Water-Chemistry Data for Selected Springs, Geysers, and Streams in Yellowstone National Park, Wyoming, 2003–2005

By James W. Ball, R. Blaine McCleskey, D. Kirk Nordstrom, and JoAnn M. Holloway

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Front Cover Photography: View taken in 2004 of Mound Spring, Sentinel Meadows, Yellowstone National Park.
Back Cover Photography: View taken in 2005 of Perpetual Spouter, Norris Geyser Basin, Yellowstone National Park.

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
Length		
kilometer (km)	0.6214	mile (mi)
meter (m)	3.281	foot (ft)
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
Area		
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (ft^2)
Volume		
cubic meter (m^3)	264.2	gallon (gal)
liter (L)	0.2642	gallon (gal)
liter (L)	1.057	quart (qt)
liter (L)	33.82	ounce, fluid (fl. oz)
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
Flow rate		
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
cubic meter per second (m^3/s)	22.83	million gallons per day (Mgal/d)
liter per second (L/s)	15.85	gallon per minute (gal/min)
Mass		
kilogram (kg)	2.205	pound, avoirdupois (lb)
gram (g)	0.03527	ounce, avoirdupois (oz)

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

$$°F=(1.8\times°C)+32$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29)
Horizontal coordinate information is referenced to North American Datum of 1927 (NAD 27)
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25°C).

Abbreviations used in this report

°C	degrees Celsius
C.I.	charge imbalance
cm	centimeter
CVAFS	cold-vapor atomic-fluorescence spectroscopy
DO	dissolved oxygen
DOC	dissolved organic carbon
Eh	redox potential relative to the Standard Hydrogen Electrode
FIAS	flow-injection analysis system
GFAAS	graphite-furnace atomic-absorption spectrometry
HGAAS	hydride-generation atomic-absorption spectrometry
IC	ion chromatography
ICP–OES	inductively coupled plasma-optical emission spectrometry
ISE	ion-selective electrode
L	liter
meq/L	milliequivalents per liter
mg/L	milligrams per liter
mL	milliliter
mm	millimeter
mM	millimolar
mV	millivolts
µm	micrometer
MPV	most probable value
ng/L	nanograms per liter
*p*K	negative common logarithm of the equilibrium constant
s	standard deviation
SLAP	standard light Antarctic precipitation
SRWS	standard reference water sample
THGA	transversely heated graphite atomizer
TISAB	total ionic strength adjustment buffer
USGS	U.S. Geological Survey
VSMOW	Vienna standard mean ocean water
YNP	Yellowstone National Park

Water-Chemistry Data for Selected Springs, Geysers, and Streams in Yellowstone National Park, Wyoming, 2003-2005

By James W. Ball, R. Blaine McCleskey, D. Kirk Nordstrom, and JoAnn M. Holloway

Abstract

Water analyses are reported for 157 samples collected from numerous hot springs, their overflow drainages, and Lemonade Creek in Yellowstone National Park (YNP) during 2003–2005. Water samples were collected and analyzed for major and trace constituents from ten areas of YNP including Terrace and Beryl Springs in the Gibbon Canyon area, Norris Geyser Basin, the West Nymph Creek thermal area, the area near Nymph Lake, Hazle Lake, and Frying Pan Spring, Lower Geyser Basin, Washburn Hot Springs, Mammoth Hot Springs, Potts Hot Spring Basin, the Sulphur Caldron area, and Lemonade Creek near the Solfatara Trail. These water samples were collected and analyzed as part of research investigations in YNP on arsenic, antimony, and sulfur redox distribution in hot springs and overflow drainages, and the occurrence and distribution of dissolved mercury. Most samples were analyzed for major cations and anions, trace metals, redox species of antimony, arsenic, iron, nitrogen, and sulfur, and isotopes of hydrogen and oxygen. Analyses were performed at the sampling site, in an on-site mobile laboratory vehicle, or later in a U.S. Geological Survey laboratory, depending on stability of the constituent and whether it could be preserved effectively.

Water samples were filtered and preserved onsite. Water temperature, specific conductance, pH, Eh (redox potential relative to the Standard Hydrogen Electrode), and dissolved hydrogen sulfide were measured onsite at the time of sampling. Acidity was determined by titration, usually within a few days of sample collection. Alkalinity was determined by titration within 1 to 2 weeks of sample collection. Concentrations of thiosulfate and polythionate were determined as soon as possible (generally minutes to hours after sample collection) by ion chromatography in an on-site mobile laboratory vehicle. Total dissolved-iron and ferrous-iron concentrations often were measured onsite in the mobile laboratory vehicle.

Concentrations of dissolved aluminum, arsenic, boron, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, potassium, lithium, magnesium, manganese, molybdenum, sodium, nickel, lead, selenium, silica, strontium, vanadium, and zinc were determined by inductively-coupled plasma-optical emission spectrometry. Trace concentrations of dissolved antimony, cadmium, cobalt, chromium, copper