile 112.1(measured from the confluence with the Missouri River) and the drainage area above the gage was 517 mi^2. The streamflow-gaging station was in continuous operation (full-year record) from October 2004 through December 2011.

The Smith River near Fort Logan streamflow-gaging station (station number 06076690) was located upstream from the mouth of Sheep Creek at river mile 83.6 and the drainage area above the gage was 846 mi^2. This streamflow-gaging station was in continuous operation from October 1977 through September 1996 and again from October 2006 through October 2007. The streamflow-gaging station was in operation seasonally (March or April through October) from 2008 through 2010.

The Smith River below Eagle Creek near Fort Logan streamflow-gaging station (station number 06077200) is located downstream of Eagle Creek at river mile 80.8 and the drainage area above the gage is 1,088 mi^2. This streamflow-gaging station has been in continuous operation since October 1996.

The Smith River near Eden streamflow-gaging station (station number 06077500) is located near the lower end of the watershed 2.6 mi upstream from Hound Creek at river mile 27.0. The drainage area above the gage is 1,594 mi^2. This streamflow-gaging station was in continuous operation from April 1951 through September 1969 and has been operated seasonally (March through October) since March 2006.

In addition to the four long-term USGS streamflow-gaging stations that were in operation during this study, 13 temporary streamflow-gaging stations were installed during the study (fig. 4). Temporary streamflow-gaging stations are defined herein as short-term, study-specific staff gages, instrumented with pressure transducers over various time periods. Temporary streamflow-gaging stations were installed at five locations within the watershed in 2006 and 2007, two on the South Fork Smith River, one on the North Fork Smith River, and two on the main stem of the Smith River as part of the groundwater and surface-water interaction monitoring network (see Groundwater and Surface-Water Interaction Monitoring Networks section). Seven additional temporary streamflow-gaging stations were installed in 2010 as an effort to estimate tributary inflow in the upper watershed. In addition, a temporary streamflow-gaging station was installed in 2009 on Big Birch Creek (station number 463357111031801). Instantaneous (field measurements) streamflow data were collected at this site beginning in 2007. Pressure transducers recorded hourly stage data seasonally at all temporary streamflow-gaging stations over various time periods. Streamflow was periodically measured at the streamflow-gaging stations to develop rating curves based on stage-streamflow relationships. Staff gages were surveyed using survey-grade GPS equipment and RTK positioning. Standard differential leveling surveys were conducted annually from 2006 through 2008 and in 2010 in order to correct for the amount of vertical movement of the staff gages.

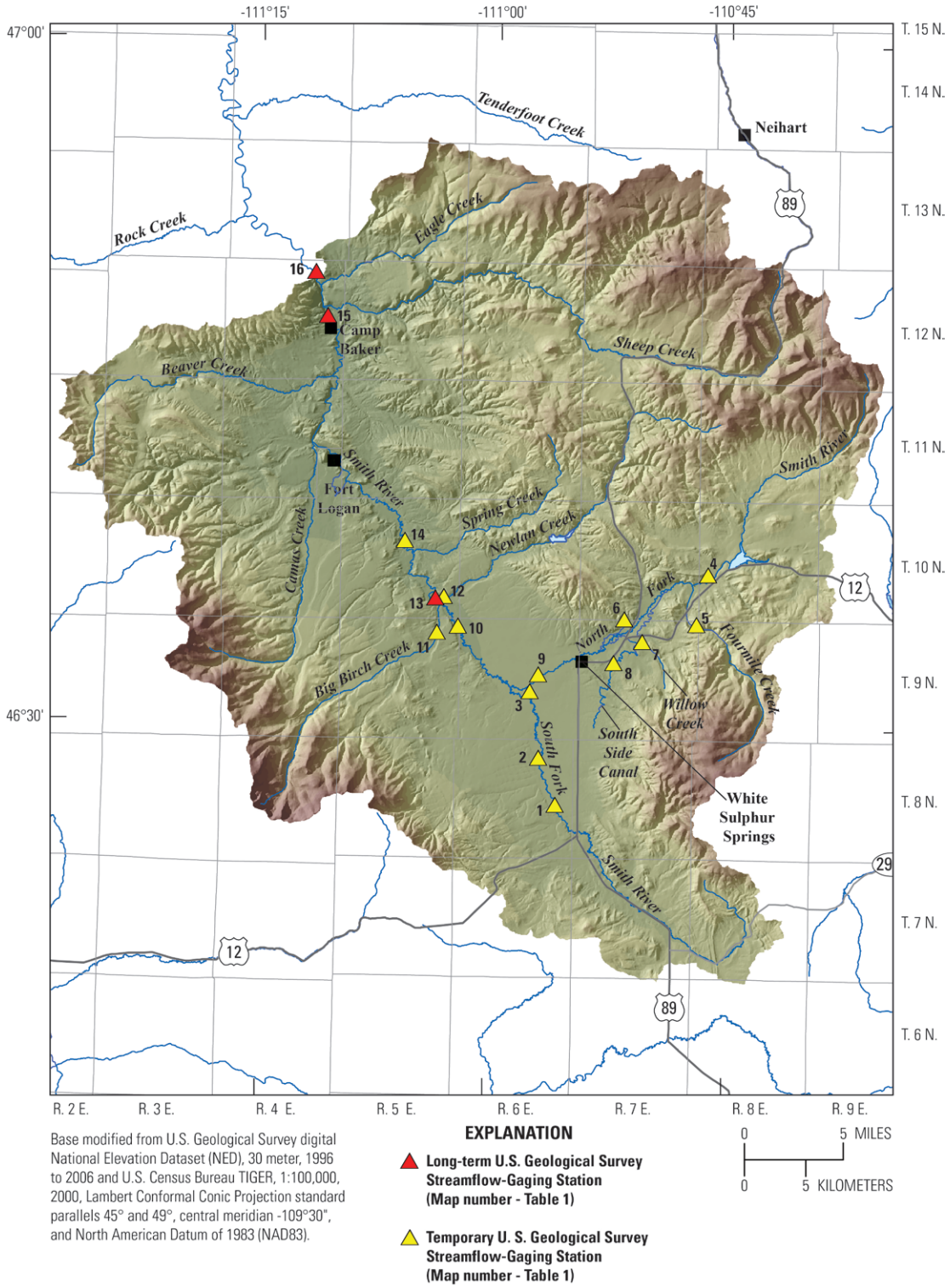

Figure 4. Location of U.S. Geological Survey streamflow-gaging stations in the upper Smith River watershed, Montana.

Synoptic and Miscellaneous Streamflow Measurements

In addition to streamflow measurements conducted at the long-term and temporary USGS streamflow-gaging stations, streamflow was measured during area-wide synoptic events at selected miscellaneous sites (fig. 5). Four area-wide synoptic streamflow measurements were conducted within the upper Smith River watershed from the headwaters of the North and South Forks of the Smith River to downstream of the Smith River below Eagle Creek streamflow-gaging station (station number 06077200) (site 45, fig. 5 and table 2). During each of the synoptic events streamflow, temperature, and specific conductance were measured at up to 45 sites along the Smith River and tributaries. Measurements were conducted over a short period of time (less than 8 hours) by a team of field personnel. The timing of the synoptic events was determined by monitoring weather forecasts and real-time streamflow data from USGS streamflow-gaging stations (Smith River below Newlan Creek (station number 06076560) and the Smith River below Eagle Creek (station number 06077200)) in an attempt to minimize precipitation and snowmelt effects on streamflow. Rapidly changing flow conditions and storm events were avoided.

Synoptic-measurement sites were selected based on aerial photographs, maps, access, and the result of an April 2006 longitudinal survey of the Smith River from the confluence of the North and South Forks of the Smith River to upstream from the mouth of Sheep Creek near Fort Logan (station number 06076690). The longitudinal survey was conducted by continuously logging location, water temperature, and specific conductance with a handheld GPS and a self-contained, multi-parameter water-quality data logger (an In-Situ Inc. multi-parameter TROLL 9500) as a crew floated downstream on a watercraft. Locations of observed tributaries and diversions, as well as possible groundwater inflows indicated by dramatic changes in specific conductance and/or temperature, were noted. Following analysis of the longitudinal survey, synoptic-measurement sites were selected in an effort to quantify tributary and groundwater inflows either by measuring streamflow of tributaries at their mouths or by calculating tributary or groundwater inflows by measuring the main stem streamflow upstream and downstream from the tributaries or suspected groundwater inflow.

Miscellaneous streamflow measurements were conducted at 14 sites ranging from one to ten times (table 3). Data collected include streamflow measurements conducted to examine canal leakage and miscellaneous tributary inflow.

Table 2. Site descriptions and locations for synoptic streamflow measurements in the upper Smith River watershed, Montana.

[Map number, used for cross reference for locations plotted on figure 5; Station Identification number, see Site-Identification System section for explanation; Station name, see Site-Identification System section for explanation; River mile, distance above mouth; Latitude and longitude reported in degrees, minutes, and seconds referenced to North American Datum of 1983; mainstem South Fork Smith River, North Fork Smith River, and Smith River stations in **bold** type]

Map number (fig. 5)	Station identification number	Station name	River mile	Latitude	Longitude
		South Fork Smith River			
1	06075775	**South Fork Smith River at Birky Road Bridge**	15.0	46°26'48"	110°55'49"
2	06075780	**South Fork Smith River at Skelton Ranch**	10.7	46°28'30"	110°56'47"
3	463057110570301	Hot Springs Creek at mouth	4.3	46°30'57"	110°57'06"
4	463107110571401	Unnamed tributary to South Fork Smith River (number 1)	3.8	46°31'07"	110°57'17"
5	463120110571701	Unnamed tributary to South Fork Smith River (number 2)	3.2	46°31'20"	110°57'20"
6	06075785	**South Fork Smith River at McGuire Bridge**	3.1	46°31'24"	110°57'23"
7	463141110583701	**South Fork Smith River at mouth**	0.1	46°31'41"	110°58'40"
		North Fork Smith River			
8	463327110523701	**North Fork Smith River above Spring Creek**	8.4	46°33'27"	110°52'40"
9	463333110525501	Spring Creek near mouth	8.4	46°33'33"	110°52'58"
10	463256110545201	**North Fork Smith River at Highway 360 Bridge**	5.3	46°32'56"	110°54'55"
11	06075700	**North Fork Smith River near mouth**	2.6	46°32'09"	110°56'52"
12	463148110583001	**North Fork Smith River at mouth**	0.3	46°31'48"	110°58'33"
		Smith River			
13	06075810	**Smith River below North Fork Smith River**	122.2	46°32'07"	110°59'48"
14	463241111001801	**Smith River above unnammed tributary** 0.5 miles above Birch Creek Road	120.8	46°32'41"	111°00'21"
15	463240111001501	Unnamed tributary at mouth 0.5 miles above Birch Creek Road	120.7	46°32'40"	111°00'18"
16	463253111002901	Ditch at mouth on south side of Birch Creek Road	120.3	46°32'53"	111°00'32"
17	463255111002801	Ditch at mouth on north side of Birch Creek Road	120.2	46°32'55"	111°00'31"
18	463313111010501	Woods Gulch at mouth	119.1	46°33'13"	111°01'08"
19	463327111011401	**Smith River at Riverside Ranch Bridge**	118.8	46°33'26"	111°01'14"
20	463330111011201	Ditch at mouth at Riverside Ranch	118.4	46°33'30"	111°01'15"
21	463413111014701	Ditch at mouth above Galt Ranch Bridge (number 1)	117.1	46°34'13"	111°01'50"
22	463355111013901	Ditch at mouth above Galt Ranch Bridge (number 2)	116.3	46°33'55"	111°01'42"
23	06075850	**Smith River at Galt Ranch Bridge**	116.0	46°34'14"	111°02'02"
24	463437111021701	**Smith River below Mud Creek**	115.2	46°34'37"	111°02'20"
25	463518111030101	**Smith River above Big Birch Creek**	112.7	46°35'18"	111°03'04"
26	06075900	Big Birch Creek at mouth	112.6	46°35'14"	111°03'16"
27	06076550	Newlan Creek at mouth	112.4	46°35'31"	111°02'57"
28	06076560	**Smith River below Newlan Creek**	112.1	46°35'29"	111°03'27"
29	463636111050701	**Smith River above Thompson Gulch**	108.2	46°36'36"	111°05'10"
30	463638111051801	Thompson Gulch near mouth	108.1	46°36'38"	111°05'21"
31	463743111042701	Spring Creek at Highway 360 Bridge	106.5	46°37'43"	111°04'30"
32	06076580	**Smith River at Bodell Ranch Bridge**	105.1	46°37'57"	111°05'30"
33	463911111055501	**Smith River below Rock Springs Creek**	103.1	46°39'11"	111°05'58"

Table 2. Site descriptions and locations for synoptic streamflow measurements in the upper Smith River watershed, Montana.—Continued

[Map number, used for cross reference for locations plotted on figure 5; Station Identification number, see Site-Identification System section for explanation; Station name, see Site-Identification System section for explanation; River mile, distance above mouth; Latitude and longitude reported in degrees, minutes, and seconds referenced to North American Datum of 1983; mainstem South Fork Smith River, North Fork Smith River, and Smith River stations in **bold** type]

Map number (fig. 5)	Station identification number	Station name	River mile	Latitude	Longitude
34	464033111083501	Smith River at Highway 360 Bridge	98.4	46°40'33"	111°08'38"
35	464034111092001	Unnamed tributary to Smith River at mouth near Fort Logan	97.8	46°40'34"	111°09'23"
36	464043111100801	Unnamed tributary to Smith River from Soldiers Lake	96.8	46°40'43"	111°10'11"
37	464218111113501	Smith River above Camas Creek	94.3	46°42'18"	111°11'31"
38	06076600	Camas Creek at mouth	94.2	46°42'19"	111°11'35"
39	06076650	Benton Gulch at mouth	94.1	46°42'20"	111°11'36"
40	464222111113201	Smith River below Benton Gulch	94.0	46°42'22"	111°11'35"
41	464550111094601	Smith River below Beaver Creek	88.1	46°45'50"	111°09'49"
42	06076690	Smith River near Fort Logan	83.6	46°47'45"	111°10'44"
43	464816111110001	Sheep Creek at mouth	82.7	46°48'17"	111°11'03"
44	464942111095101	Eagle Creek near mouth	81.4	46°49'42"	111°09'54"
45	06077200	Smith River below Eagle Creek	80.8	46°49'41"	111°11'32"

Table 3. Site descriptions and locations for miscellaneous streamflow measurements in the upper Smith River watershed, Montana.

[Station identification number, see Site-Identification System section for explanation; Station name, see Site-Identification System section for explanation; Latitude and longitude reported in degrees, minutes, and seconds referenced to North American Datum of 1983. Abbreviations: mi, miles; ft, feet]

Station identification number	Station name	Latitude	Longitude	Begin date	End date
463257110444001	Fourmile Creek above Grasshopper Creek near White Sulphur Springs, Montana	46°32'57"	110°44'43"	5/18/2010	10/8/2010
463245110444701	Grasshopper Creek near mouth near White Sulphur Springs, Montana	46°32'45"	110°44'50"	5/20/2010	10/8/2010
463546110491101	South Side Canal near diversion near White Sulphur Springs, Montana	46°35'46"	110°49'14"	6/29/2010	9/16/2010
463254110560601	Unnamed ditch 2800 ft downstream North Fork Smith River near White Sulphur Springs, Montana	46°32'54"	110°56'09"	5/27/2010	8/18/2010
463307110564801	Unnamed ditch 1.15 mi downstream North Fork Smith River near White Sulphur Springs, Montana	46°33'07"	110°56'54"	5/27/2010	5/27/2010
462756110533901	Catlin Spring at mouth near White Sulphur Springs, Montana	46°27'56"	110°53'42"	5/1/2008	6/13/2008
06075810	Smith River below North Fork Smith River near White Sulphur Springs, Montana	46°32'07"	110°59'48"	4/27/2006	10/22/2008
463257111002801	Smith River below Birch Creek Road Bridge, Montana	46°32'57"	111°00'31"	4/27/2006	4/27/2006
464515111101501	Unnamed ditch at diversion from Smith River near Fort Logan, Montana	46°45'15"	111°10'18"	8/5/2008	9/15/2010
464525111100301	Unnamed ditch 1700 ft downstream Smith River near Fort Logan, Montana	46°45'25"	111°10'06"	6/22/2010	9/15/2010
464600111094001	Unnamed ditch 1.2 mi downstream Smith River near Fort Logan, Montana	46°46'00"	111°09'43"	6/22/2010	9/15/2010
464624111093701	Unnamed ditch 1.65 mi downstream Smith River near Fort Logan, Montana	46°46'24"	111°09'40"	8/5/2008	9/15/2010
464822111094901	Unnamed ditch 100 ft downstream Sheep Creek near Fort Logan, Montana	46°48'22"	111°09'52"	6/22/2010	6/22/2010
464810111100101	Unnamed ditch 1500 ft downstream Sheep Creek near Fort Logan, Montana	46°48'10"	111°10'04"	6/22/2010	6/22/2010

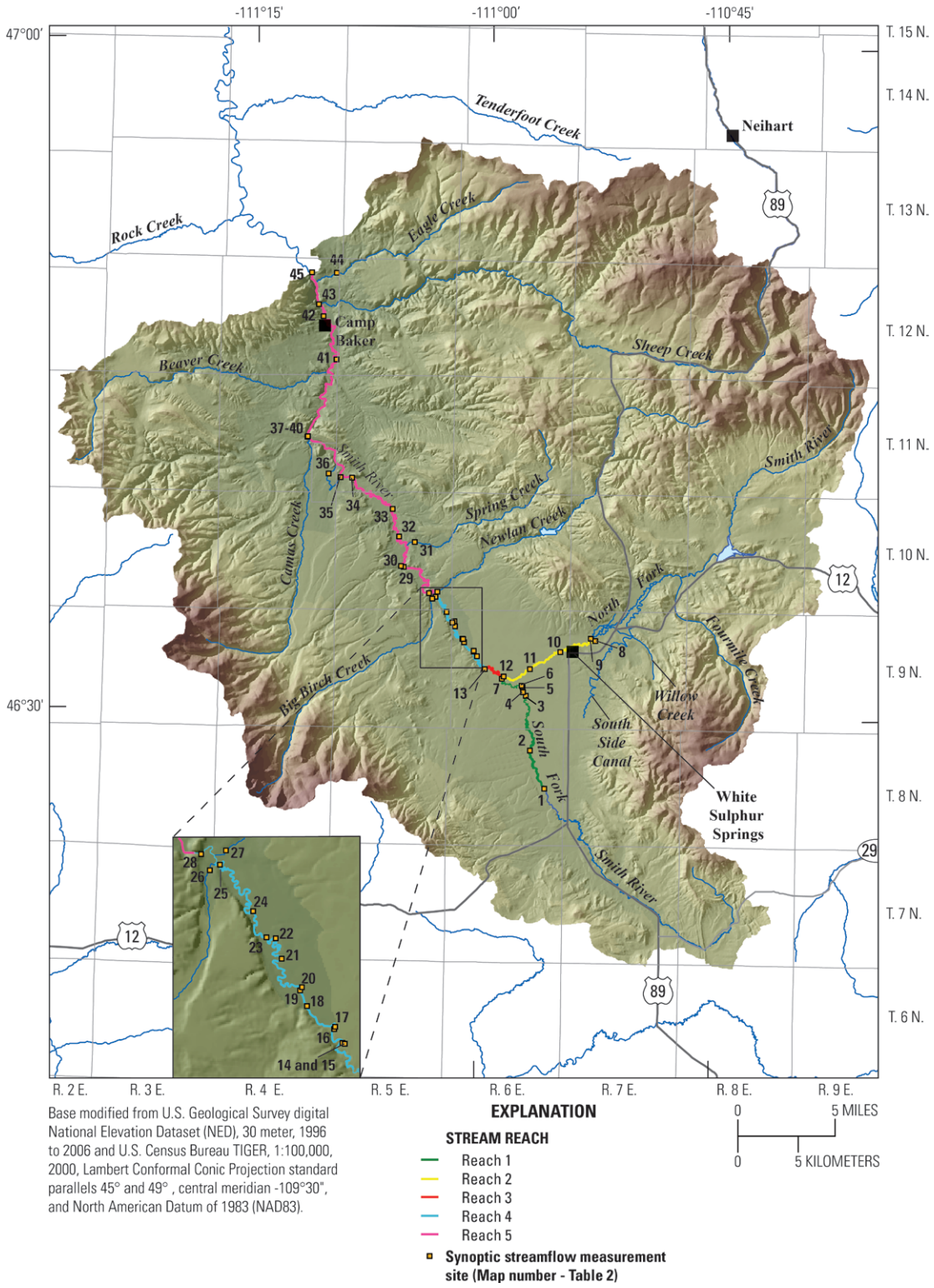

Figure 5. Location of synoptic streamflow measurement sites in the upper Smith River watershed, Montana.

Groundwater and Surface-Water Interaction Monitoring Networks

Ten locations were selected along the North Fork Smith River, South Fork Smith River, and the main stem of the Smith River to examine groundwater and surface-water interactions (table 4, fig. 6). Each groundwater and surface-water monitoring site consisted of one to five monitoring wells and a staff gage. Sites with one or two wells were designed to determine the general groundwater and surface-water flow direction, whereas sites with four or five wells were designed to also estimate streambed conductance and fluxes. The four sites with one or two wells were typically installed within the stream approximately 2.5 ft from the stream bank. A typical cross section with four or five wells had a well installed on both the left and right stream banks approximately 2.5 ft from the water's edge. In addition, a well was installed within the stream approximately 2.5 ft from each stream bank. Deeper wells were installed at three locations to examine groundwater-level variations with depth. The deeper wells were installed in the streams about 2.5 ft from the stream bank adjacent to the shallower wells. In some cases, existing monitoring wells or water-supply wells were also in near proximity.

Monitoring wells were constructed of either 1¼ -in. or 2-in. diameter galvanized pipe with a threaded drive point attached to the end. The lower 0.1 ft of the pipe (just above the drive point) was perforated with up to 50 drilled holes of $^{1}/_{8}$-in. diameter. Three initial wells were installed using a fence-post driver. The remaining wells were installed with an air-powered jack hammer. An effort was made to install all of the wells at least 4.5 ft below the stream bottom. For a small number of wells this wasn't possible because substrate such as boulders or bedrock prevented further progress with this method. Wells were developed with compressed air until the water became clear. Well heads and staff gages at each groundwater and surface-water interaction monitoring site were surveyed annually from 2006 through 2008 using standard differential leveling methods in order to correct for the vertical movement of the wells and staff gages.

Stream stage, groundwater levels, and water temperature were measured manually on a semi-monthly basis primarily from March 2007 through December 2008 at the groundwater and surface-water interaction monitoring sites. Manual measurements were discontinued during the winter due to freezing conditions in both the streams and monitoring wells. Manual measurements were used for verification and calibration of the data collected continuously with data loggers.

Hourly pressure and water-temperature data were collected in seven of the monitoring wells (table 4) using LevelTROLL 300 loggers (In-Situ Inc.) with non-vented pressure transducers. Data were collected hourly at these sites between April and November, 2007, and April and November, 2008. Barometric pressure data were collected hourly at two locations within the study area using BaroTROLL loggers (In-Situ Inc.) for use in calculating the net pressure head and groundwater levels in the seven monitoring wells.

Continuous (hourly) water-temperature data were collected in the streams and at two depths (approximately 1.5 and 3.0 ft below the stream bottom) in 28 monitoring wells (table 4) at the groundwater and surface-water interaction monitoring sites using StowAway TidBit temperature loggers (Onset Computer Corporation). The loggers recorded water-temperature every hour from April through November in 2007 and 2008. The loggers were retrieved during the winter to avoid damage from freezing or loss during spring run-off. One well was lost in March 2007 due to a rapid thawing of the stream followed by a rapid rise in stage and movement of ice downstream. This well was replaced.

Table 4. Groundwater and surface-water interaction monitoring sites in the upper Smith River watershed, Montana.

[Map number, used for cross reference for locations plotted on figure 6; Station name, see Site-Identification System section for explanation; Station identification number, see Site-Identification System section for explanation; Site identification number, see Site-Identification System section for explanation; Well local identification number, identification number assigned to wells installed for the U.S. Geological Survey groundwater/surface-water interaction monitoring network; Latitude and longitude of well reported in degrees, minutes, seconds, and tenths of seconds referenced to North American Datum of 1983; Altitude of land surface, land-surface altitude in feet referenced to North American Vertical datum of 1988; Well depth, depth of well below land surface in feet; Open interval top, depth of top of open interval below land surface in feet; Remarks: Midstream, well located near middle of stream; Instream, well located in stream channel; Bank, well located on stream bank; Temperature, instrumented with temperature loggers; Pressure, instrumented with pressure transducer. Abbreviations: ft, feet; LEW, left edge of water; REW, right edge of water.]

Map Number (fig. 6)	Station name and station identification number of stream	Site identification number of well	Station name of well	Well local identification number	Latitude of well	Longitude of well	Altitude of land surface (feet)	Well depth (feet)	Open interval top (feet)	Remarks
1	South Fork Smith River at Birky road (station 06075775)	462649110554901	08N06E13CCCC01	SF0606B	46°26'48.8"	110°55'49.1"	5040.70	4.80	4.50	Midstream, Temperature
2	South Fork Smith River at Skelton Ranch (station 06075780)	462830110564701	08N06E11BABB02	SF0605	46°28'30.0"	110°56'47.3"	4991.40	4.65	4.35	Midstream, Temperature, Pressure
3	South Fork Smith River at McGuire Bridge (station 06075785)	463124110572301	09N06E22DBCD01	SF0601	46°31'23.9"	110°57'22.6"	4921.10	4.97	4.67	Instream - 2.5 ft from REW, Temperature
3	South Fork Smith River at McGuire Bridge (station 06075785)	463124110572302	09N06E22DBCD02	SF0602	46°31'24.0"	110°57'22.6"	4921.60	5.00	4.70	Bank - 2.5 ft from REW, Temperature
3	South Fork Smith River at McGuire Bridge (station 06075785)	463124110572303	09N06E22DBCD03	SF0603	46°31'23.7"	110°57'22.8"	4920.76	4.76	4.46	Instream - 2.5 ft from LEW, Temperature, Pressure
3	South Fork Smith River at McGuire Bridge (station 06075785)	463124110572304	09N06E22DBCD04	SF0604	46°31'23.6"	110°57'22.8"	4922.46	7.23	6.93	Bank - 2.5 ft from LEW, Temperature
4	North Fork Smith River near mouth (station 06075700)	463210110565101	09N06E14CCBC01	NF0601	46°32'09.6"	110°56'51.0"	4950.01	5.40	5.10	Bank - 2.5 ft from REW, Temperature
4	North Fork Smith River near mouth (station 06075700)	463210110565102	09N06E14CCBC02	NF0602	46°32'09.6"	110°56'51.0"	4948.69	4.72	4.42	Instream - 2.5 ft from REW, Temperature, Pressure
4	North Fork Smith River near mouth (station 06075700)	463210110565103	09N06E14CCBC03	NF0603	46°32'09.5"	110°56'50.6"	4949.26	4.50	4.20	Instream - 2.5 ft from LEW, Temperature
4	North Fork Smith River near mouth (station 06075700)	463209110565101	09N06E14CCBC04	NF0604	46°32'09.4"	110°56'50.6"	4950.51	5.74	5.44	Bank - 2.5 ft from LEW, Temperature
5	Smith River below North Fork Smith River (station 06075775)	463207110594801	09N06E17DCDB01	SR0614	46°32'07.3"	110°59'48.5"	4883.70	6.55	6.25	Bank - 2.5 ft from REW, Temperature
5	Smith River below North Fork Smith River (station 06075775)	463207110594802	09N06E17DCDB02	SR0615	46°32'07.2"	110°59'48.5"	4882.20	4.85	4.55	Instream - 2.5 ft from REW, Temperature
5	Smith River below North Fork Smith River (station 06075775)	463207110594803	09N06E17DCDB03	SR0616	46°32'07.0"	110°59'48.5"	4881.50	4.45	4.15	Instream - 2.5 ft from LEW, Temperature, Pressure
5	Smith River below North Fork Smith River (station 06075775)	463207110594804	09N06E17DCDB04	SR0617D	46°32'07.0"	110°59'48.5"	4881.60	7.40	7.10	Instream - 2.5 ft from LEW
5	Smith River below North Fork Smith River (station 06075775)	463207110594805	09N06E17DCDB05	SR0617	46°32'07.0"	110°59'48.5"	4884.80	8.40	8.10	Bank - 2.5 ft from LEW, Temperature
6	Smith River at Birch Creek Road (station 463257111002801)	463251111003301	09N06E17BBBD01	SR06B	46°32'51.2"	111°00'33.4"	4866.30	1.90	1.60	Instream - 2.5 ft from REW, Temperature
7	Smith River at Riverside Ranch (station 463327111011401)	463326111011801	09N06E07ACBC01	SR0612	46°33'26.3"	111°01'17.9"	4849.90	5.00	4.70	Instream - 2.5 ft from LEW, Temperature
7	Smith River at Riverside Ranch (station 463327111011401)	463326111011802	09N06E07ACBC02	SR0613	46°33'26.2"	111°01'17.6"	4849.90	4.40	4.10	Instream - 2.5 ft from REW, Temperature
8	Smith River at Galt Bridge (station 06075850)	463414111020201	09N05E01CDDA01	SR0608	46°34'14.2"	111°02'02.4"	4829.20	6.15	5.85	Bank - 2.5 ft from REW, Temperature
8	Smith River at Galt Bridge (station 06075850)	463414111020202	09N05E01CDDA02	SR0609	46°34'14.1"	111°02'02.5"	4827.70	4.55	4.25	Instream - 2.5 ft from REW, Temperature, Pressure
8	Smith River at Galt Bridge (station 06075850)	463414111020203	09N05E01CDDA03	SR0609D	46°34'14.1"	111°02'02.4"	4827.70	9.46	9.16	Instream - 2.5 ft from REW
8	Smith River at Galt Bridge (station 06075850)	463414111020301	09N05E01CDDA04	SR0610	46°34'13.9"	111°02'02.6"	4827.50	4.15	3.85	Instream - 2.5 ft from LEW, Temperature

Table 4. Groundwater and surface-water interaction monitoring sites in the upper Smith River watershed, Montana.—Continued

[Map number, used for cross reference for locations plotted on figure 6; Station name, see Site-Identification System section for explanation; Station identification number, see Site-Identification System section for explanation; Site identification number, see Site-Identification System section for explanation; Well local identification number, identification number assigned to wells installed for the U.S. Geological Survey groundwater/surface-water interaction monitoring network; Latitude and longitude of well reported in degrees, minutes, seconds, and tenths of seconds referenced to North American Datum of 1983; Altitude of land surface, land-surface altitude in feet referenced to North American Vertical datum of 1988; Well depth, depth of well below land surface in feet; Open interval top, depth of top of open interval below land surface in feet; Remarks: Midstream, well located near middle of stream; Instream, well located in stream channel; Bank, well located on stream bank; Temperature, instrumented with temperature loggers; Pressure, instrumented with pressure transducer. Abbreviations: ft, feet; LEW, left edge of water; REW, right edge of water.]

Map Number (fig. 6)	Station name and station identification number of stream	Site identification number of well	Station name of well	Well local identification number	Latitude of well	Longitude of well	Altitude of land surface (feet)	Well depth (feet)	Open interval top (feet)	Remarks
8	Smith River at Galt Bridge (station 06075850)	463414111020302	09N05E01CDDA05	SR0611	46°34'13.9"	111°02'02.7"	4829.00	5.65	5.35	Bank - 2.5 ft from LEW, Temperature
9	Smith River below Newlan Creek (station 06076560)	463529111032501	10N05E35AABA01	SR06A	46°35'28.7"	111°03'25.3"	4791.10	2.15	1.85	Instream - 2.5 ft from LEW, Temperature, Pressure
9	Smith River below Newlan Creek (station 06076560)	463529111032502	10N05E35AABA02	SR0601	46°35'28.9"	111°03'25.1"	4793.90	6.35	6.05	Bank - 2.5 ft from LEW, Temperature
9	Smith River below Newlan Creek (station 06076560)	463529111032503	10N05E35AABA03	SR0602	46°35'28.9"	111°03'25.1"	4791.30	4.05	3.75	Instream - 2.5 ft from LEW, Temperature
10	Smith River at Bodell Bridge (station 06076580)	463757111053001	10N05E15BACB01	SR0604	46°37'57.2"	111°05'30.1"	4680.20	7.60	7.30	Bank - 2.5 ft from REW, Temperature
10	Smith River at Bodell Bridge (station 06076580)	463757111053002	10N05E15BACB02	SR0605	46°37'57.2"	111°05'30.2"	4677.50	4.70	4.40	Instream - 2.5 ft from REW, Temperature, Pressure
10	Smith River at Bodell Bridge (station 06076580)	463757111053003	10N05E15BACB03	SR0605D	46°37'57.1"	111°05'30.2"	4677.30	6.35	6.05	Instream - 2.5 ft from REW
10	Smith River at Bodell Bridge (station 06076580)	463757111053101	10N05E15BACB04	SR0606B	46°37'56.9"	111°05'30.6"	4677.60	4.90	4.50	Instream - 2.5 ft from LEW, Temperature
10	Smith River at Bodell Bridge (station 06076580)	463757111053102	10N05E15BACB05	SR0607	46°37'56.9"	111°05'30.7"	4679.20	5.50	5.20	Bank - 2.5 ft from LEW, Temperature

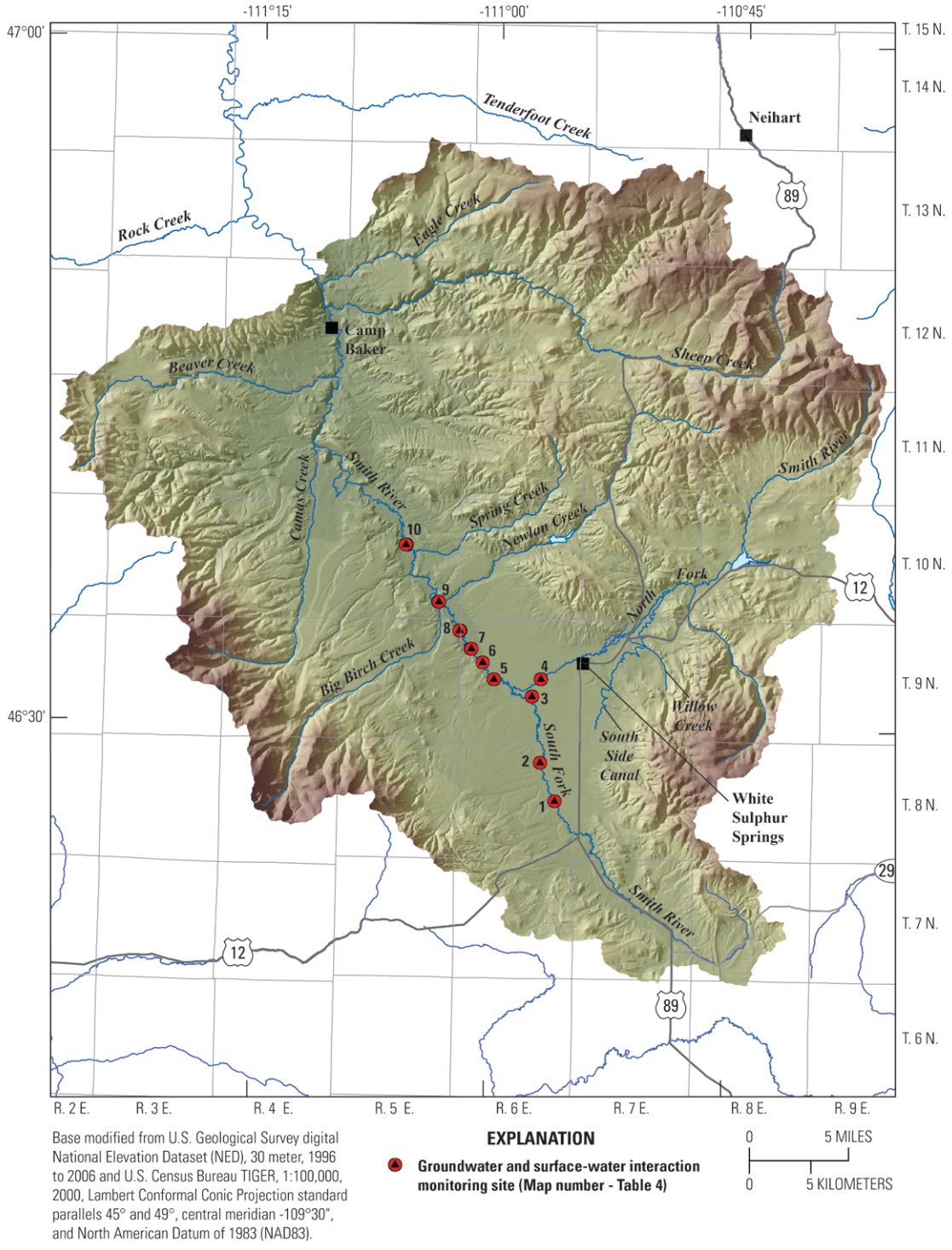

Figure 6. Location of groundwater and surface-water monitoring sites in the upper Smith River watershed, Montana.

Groundwater Chemistry and Quality Assurance

Eight wells were sampled to examine water chemistry and calculate groundwater age (fig. 3, appendix 1). Six of the sampled wells were low-production water-supply wells with existing submersible pumps. Two of the sampled wells did not have existing pumps and were sampled with a portable submersible pump. Samples were analyzed for field parameters (water temperature, pH, specific conductance, and dissolved oxygen), major ions, chlorofluorocarbons, sulfur hexafluoride, tritium, and stable isotopes of oxygen and hydrogen.

Water samples were collected and processed using established sampling procedures (U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data). Prior to sampling at wells, casing volume and pumping rate were calculated to estimate purge time required to evacuate three casing volumes of water. Three casing volumes were purged before sample collection in order to remove standing water and to ensure that the well was replenished with water representative of the aquifer. Field parameters were recorded at 3–5 minute intervals during purging. Samples were collected after three well volumes had been purged and field measurements had stabilized for three consecutive measurements. Sampled water was collected using Teflon tubing, stainless-steel connections, and Teflon valves. Flow from the wells was controlled using a two-valve manifold that diverted a continuous stream of water from the well to an enclosed collection chamber. All equipment was cleaned immediately after sampling each well using established procedures (U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data).

All samples were processed in the field within 1 hour of sample collection. Alkalinity was determined in the field using the incremental titration method. Samples analyzed for major ions were filtered onsite with a disposable 0.45-micron pore-size filter. Major ions (cation species) were acidified immediately following collection. Samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colo., the USGS Reston Chlorofluorocarbon Laboratory (RCL) in Reston, Va., and the USGS Isotopes Tracers Laboratory (ITL) in Menlo Park, Calif.

Quality-control samples were collected to examine potential contamination and analytical measurement variability. Quality-control samples collected for this study included a replicate for one well for major-ion and tritium analyses. Replicate analyses were conducted on samples from all 8 wells for sulfur hexafluoride, 1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113), Dichlorodifluoromethane (CFC-12), and trichlorofluoromethane (CFC-11). Procedures for collecting quality-control samples are described in Koterba and others (1995). In addition to quality control samples submitted from the field, internal quality-assurance practices at the laboratories were performed systematically to provide quality control for analytical procedures (Pritt and Raese, 1995).

Replicate samples consisted of two environmental samples considered to be identical in composition and were used to assess variability in sample-collection procedures and laboratory analysis. In the field, the two replicate bottles were filled sequentially, one immediately after the other. The combined effects of sample-collection variability and precision of analytical results were evaluated by calculating the relative percent difference (RPD) of the constituent concentrations in replicate analyses. The RPD was calculated for a constituent by dividing the absolute value of the difference between the two concentrations by the mean of the two concentrations and then multiplying by 100.

Hydrologic Data

Summary tables and graphs of data are included in this section of the report and data are included as digital files in the appendixes. Data collected by the USGS are also stored in the USGS

National Water Information System database which can be accessed from the USGS NWIS Water Data for Montana Web page at *http://waterdata.usgs.gov/mt/nwis/*.

Groundwater-Level Data

Groundwater-level data consist of measurements collected by USGS personnel on a semi-monthly or synoptic basis and data collected by other agencies since the 1990s on a semi-monthly basis. Appendix 2 includes groundwater-level data from 74 wells measured primarily by the USGS during 2006–2008 and 2010. Appendix 2 also includes synoptic measurements made in March 2007, August 2007, October 2007, March 2008, and March 2010. Groundwater-level data for wells measured primarily by other agencies including MDNRC, MCCD, and MBMG are included in Appendix 3.

Exploration Well Data

Two exploration wells were drilled for this study in an attempt to define the thickness of basin-fill sediments within the central part of the upper Smith River watershed (fig. 3). The first well (station name 09N06E10CDDD02, Appendix 4) was drilled in 2008 approximately 40 ft north of an existing 46–ft deep well (09N06E10CDDD01, Appendix 1) that had been drilled for the MCCD. The well was cased to 198 ft and drilled open hole to a depth of 425 ft. However, the well collapsed after the removal of the drill stem and the total depth is now 235 ft. The second well (station name 09N06E10DCCC01, Appendix 4), located approximately 100 ft east of the existing MCCD well (09N06E10CDDD01), was drilled in 2008 with the air rotary method using an under reamer to 662 ft and then deepened in 2009 to 905 ft as an open hole.

Both USGS exploration wells encountered unconsolidated to moderately cemented sedimentary material of mixed sources ranging in grain size from clay to gravel. Well yields were estimated at various depths while drilling, with some estimates of more than 400 gallons per minute. Estimates of yield provided by the driller and lithologic descriptions of cuttings are included in Appendix 4.

Surface-Water Monitoring Network

Streamflow data from long-term (operated 4 yr or more) USGS streamflow-gaging stations, temporary streamflow-gaging stations, synoptic streamflow measurements, and miscellaneous measurements are included in appendixes 6 through 8, tables 5 through 8, and represented in figures 7 through 11.

Streamflow Data from Long-term USGS Streamflow-Gaging Stations

Instantaneous (measured) and computed daily streamflow data for the four long-term Smith River streamflow-gaging stations operated during the course of this investigation are included in Appendix 6. Hydrographs for the four long-term USGS Smith River streamflow-gaging stations operated through water year 2010 are included in figures 7 through 10.

The Smith River below Newlan Creek streamflow-gaging station (station identification number 06076560) was located 0.3 mi downstream of Newlan Creek at river mile 112.1 with upstream tributaries including the North Fork Smith River, South Fork Smith River, Birch Creek, Newlan Creek, Fourmile Creek, and Willow Creek. Flow is partly regulated by Lake Sutherlin (a reservoir in the upper North Fork Smith River watershed) and by Newlan Creek Reservoir. The average annual streamflow for water years 2005–2010 was 80.9 cubic feet per second (ft^3/s).

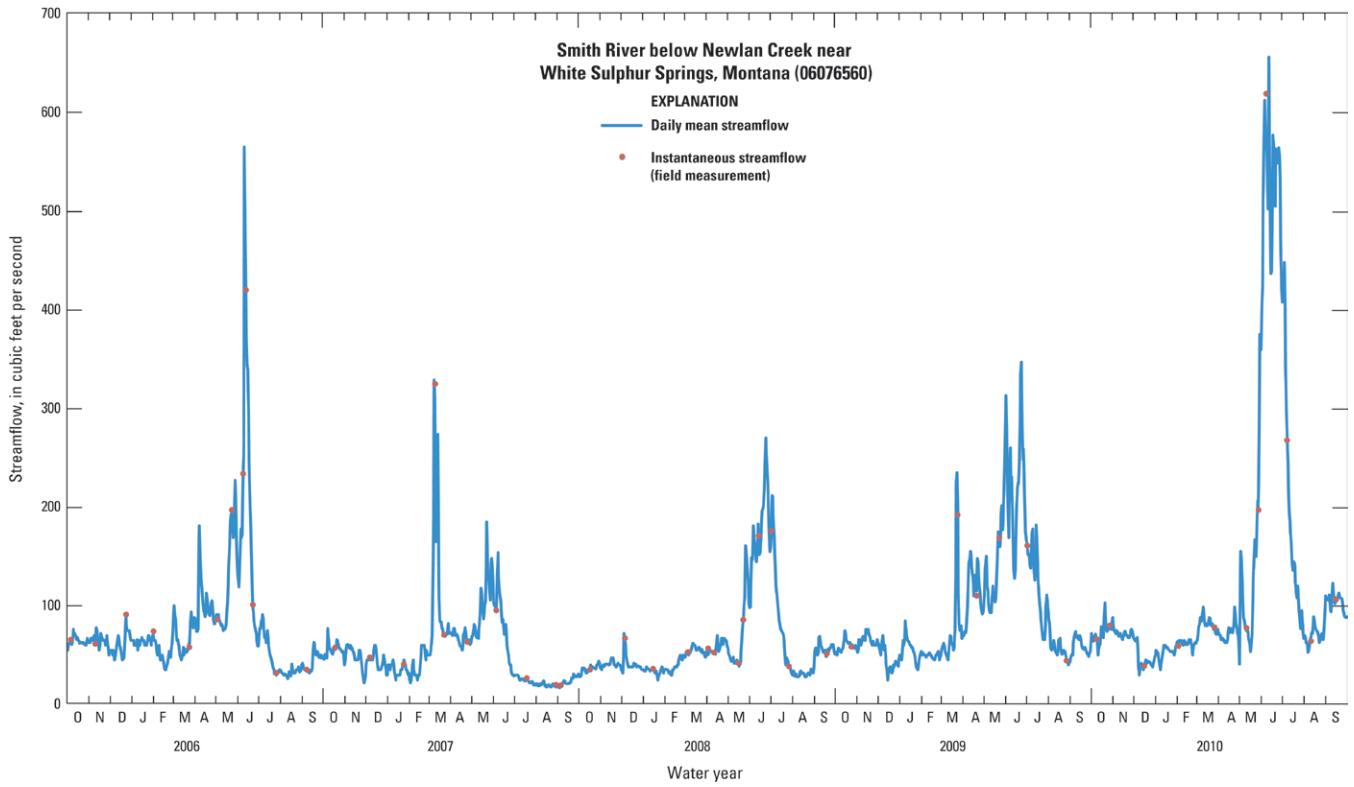

Figure 7. Daily mean streamflow and instantaneous streamflow for U.S. Geological Survey streamflow-gaging station (station identification number 06076560) Smith River below Newlan Creek near White Sulphur Springs, Montana, October 1, 2005, through September 30, 2010.

The Smith River near Fort Logan streamflow-gaging station (station identification number 06076690) was located 1.0 mile upstream of Sheep Creek at river mile 83.6. Tributaries between the Smith River below Newlan Creek streamflow-gaging station (station identification number 06076560) and the Smith River near Fort Logan streamflow-gaging station (station identification number 06076690) include Camas Creek, Benton Gulch, Beaver Creek, and Whitetail Creek. The streamflow-gaging station was in continuous operation during water year 2007 and was operated seasonally (March or April through October) from 2008 through 2010. The average annual streamflow for the available record from 2007 through 2010 was 159 ft^3/s.

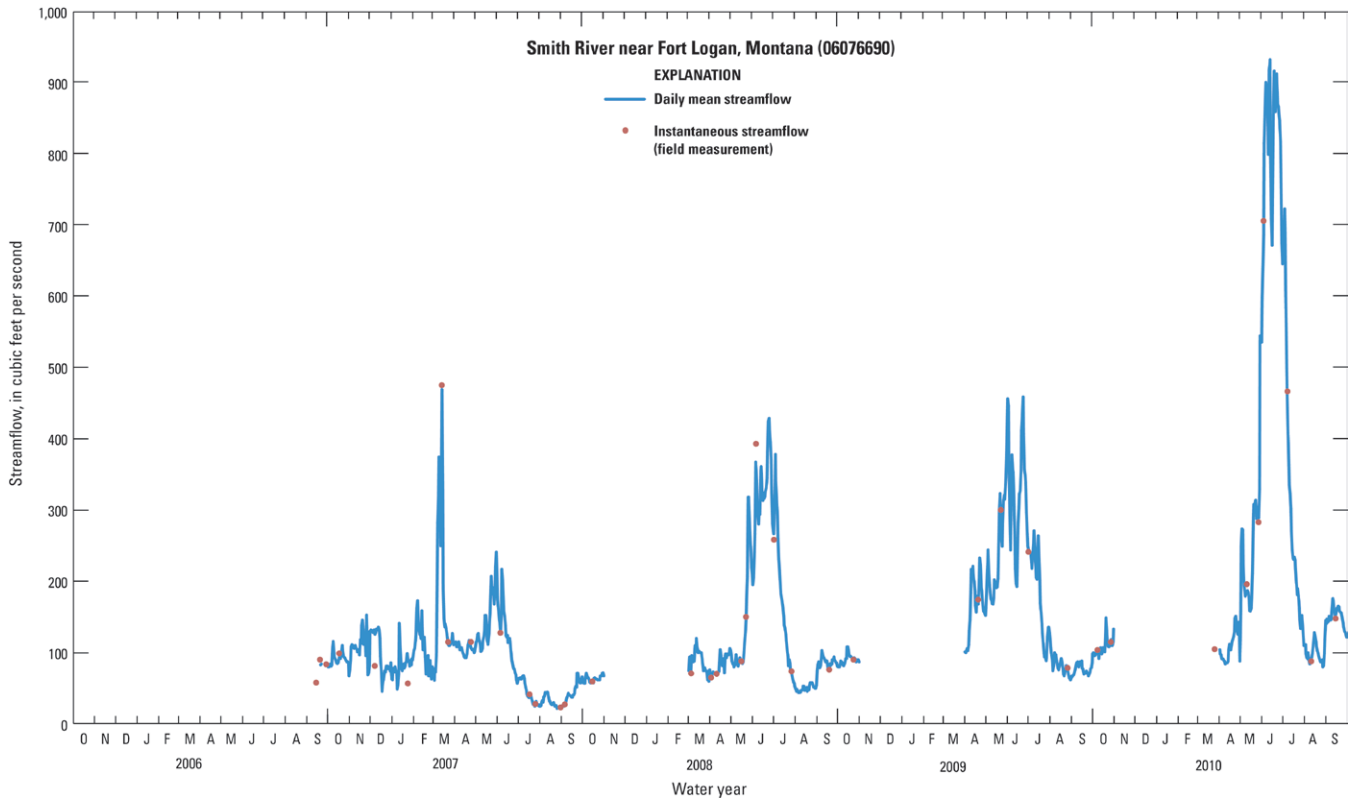

Figure 8. Daily mean streamflow and instantaneous streamflow for U.S. Geological Survey streamflow-gaging station (station identification number 06076690) Smith River near Fort Logan, Montana, September 14, 2006, through September 30, 2010.

The Smith River below Eagle Creek near Fort Logan streamflow-gaging station (station identification number 06077200) is located 0.6 mi below Eagle Creek at river mile 80.8. Tributaries between the Smith River near Fort Logan streamflow-gaging station (station identification number 06076690) and the Smith River below Eagle Creek streamflow-gaging station (station identification number 06077200) include Sheep Creek and Eagle Creek. The average annual streamflow for water years 2005–2010 was 243.8 ft^3/s.

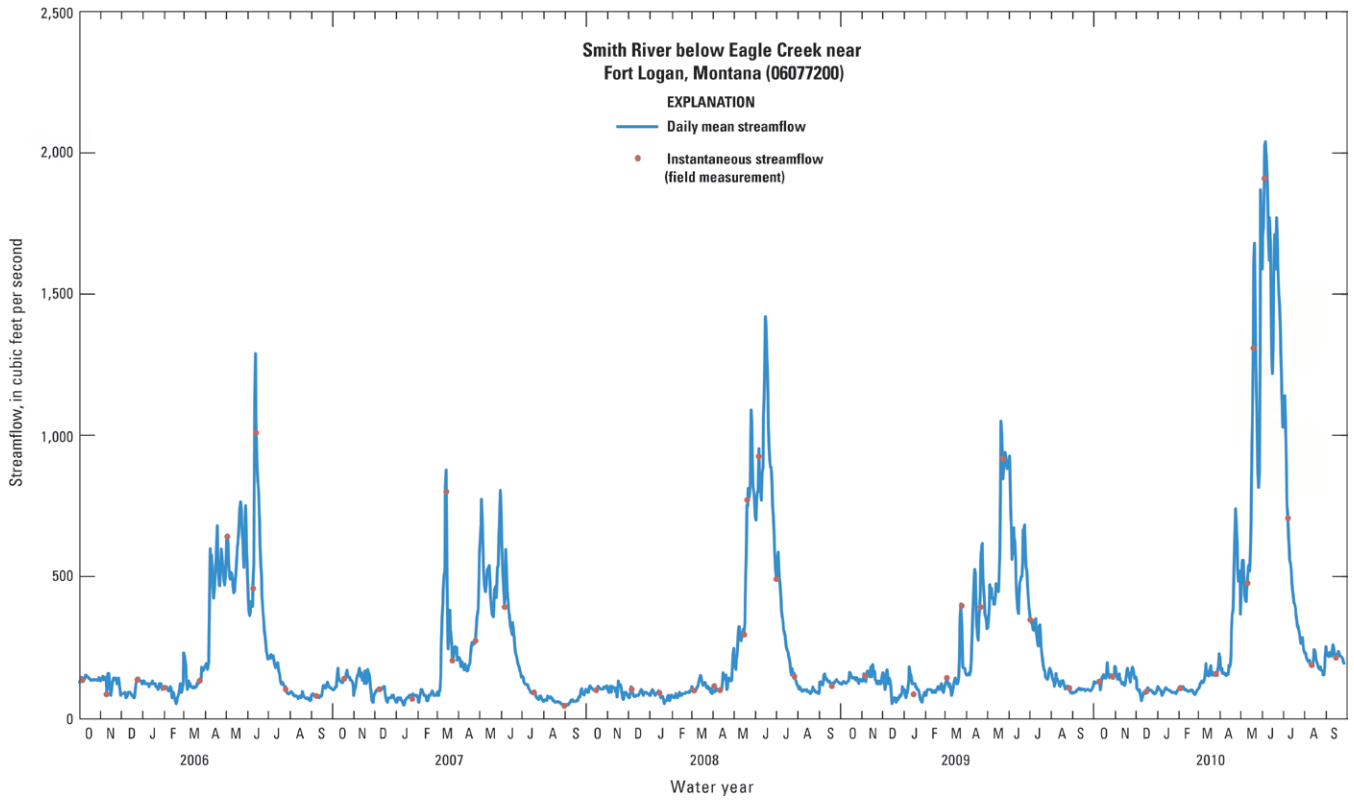

Figure 9. Daily mean streamflow and instantaneous streamflow for U.S. Geological Survey streamflow-gaging station (station identification number 06077200) Smith River below Eagle Creek near Fort Logan, Montana, October 1, 2005, through September 30, 2010.

The Smith River near Eden streamflow-gaging station (station identification number 06077500) is located near the lower end of the watershed, 2.6 mi upstream from Hound Creek at river mile 27.0. This gage includes contributions from several tributaries including Rock Creek and Tenderfoot Creek as the Smith River flows nearly 54 mi downstream from the Smith River below Eagle Creek streamflow-gaging station (station identification number 06077200). The streamflow-gaging station has been operated seasonally (March through October) since March 2006. The average annual streamflow for the available record for water years 2006 through 2010 was 470 ft^3/s.

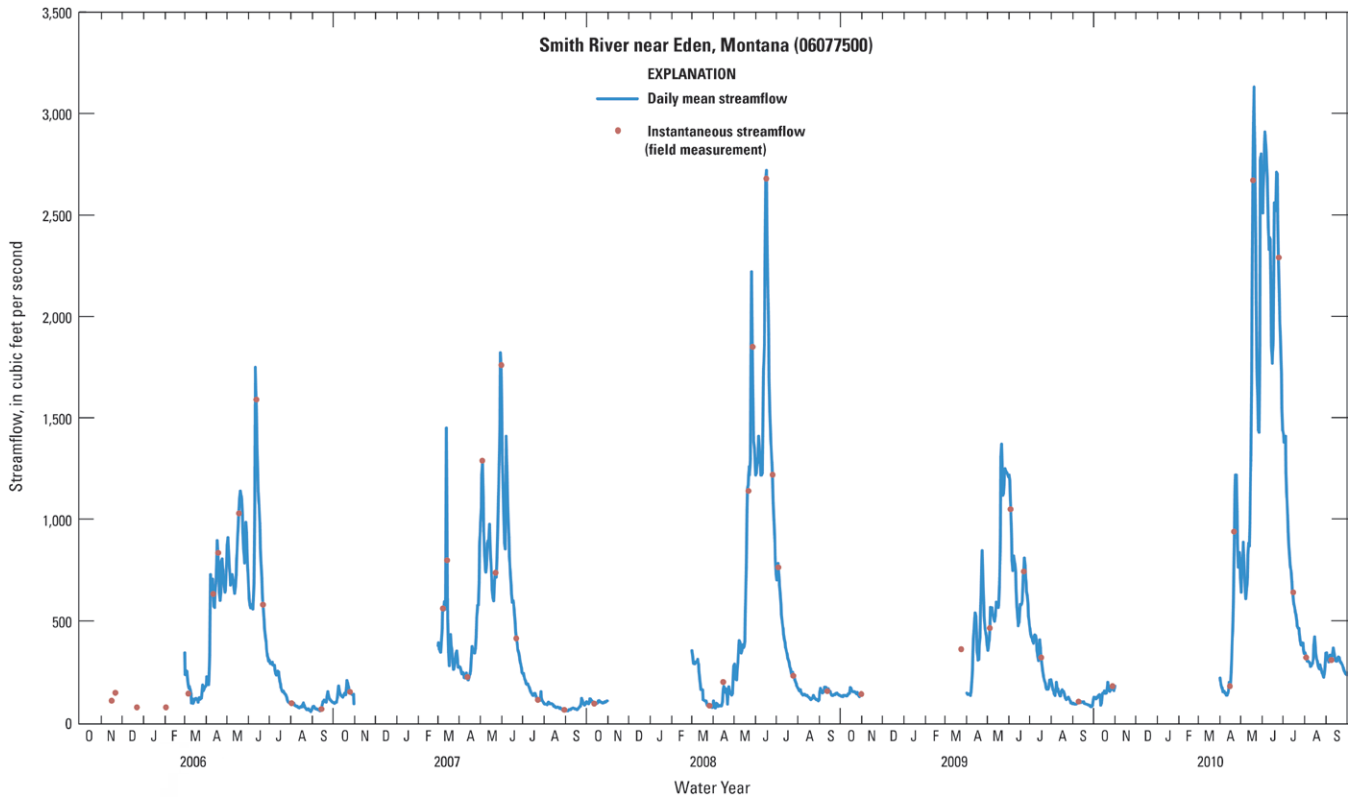

Figure 10. Daily mean streamflow and instantaneous streamflow for U.S. Geological Survey streamflow-gaging station (station identification number 06077500) Smith River near Eden, Montana, November 16, 2005, through September 30, 2010.

Streamflow Data from Temporary USGS Streamflow-Gaging Stations

Instantaneous and computed daily streamflow data for temporary streamflow-gaging stations on Smith River and selected tributaries are included in Appendix 7. Hydrographs of computed daily streamflow for the temporary streamflow-gaging stations are included in figure 11.

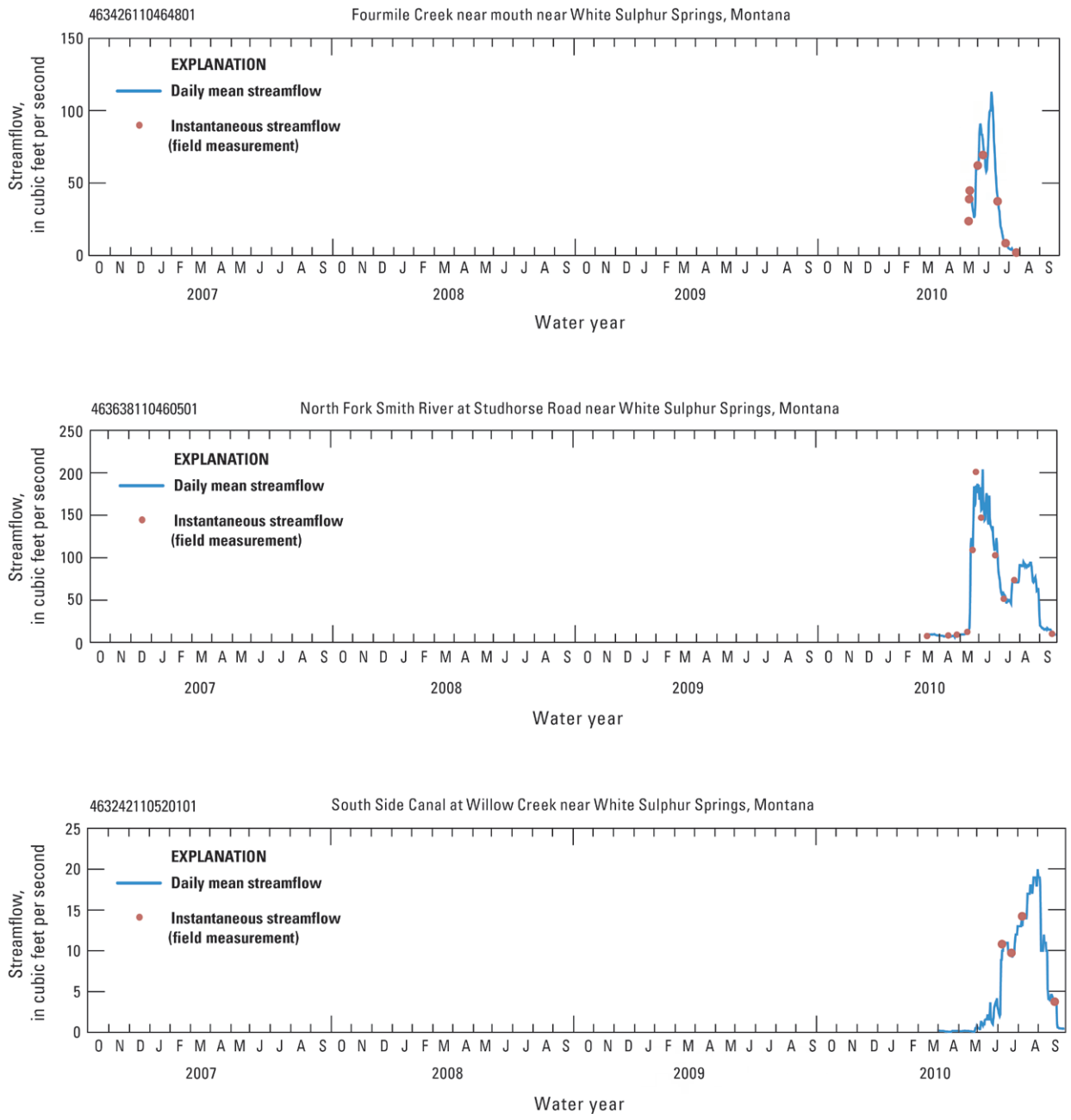

Figure 11. Daily mean streamflow and instantaneous streamflow at temporary U.S. Geological Survey streamflow-gaging stations in the upper Smith River watershed, Montana, 2007–2010.

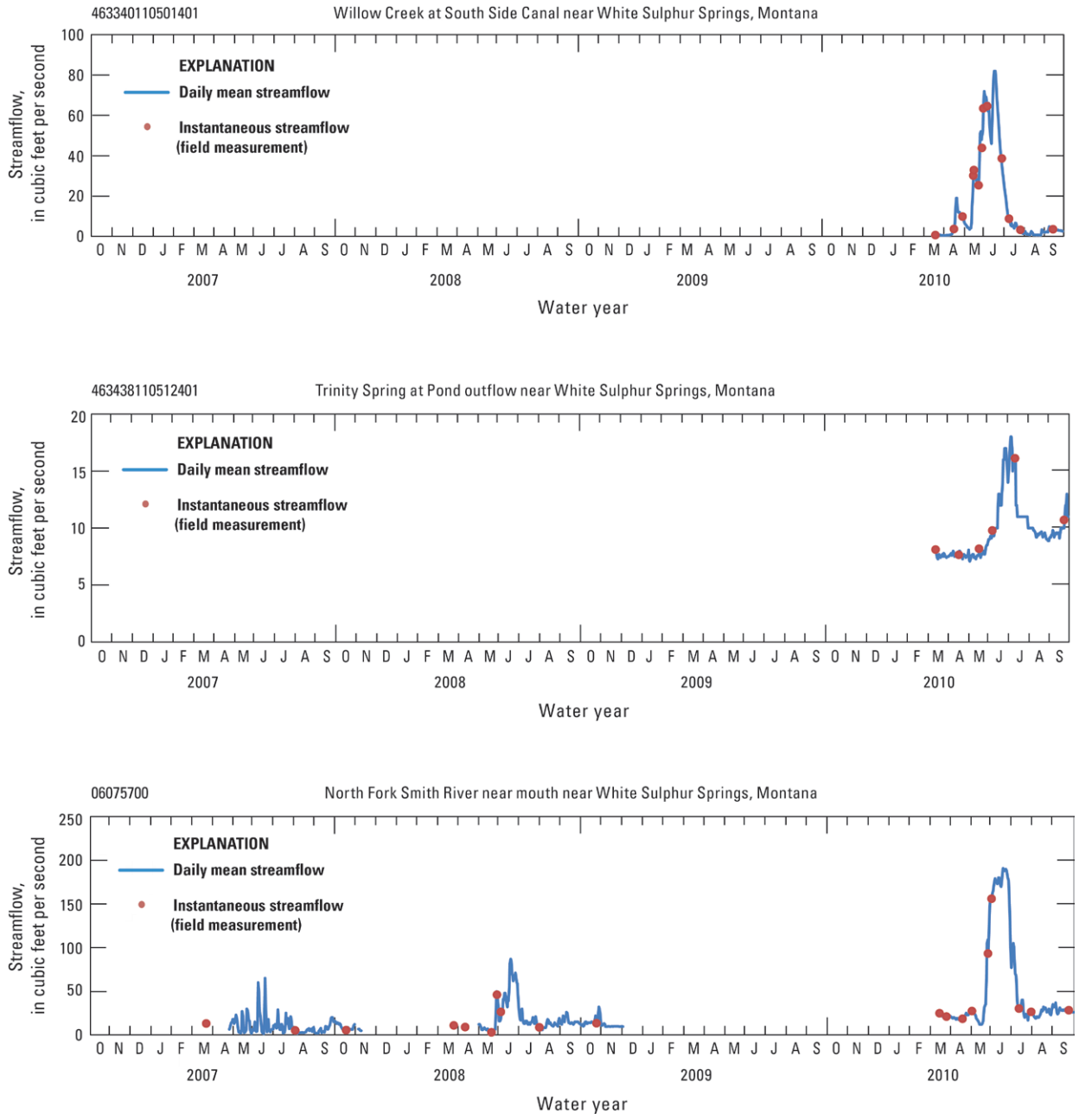

Figure 11. Daily mean streamflow and instantaneous streamflow at temporary U.S. Geological Survey streamflow-gaging stations in the upper Smith River watershed, Montana, 2007–2010.—Continued

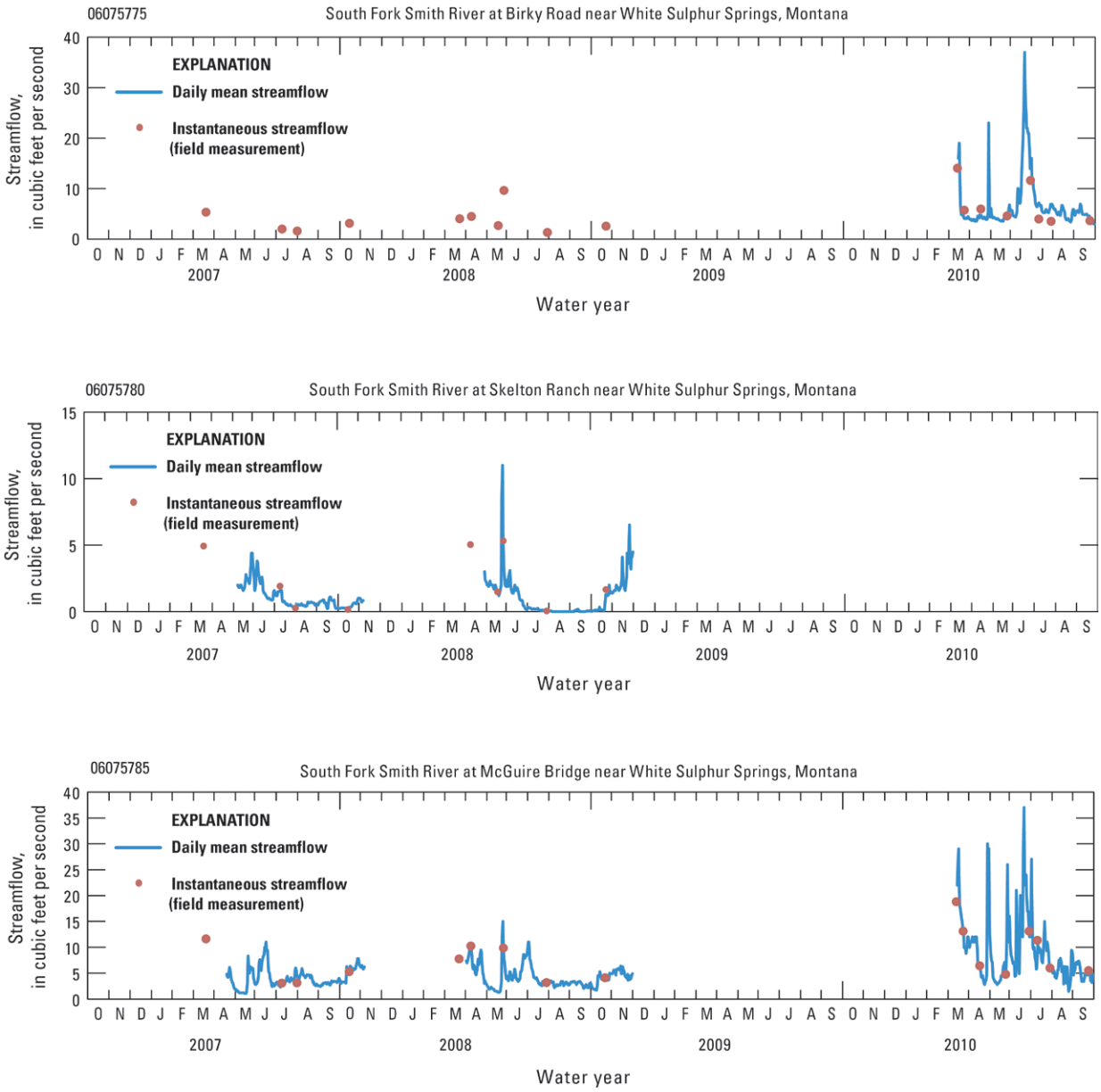

Figure 11. Daily mean streamflow and instantaneous streamflow at temporary U.S. Geological Survey streamflow-gaging stations in the upper Smith River watershed, Montana, 2007–2010.—Continued

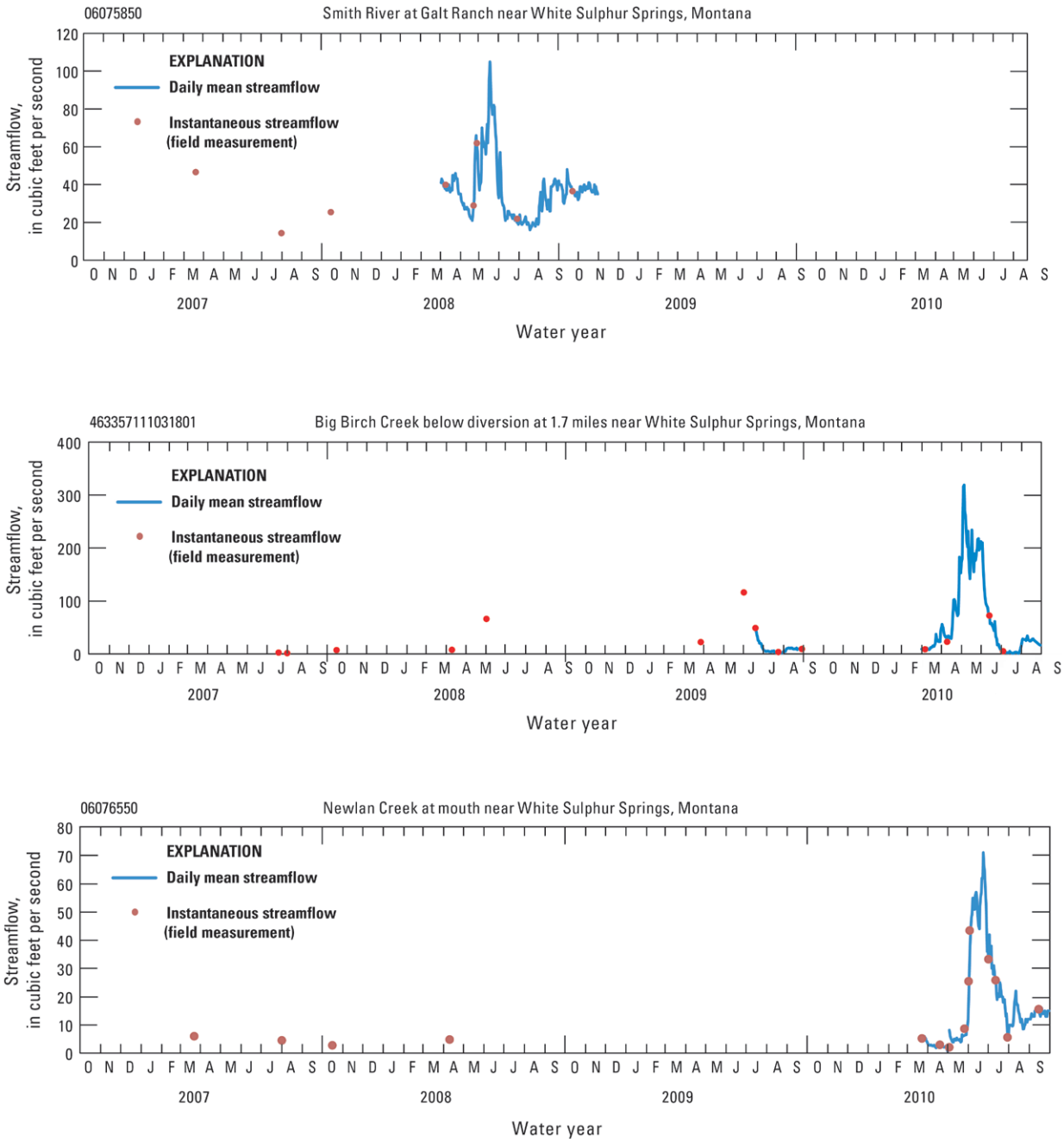

Figure 11. Daily mean streamflow and instantaneous streamflow at temporary U.S. Geological Survey streamflow-gaging stations in the upper Smith River watershed, Montana, 2007–2010.—Continued

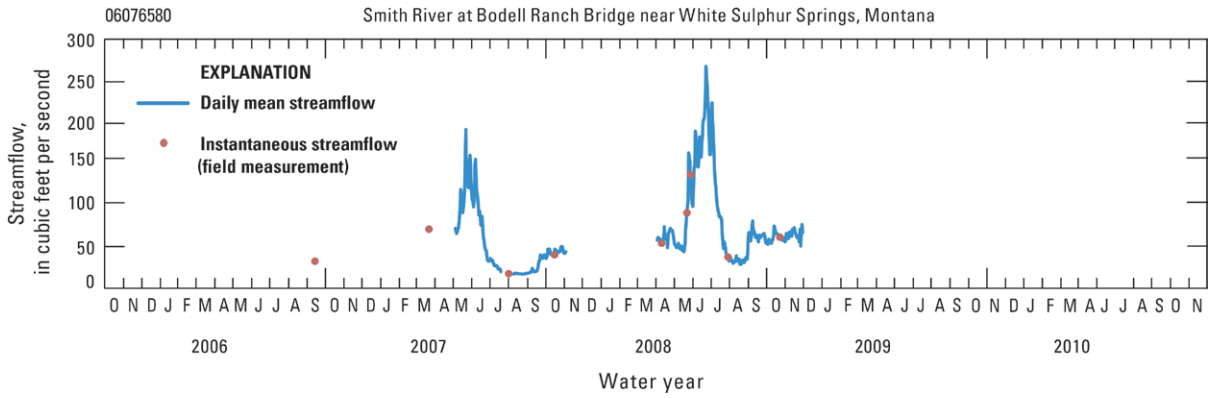

Figure 11. Daily mean streamflow and instantaneous streamflow at temporary U.S. Geological Survey streamflow-gaging stations in the upper Smith River watershed, Montana, 2007–2010.—Continued

Synoptic Streamflow Measurements

Large-scale synoptic streamflow measurements at up to 45 sites along the Smith River and its tributaries were conducted within the upper Smith River watershed from the headwaters of the North and South Forks of the Smith River downstream to the Smith River below Eagle Creek streamflow-gaging station (station identification number 06077200) (fig. 5, table 2). Data for each of the synoptic events (3/22/2007, 8/1/2007, 10/16/2007, and 4/10/2008), including measurements of streamflow, temperature, and specific conductance, are included in tables 5 through 8.

Table 5. Summary of synoptic streamflow measurements, upper Smith River watershed, Montana, March 22, 2007.

[Station name,see Site-Identification System section for explanation; Map number, used for cross reference for locations plotted on figure 5; River mile, distance above mouth; Temperature, water temperature in degrees Celsius; Streamflow measurement rating: (G) good (less than 5 percent measurement error), (F) fair (5 to 8 percent measurement error), (P) poor (greater than 8 percent measurement error). Abbreviations: °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second. Symbols: --, not applicable or not measured. Note: mainstem values in **bold** type]

Station name	Map number (fig. 5)	Time	River mile	Temperature (ºC)	Specific conductance **(µS/cm)**	Main stem streamflow **(ft^3/s)**	Tributary streamflow **(ft^3/s)**	Streamflow measurement rating
Reach 1 (see figure 5)- Lower South Fork Smith River								
South Fork Smith River at Birky Road Bridge	1	0900	15.0	2.5	860	5.28	--	G
South Fork Smith River at Skelton Ranch	2	0842	11.8	1.7	814	4.94	--	G
Hot Springs Creek at mouth	3	0955	4.3	3.0	954	--	.88	F
Unnamed tributary to South Fork Smith River (number 1)	4	1015	3.8	4.2	611	--	.43	P
Unnamed tributary to South Fork Smith River (number 2)	5	1050	3.2	3.8	801	--	.18	P
South Fork Smith River at McGuire Bridge	6	1105	3.1	3.4	747	11.6	--	G
South Fork Smith River at mouth	7	1330	0.1	6.3	701	16.1	--	G
Reach 2 (see figure 5) - Lower North Fork Smith River								
North Fork Smith River above Spring Creek	8	0917	8.4	1.3	337	7.06	--	G
Spring Creek near mouth	9	0950	8.4	4.8	290	--	9.37	G
North Fork Smith River at Highway 360 Bridge	10	1100	5.3	3.3	330	15.2	--	G
North Fork Smith River near mouth	11	1200	2.6	4.3	341	12.8	--	F
North Fork Smith River at mouth	12	1255	0.3	5.5	337	14.2	--	G
Reach 3 (see figure 5) - Upper Smith River below confluence of North and South Forks of Smith River								
South Fork Smith River at mouth	7	1330	124.8	6.3	701	16.1	--	G
North Fork Smith River at mouth	12	1255	124.7	5.5	337	14.2	--	G
Smith River below North Fork Smith River	13	1440	122.2	6.4	549	33.2	--	G
Reach 4 (see figure 5) - Smith River								
Smith River below North Fork Smith River	13	1440	122.2	6.4	549	33.2	--	G
Smith River above unnammed tributary	14	0940	120.8	2.6	559	35.2	--	F
Unnamed tributary at mouth 0.5 miles above Birch Creek Road	15	0945	120.7	4.2	471	--	1.25	F
Ditch at mouth on south side of Birch Creek Road	16	0945	120.3	1.3	470	--	.75	F
Ditch at mouth on north side of Birch Creek Road	17	0958	120.2	2.8	439	--	.68	F
Woods Gulch at mouth	18	1115	119.1	4.2	503	--	1.61	F
Ditch at mouth at Riverside Ranch	20	1250	118.4	6.1	480	--	3.33	F
Ditch at mouth above Galt Ranch Bridge (number 1)	21	1420	117.1	6.3	515	--	1.91	F
Ditch at mouth above Galt Ranch Bridge (number 2)	22	1455	116.3	7.2	495	--	1.25	F
Smith River at Galt Ranch Bridge	23	1400	116.0	5.2	541	46.7	--	F
Smith River below Mud Creek	24	1550	115.2	6.6	536	48.8	--	F
Smith River above Big Birch Creek	25	0920	112.7	2.9	542	51.6	--	F
Big Birch Creek at mouth	26	1020	112.6	1.9	238	--	11.1	G
Newlan Creek at mouth	27	1115	112.4	2.5	481	--	5.93	G
Smith River below Newlan Creek	28	1340	112.1	4.1	490	68.8	--	F
Reach 5 (see figure 5) - Smith River								
Smith River below Newlan Creek	28	1340	112.1	4.1	490	68.8	--	F
Smith River above Thompson Gulch	29	1535	108.2	6.1	487	68.0	--	G
Thompson Gulch near mouth	30	1105	108.1	5.5	345	--	1.35	F

Table 5. Summary of synoptic streamflow measurements, upper Smith River watershed, Montana, March 22, 2007.—Continued

[Station name,see Site-Identification System section for explanation; Map number, used for cross reference for locations plotted on figure 5; River mile, distance above mouth; Temperature, water temperature in degrees Celsius; Streamflow measurement rating: (G) good (less than 5 percent measurement error), (F) fair (5 to 8 percent measurement error), (P) poor (greater than 8 percent measurement error). Abbreviations: °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second. Symbols: --, not applicable or not measured. Note: mainstem values in **bold** type]

Station name	Map number (fig. 5)	Time	River mile	Temperature (ºC)	Specific conductance (µS/cm)	Main stem streamflow (ft^3/s)	Tributary streamflow (ft^3/s)	Streamflow measurement rating
Spring Creek at Highway 360 Bridge	31	1210	106.5	5.1	476	--	.65	F
Smith River at Bodell Ranch Bridge	32	1235	105.1	4.7	473	71.3	--	G
Smith River below Rock Springs Creek	33	1336	103.1	4.8	473	73.8	--	G
Smith River at Highway 360 Bridge	34	1100	98.4	3.3	461	76.9	--	F
Unnamed tributary to Smith River at mouth near Fort Logan	35	1230	97.8	5.4	404	--	3.13	G
Unnamed tributary to Smith River from Soldiers Lake	36	1153	96.8	5.3	331	--	1.83	G
Smith River above Camas Creek	37	1000	94.3	2.8	475	87.2	--	F
Smith River below Benton Gulch	40	1100	94.0	--	471	94.5	--	F
Smith River below Beaver Creek	41	1255	88.1	4.3	468	110	--	G
Smith River near Fort Logan	42	1415	83.6	4.8	477	115	--	G
Sheep Creek at mouth	43	1605	82.7	2.8	202	--	70.9	F
Eagle Creek near mouth	44	1705	81.4	2.4	256	--	11.3	F
Smith River below Eagle Creek	45	1352	80.8	4.2	366	204	--	G

Table 6. Summary of synoptic streamflow measurements, upper Smith River watershed, Montana, August 1, 2007.

[Station name,see Site-Identification System section for explanation; Map number, used for cross reference for locations plotted on figure 5; River mile, distance above mouth; Temperature, water temperature in degrees Celsius; Streamflow measurement rating: (G) good (less than 5 percent measurement error), (F) fair (5 to 8 percent measurement error), (P) poor (greater than 8 percent measurement error). Abbreviations:°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft3/s, cubic feet per second. Symbols: --, not applicable or not measured. Note: mainstem values in bold type]

Station name	Map number (fig. 5)	Time	River mile	Temperature (°C)	Specific conductance **(µS/cm)**	Main stem streamflow (ft^3**/s)**	Tributary streamflow (ft^3**/s)**	Streamflow measurement rating
Reach 1 (see figure 5)- Lower South Fork Smith River								
South Fork Smith River at Birky Road Bridge	1	0952	15.0	16.1	480	1.59	--	F
South Fork Smith River at Skelton Ranch	2	1100	11.8	15.4	449	.27	--	P
Hot Springs Creek at mouth	3	0958	4.3	16.3	436	--	1.13	P
Unnamed tributary to South Fork Smith River (number 1)	4	1040	3.8	11.5	595	--	.20	P
Unnamed tributary to South Fork Smith River (number 2)	5	0914	3.2	8.5	759	--	.060	P
South Fork Smith River at McGuire Bridge	6	1220	3.1	15.6	553	3.11	--	P
Reach 2 (see figure 5) - Lower North Fork Smith River								
North Fork Smith River above Spring Creek	8	0910	8.4	14.2	363	61.9	--	G
Spring Creek near mouth	9	1000	8.4	11.9	307	--	10.6	G
North Fork Smith River at Highway 360 Bridge	10	1110	5.3	16.1	351	13.7	--	F
North Fork Smith River near mouth	11	0915	2.6	15.5	398	4.86	--	F
Reach 3 (see figure 5) - Upper Smith River below confluence of North and South Forks of Smith River								
South Fork Smith River at McGuire Bridge	6	1220	3.1	15.6	553	3.11	--	P
North Fork Smith River near mouth	11	0915	2.6	15.5	398	4.86	--	F
Smith River below North Fork Smith River	13	1123	122.2	19.3	452	13.1	--	G
Reach 4 (see figure 5) - Smith River								
Smith River below North Fork Smith River	13	1123	122.2	19.3	452	13.1	--	G
Unnamed tributary at mouth 0.5 mi above Birch Creek Road	15	0836	120.7	--	--	--	.080	F
Ditch at mouth on south side of Birch Creek Road	16	0900	120.3	14.3	458	--	.19	P
Ditch at mouth on north side of Birch Creek Road	17	0920	120.2	10.1	423	--	.20	F
Woods Gulch at mouth	18	0957	119.1	12.3	663	--	.20	F
Smith River at Riverside Ranch Bridge	19	1100	118.8	17.0	479	10.8	--	G
Smith River at Galt Ranch Bridge	23	1240	116.0	18.4	470	14.3	--	G
Smith River below Mud Creek	24	1405	115.2	20.2	460	14.6	--	G
Big Birch Creek at mouth	26	1555	112.6	24.0	320	--	.98	P
Newlan Creek at mouth	27	1500	112.4	20.8	439	--	4.45	G
Smith River below Newlan Creek (computed from gage)	28	1500	112.1	--	--	21.0	--	G
Reach 5 (see figure 5) - Smith River								
Smith River below Newlan Creek (computed from gage)	28	1500	112.1	--	--	21.0	--	G
Smith River at Bodell Ranch Bridge	32	1300	105.1	22.0	394	17.5	--	G
Smith River at Highway 360 Bridge	34	1405	98.4	23.5	385	15.0	--	G
Smith River above Camas Creek	37	1330	94.3	23.1	370	13.2	--	F
Smith River below Benton Gulch	40	1440	94.0	24.8	415	24.2	--	F
Smith River near Fort Logan (computed from gage)	42	1500	83.6	--	--	24.0	--	G
Smith River below Eagle Creek	45	1500	80.8	--	--	57.0	--	G

Table 7. Summary of synoptic streamflow measurements, upper Smith River watershed, Montana, October 16, 2007.

[Station name,see Site-Identification System section for explanation; Map number, used for cross reference for locations plotted on figure 5; River mile, distance above mouth; Map number, used for cross reference for locations plotted on figure 5;Temperature, water temperature in degrees Celsius; Streamflow measurement rating: (G) good (less than 5 percent measurement error), (F) fair (5 to 8 percent measurement error), (P) poor (greater than 8 percent measurement error). Abbreviations:ºC, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft3/s, cubic feet per second. Symbols: --, not applicable or not measured. Note: mainstem values in bold type]

Station name	Map number (fig. 5)	Time	River mile	Temperature (°C)	Specific conductance (µS/cm)	Main stem streamflow (ft^3/s)	Tributary streamflow (ft^3/s)	Streamflow measurement rating
Reach 1 (see figure 5)- Lower South Fork Smith River								
South Fork Smith River at Birky Road Bridge	**1**	**0855**	**15.0**	**--**	**--**	**3.08**	**--**	**G**
South Fork Smith River at Skelton Ranch	**2**	**1004**	**11.8**	**3.0**	**931**	**.16**	**--**	**P**
Hot Springs Creek at mouth	3	0946	4.3	5.9	1045	--	1.34	F
Unnamed tributary to South Fork Smith River (number 1)	4	1017	3.8	7.3	612	--	.50	F
Unnamed tributary to South Fork Smith River (number 2)	5	1108	3.2	5.7	892	--	.31	P
South Fork Smith River at McGuire Bridge	**6**	**1053**	**3.1**	**5.6**	**786**	**5.28**	**--**	**G**
South Fork Smith River at mouth	**7**	**1539**	**0.1**	**10.7**	**670**	**7.67**	**--**	**G**
Reach 2 (see figure 5) - Lower North Fork Smith River								
North Fork Smith River above Spring Creek	**8**	**1015**	**8.4**	**6.8**	**400**	**2.53**	**--**	**F**
Spring Creek near mouth	9	1115	8.4	9.2	265	--	10.7	G
North Fork Smith River at Highway 360 Bridge	**10**	**1235**	**5.3**	**7.5**	**320**	**13.2**	**--**	**G**
North Fork Smith River near mouth	**11**	**1340**	**2.6**	**8.6**	**336**	**5.23**	**--**	**F**
North Fork Smith River at mouth	**12**	**1445**	**0.3**	**11.0**	**392**	**4.74**	**--**	**G**
Reach 3 (see figure 5) - Upper Smith River below confluence of North and South Forks of Smith River								
South Fork Smith River at mouth	**7**	**1539**	**124.8**	**10.7**	**670**	**7.67**	**--**	**G**
North Fork Smith River at mouth	**12**	**1445**	**124.7**	**11.0**	**392**	**4.74**	**--**	**G**
Smith River below North Fork Smith River	**13**	**1204**	**122.2**	**8.7**	**590**	**16.50**	**--**	**G**
Reach 4 (see figure 5) - Smith River								
Smith River below North Fork Smith River	**13**	**1204**	**122.2**	**8.7**	**590**	**16.5**	**--**	**G**
Unnamed tributary at mouth 0.5 miles above Birch Creek Road	15	0915	120.7	5.6	483	--	.94	F
Ditch at mouth on south side of Birch Creek Road	16	0902	120.3	--	527	--	.51	P
Ditch at mouth on north side of Birch Creek Road	17	0925	120.2	--	489	--	.44	P
Woods Gulch at mouth	18	1022	119.1	--	752	--	.42	P
Smith River at Riverside Ranch Bridge	**19**	**1020**	**118.8**	**5.7**	**596**	**20.3**	**--**	**G**
Ditch at mouth at Riverside Ranch	20	1135	118.4	7.0	498	--	2.49	P
Ditch at mouth above Galt Ranch Bridge (number 1)	21	1340	117.1	7.6	541	--	1.76	F
Ditch at mouth above Galt Ranch Bridge (number 2)	22	1315	116.3	8.8	501	--	.70	F
Smith River at Galt Ranch Bridge	**23**	**1205**	**116.0**	**7.0**	**570**	**25.5**	**--**	**G**
Smith River below Mud Creek	**24**	**1445**	**115.2**	**9.6**	**556**	**28.1**	**--**	**G**
Big Birch Creek at mouth	26	0945	112.6	3.5	272	--	5.78	G
Newlan Creek at mouth	27	1100	112.4	--	--	--	2.69	F
Smith River below Newlan Creek	**28**	**0915**	**112.1**	**5.0**	**467**	**35.5**	**--**	**F**
Reach 5 (see figure 5) - Smith River								
Smith River below Newlan Creek	**28**	**0915**	**112.1**	**5.0**	**467**	**35.5**	**--**	**F**
Thompson Gulch near mouth	30	1345	108.1	6.4	359	--	1.31	G
Spring Creek at Highway 360 Bridge	31	1118	106.5	--	503	--	.56	P
Smith River at Bodell Ranch Bridge	**32**	**1335**	**105.1**	**8.0**	**482**	**40.5**	**--**	**G**

Table 7. Summary of synoptic streamflow measurements, upper Smith River watershed, Montana, October 16, 2007.—Continued

[Station name,see Site-Identification System section for explanation; Map number, used for cross reference for locations plotted on figure 5; River mile, distance above mouth; Map number, used for cross reference for locations plotted on figure 5;Temperature, water temperature in degrees Celsius; Streamflow measurement rating: (G) good (less than 5 percent measurement error), (F) fair (5 to 8 percent measurement error), (P) poor (greater than 8 percent measurement error). Abbreviations:ºC, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft3/s, cubic feet per second. Symbols: --, not applicable or not measured. Note: mainstem values in bold type]

Station name	Map number (fig. 5)	Time	River mile	Temperature (°C)	Specific conductance (µS/cm)	Main stem streamflow (ft^3/s)	Tributary streamflow (ft^3/s)	Streamflow measurement rating
Smith River below Rock Springs Creek	**33**	**1248**	**103.1**	**7.4**	**490**	**38.3**	**--**	**G**
Smith River at Highway 360 Bridge	**34**	**1525**	**98.4**	**9.0**	**475**	**38.6**	**--**	**G**
Unnamed tributary to Smith River at mouth near Fort Logan	35	1200	97.8	--	419	--	4.03	F
Unnamed tributary to Smith River from Soldiers Lake	36	1228	96.8	--	342	--	1.81	P
Smith River above Camas Creek	**37**	**1030**	**94.3**	**6.2**	**475**	**45.7**	**--**	**G**
Smith River below Benton Gulch	**40**	**1130**	**94.0**	**7.2**	**475**	**58.3**	**--**	**G**
Smith River below Beaver Creek	**41**	**1325**	**88.1**	**8.1**	**485**	**59.2**	**--**	**G**
Sheep Creek at mouth	43	1535	82.7	8.0	280	--	24.7	G
Eagle Creek near mouth	44	1640	81.4	7.6	380	--	3.25	G

Table 8. Summary of synoptic streamflow measurements, upper Smith River watershed, Montana, April 10, 2008.

[Station name,see Site-Identification System section for explanation; Map number, used for cross reference for locations plotted on figure 5; River mile, distance above mouth; Temperature, water temperature in degrees Celsius; Streamflow measurement rating: (G) good (less than 5 percent measurement error), (F) fair (5 to 8 percent measurement error), (P) poor (greater than 8 percent measurement error). Abbreviations: °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second. Symbols: --, not applicable or not measured. Note: mainstem values in **bold** type]

Station name	Map number (fig. 5)	Time	River mile	Temperature (°C)	Specific conductance **(µS/cm)**	Main stem streamflow **(ft^3/s)**	Tributary streamflow **(ft^3/s)**	Streamflow measurement rating
Reach 1 (see figure 5)- Lower South Fork Smith River								
South Fork Smith River at Birky Road Bridge	1	0900	15.0	3.3	886	4.43	--	G
South Fork Smith River at Skelton Ranch	2	1000	11.8	1.8	746	5.04	--	F
Hot Springs Creek at mouth	3	1015	4.3	2.2	916	--	0.91	F
Unnamed tributary to South Fork Smith River (number 1)	4	1110	3.8	6.0	627	--	.38	P
Unnamed tributary to South Fork Smith River (number 2)	5	1150	3.2	4.3	829	--	.22	P
South Fork Smith River at McGuire Bridge	6	1115	3.1	3.3	755	10.2	--	G
South Fork Smith River at mouth	7	1255	0.1	5.5	694	12.8	--	F
Reach 2 (see figure 5) - Lower North Fork Smith River								
North Fork Smith River above Spring Creek	8	0920	8.4	1.0	360	3.88	--	F
Spring Creek near mouth	9	1000	8.4	5.2	286	--	8.55	F
North Fork Smith River at Highway 360 Bridge	10	1115	5.3	2.5	325	14.2	--	G
North Fork Smith River near mouth	11	1215	2.6	4.0	332	8.87	--	G
North Fork Smith River at mouth	12	1345	0.3	5.7	417	8.39	--	G
Reach 3 (see figure 5) - Upper Smith River below confluence of North and South Forks of Smith River								
South Fork Smith River at McGuire Bridge	7	1255	124.8	5.5	694	12.8	--	F
North Fork Smith River at mouth	12	1345	124.7	5.7	417	8.39	--	G
Smith R bl NF nr White Sulphur Springs, Mont.	13	1320	122.2	4.8	536	26.5	--	G
Reach 4 (see figure 5) - Smith River								
Smith River below North Fork Smith River	13	1320	122.2	4.8	536	26.5	--	G
Unnamed tributary at mouth 0.5 miles above Birch Creek Road	15	1025	120.7	6.7	470	--	1.22	P
Ditch at mouth on south side of Birch Creek Road	16	0915	120.3	1.0	471	--	.42	P
Ditch at mouth on north side of Birch Creek Road	17	0945	120.2	2.7	474	--	.62	P
Woods Gulch at mouth	18	1050	119.1	3.6	526	--	1.76	P
Smith River at Riverside Ranch Bridge	19	0940	118.8	3.6	528	29.8	--	G
Ditch at mouth at Riverside Ranch	20	1020	118.4	5.6	526	--	2.85	F
Ditch at mouth above Galt Ranch Bridge (number 1)	21	1210	117.1	6.0	519	--	2.12	F
Ditch at mouth above Galt Ranch Bridge (number 2)	22	1240	116.3	5.9	519	--	1.42	F
Smith River at Galt Ranch Bridge	23	1215	116.0	5.3	518	39.9	--	G
Smith River below Mud Creek	24	1255	115.2	5.7	518	--	--	--
Big Birch Creek at mouth	26	0915	112.6	1.5	278	--	7.04	G
Newlan Creek at mouth	27	0915	112.4	2.0	253	--	4.74	F
Smith River below Newlan Creek	28	1340	112.1	5.5	481	52.8	--	F
Reach 5 (see figure 5) - Smith River								
Smith River below Newlan Creek	28	1340	112.1	5.5	481	52.8	--	F
Thompson Gulch near mouth	30	1115	108.1	2.5	349	--	1.12	P
Spring Creek at Highway 360 Bridge	31	1150	106.5	7.8	499	--	.33	P

Table 8. Summary of synoptic streamflow measurements, upper Smith River watershed, Montana, April 10, 2008.—Continued

[Station name,see Site-Identification System section for explanation; Map number, used for cross reference for locations plotted on figure 5; River mile, distance above mouth; Temperature, water temperature in degrees Celsius; Streamflow measurement rating: (G) good (less than 5 percent measurement error), (F) fair (5 to 8 percent measurement error), (P) poor (greater than 8 percent measurement error). Abbreviations: °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft^3/s, cubic feet per second. Symbols: --, not applicable or not measured. Note: mainstem values in **bold** type]

Station name	Map number (fig. 5)	Time	River mile	Temperature (°C)	Specific conductance (µS/cm)	Main stem streamflow (ft^3/s)	Tributary streamflow (ft^3/s)	Streamflow measurement rating
Smith River at Bodell Ranch Bridge	32	0905	105.1	2.9	480	54.4	--	G
Smith River below Rock Springs Creek	33	1015	103.1	3.4	482	57.1	--	G
Smith River at Highway 360 Bridge	34	1130	98.4	4.8	483	61.0	--	G
Unnamed tributary to Smith River at mouth near Fort Logan	35	1300	97.8	5.7	414	--	2.86	F
Unnamed tributary to Smith River from Soldiers Lake	36	1345	96.8	7.0	440	--	1.75	F
Smith River above Camas Creek	37	1015	94.3	3.4	465	60.8	--	G
Camas Creek at mouth	38	1100	94.2	2.7	405	--	4.19	F
Benton Gulch at mouth	39	1140	94.1	5.4	630	--	3.79	P
Smith River below Benton Gulch	40	1215	94.0	6.2	470	69.3	--	G
Smith River near Fort Logan	42	1245	83.6	5.5	481	70.1	--	G
Sheep Creek at mouth	43	1420	82.7	3.0	255	--	19.9	G
Eagle Creek near mouth	44	1110	81.4	0.7	360	--	3.27	F
Smith River below Eagle Creek	45	1015	80.8	3.0	430	98.9	--	G

Miscellaneous Streamflow Measurements

Streamflow data collected at 14 miscellaneous sites are included in Appendix 8.

Groundwater and Surface-Water Interaction Monitoring Networks

The groundwater and surface-water interaction monitoring network included staff gages and one to five shallow monitoring wells installed at 10 locations along the Smith River, North Fork Smith River, and South Fork Smith River. Stream stage and groundwater altitudes measured manually (semi-monthly) and continuously (hourly) from October 2006 through December 2008 are included in Appendix 9. Surface-water and groundwater temperatures were measured continuously (hourly) at two depths, approximately 1.5 and 3.0 ft below the stream bottom, in 28 groundwater and surface-water monitoring network wells measured from March 2007 through December 2008 and are included in Appendix 10. Measurements were discontinued during the winter due to freezing conditions in both the streams and monitoring wells. Manual measurements were used for verification and calibration of the data collected continuously with data loggers.

Groundwater Chemistry

Water-chemistry data were collected from eight wells in the upper Smith River watershed in an effort to calculate groundwater age (fig. 3, appendix 1). Samples were analyzed for field parameters, major ions, and stable isotopes of water (hydrogen-2/hydrogen-1 and oxygen-18/oxygen-16), as well as groundwater age-dating constituents including tritium, sulfur hexafluoride, and chlorofluorocarbons including 1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113), Dichlorodifluoromethane (CFC-12), and trichlorofluoromethane (CFC-11) (table 9). The USGS Reston Chlorofluorocarbon Laboratory (RCL) typically reports two sulfur hexafluoride and chlorofluorocarbons results for each sample submitted for analysis; these results are generally averaged for interpretation. Table 9 includes all sulfur hexafluoride and chlorofluorocarbons data reported by the RCL for the environmental samples.

Results of the replicate samples indicate good relative agreement between the measured concentrations. The relative percent difference (RPD) between replicate pairs for major ions and tritium were less than 5 percent and were less than 10 percent for the sulfur hexafluoride and chlorofluorocarbons. The RPD between sulfur hexafluoride and chlorofluorocarbons data reported by the RCL for the environmental samples were all less than 25 percent, except for a sample collected at well 09NE10CDDD01which had a RPD of 54 percent for CFC-11.

Table 9. Water-chemistry data for groundwater samples collected in the upper Smith River watershed, Montana, 2008.

[Station name, see Site-Identification System section for explanation; Station identification number, see Site-Identification System section for explanation; Abbreviations; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft, feet; R, radiochemical value below sample-specific critical level; fmol/L, femtomoles per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; CFC-11, trichlorofluoromethane; CFC-12, dichlorodifluoromethane; CFC-113, 1,1,2-Trichloro-1,2,2-trifluoroethane; pg/kg, picograms per kilogram; per mil, parts per thousand; fmol/L, femtomol per liter; Symbols: <, less than; --, no data]

Station name	Station identification number	Sample date	Sample time	Depth to water below land surface (ft)	Oxygen, dissolved (mg/L)	pH, field (standard units)	Specific conductance, field (uS/cm at 25°C)	Water temperature (°C)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)
09N06E09CADA01	463311110584401	11/11/2008	1200	--	7.7	7.5	484	8.5	77.7	15.4
09N06E10CDDD01	463255110573101	9/29/2008	1800	18.86	6.6	7.4	413	10.0	65.8	13.0
09N06E10DCCC01	463255110572701	9/29/2008	2000	26.34	2.4	7.6	478	10.5	50.5	9.09
09N06E14CBCC01	463218110564901	8/21/2008	1400	7.25	<1.0	7.6	413	8.5	57.0	13.7
09N06E22DBBB01	463135110572801	9/30/2008	1400	2.78	1.2	7.5	558	9.0	68.2	18.3
09N06E24DDDC01	463111110542401	11/5/2008	1100	66.24	11.0	7.4	523	7.5	75.0	16.9
09N07E30DDDD01	463019110530801	8/21/2008	1100	196.16	9.0	7.3	210	11.5	23.2	4.23
10N06E31BACC01	463518111013701	9/30/2008	1100	35.21	8.2	7.7	679	9.5	75.5	34.9

Station name	Site identification number	Sample date	Sample time	Potassium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Alkalinity, dissolved, mg/L as $CaCO_3$	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Sulfate, dissolved (mg/L)
09N06E09CADA01	463311110584401	11/11/2008	1200	1.73	8.19	239	2.72	0.28	17.4	12.7
09N06E10CDDD01	463255110573101	9/29/2008	1800	1.75	7.50	208	2.57	0.23	17.5	12.5
09N06E10DCCC01	463255110572701	9/29/2008	2000	13.0	31.9	161	22.6	0.34	59.1	40.7
09N06E14CBCC01	463218110564901	8/21/2008	1400	2.03	9.54	199	4.10	0.26	16.2	17.5
09N06E22DBBB01	463135110572801	9/30/2008	1400	4.58	32.8	274	6.39	0.42	21.2	19.9
09N06E24DDDC01	463111110542401	11/5/2008	1100	3.35	22.5	235	4.85	0.30	31.7	35.5
09N07E30DDDD01	463019110530801	8/21/2008	1100	2.96	11.4	82	2.21	0.74	52.8	18.6
10N06E31BACC01	463518111013701	9/30/2008	1100	4.39	16.7	201	38.6	0.31	38.4	88.3

Station name	Site identification number	Sample date	Sample time	Sulfur hexafluoride, unfiltered, (fmol/L)	CFC-113 (pg/kg)	CFC-12 (pg/kg)	CFC-11 (pg/kg)	Tritium, unfiltered, (pCi/L)	Stable-isotope ratio (per mil) Hydrogen-2 / Hydrogen-1	Stable-isotope ratio (per mil) Oxygen-18 / Oxygen-16
09N06E09CADA01	463311110584401	11/11/2008	1200	3.44	79	300	460	30	-135	-17.61
09N06E09CADA01	463311110584401	11/11/2008	1200	3.40	83	320	470	--	--	--
09N06E10CDDD01	463255110573101	9/29/2008	1800	2.64	76	330	300	28.4	-134	-17.69
09N06E10CDDD01	463255110573101	9/29/2008	1800	2.73	82	320	520	--	--	--
09N06E10DCCC01	463255110572701	9/29/2008	2000	0.81	2.5	6.2	8.9	R .2	-149	-19.33
09N06E10DCCC01	463255110572701	9/29/2008	2000	0.72	2.2	7.7	8.5	--	--	--
09N06E14CBCC01	463218110564901	8/21/2008	1400	3.96	60	330	390	32.4	-137	-17.93
09N06E14CBCC01	463218110564901	8/21/2008	1400	4.05	61	350	410	--	--	--

Table 9. Water-chemistry data for groundwater samples collected in the upper Smith River watershed, Montana, 2008.—Continued

[Station name, see Site-Identification System section for explanation; Station identification number, see Site-Identification System section for explanation; Abbreviations; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ft, feet; R, radiochemical value below sample-specific critical level; fmol/L, femtomoles per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; CFC-11, trichlorofluoromethane; CFC-12, dichlorodifluoromethane; CFC-113, 1,1,2-Trichloro-1,2,2-trifluoroethane; pg/kg, picograms per kilogram; per mil, parts per thousand; fmol/L, femtomol per liter; Symbols: --, no data]

Station name	Site identification number	Sample date	Sample time	Sulfur hexafluoride, unfiltered, (fmol/L)	CFC-113 (pg/kg)	CFC-12 (pg/kg)	CFC-11 (pg/kg)	Tritium, unfiltered, (pCi/L)	Hydrogen-2 / Hydrogen-1	Oxygen-18 / Oxygen-16
09N06E22DBBB01	463135110572801	9/30/2008	1400	6.15	44	290	190	--	-134	-17.4
09N06E22DBBB01	463135110572801	9/30/2008	1400	6.19	44	290	190	--	--	--
09N06E24DDDC01	463111110542401	11/5/2008	1100	0.16	14	100	190	62.2	-134	-16.95
09N06E24DDDC01	463111110542401	11/5/2008	1100	--	13	94	190	--	--	--
09N07E30DDDD01	463019110530801	8/21/2008	1100	0.14	5.8	26	44	1.4	-156	-20.16
09N07E30DDDD01	463019110530801	8/21/2008	1100	0.12	5.8	24	42	--	--	--
10N06E31BACC01	463518111013701	9/30/2008	1100	0.69	42	190	330	55.8	-138	-17.77
10N06E31BACC01	463518111013701	9/30/2008	1100	0.67	43	190	350	--	--	--

References Cited

Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000, 1 sheet.

Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program—Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95–399, 113 p.

National Climatic Data Center, 2011, Annual Climatological Summary, accessed November 17, 2011 at *http://cdo.ncdc.noaa.gov/ancsum/ACS?coban=248930*.

Nolan, K.M., and Shields, R.R., 2000, Measurement of stream discharge by wading: U.S. Geological Survey Water-Resources Investigations Report 00-4036. [CD-ROM]

Oregon State University PRISM Group, 2006, United States average monthly or annual precipitation, 1971–2000: Corvallis, Oreg., Oregon State University, accessed March 31, 2009, at *http://www.prism.oregonstate.edu/*.

Pritt, J.W., and Raese, J.W., 1995, Quality assurance/quality control manual—National Water Quality Laboratory: U.S. Geological Survey Open-File Report 95–443, 35 p.

Rantz, S.E., and others, 1982, Measurement and computation of streamflow: U.S. Geological Survey Water-Supply Paper 2175, 631 p. [Two volumes]

Turnipseed, D.P., and Sauer, V.B., 2010, Discharge measurements of gaging stations: U.S. Geological Survey Techniques and Methods, book 3, chap. A8, 87 p.

U.S. Geological Survey, 2000, National Land Cover Data for Montana, vector format: U.S. Geological Survey, accessed March 16, 2009, at *http://nris.mt.gov/nsdi/nris/nlcd/nlcdvector.asp*.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1–A9, accessed June 10, 2011, at *http://pubs.water.usgs.gov/twri9A*.

Appendix – Data Files

A text document (README.txt) and data files (Appendixes 1–9) can be downloaded from *http://pubs.usgs.gov/of/2012/1134/*.

README.TXT

APPENDIX 1.XLS Summary of wells used in the study of the Smith River watershed, Montana

APPENDIX 2.XLS Groundwater-level data collected primarily by the U.S. Geological Survey, upper Smith River watershed, Montana, 2006 - 2010

APPENDIX 3.XLS Groundwater-level data collected primarily by other agencies, upper Smith River watershed, Montana through 2010

APPENDIX 4.XLS Lithologic logs and completion data for U.S. Geological Survey exploration wells in the upper Smith River watershed, Montana

APPENDIX 5.XLS Streamflow monitoring sites through water year 2010, Smith River watershed, Montana

APPENDIX 6.XLS Computed daily mean streamflow and instantaneous streamflow data for long-term U.S. Geological Survey streamflow-gaging stations in the Smith River watershed, Montana through 2010

APPENDIX 7.XLS Computed daily mean streamflow and instantaneous streamflow data for temporary U. S. Geological Survey streamflow-gaging stations in the upper Smith River watershed, Montana through 2010

APPENDIX 8.XLS Streamflow data for miscellaneous sites in the upper Smith River watershed, Montana through 2010

APPENDIX 9.XLS Stream stage and groundwater altitude at groundwater and surface-water interaction monitoring sites in the upper Smith River watershed, Montana through 2008

APPENDIX 10.XLS Water-temperature data from groundwater and surface-water interaction monitoring sites in the upper Smith River watershed, Montana through 2008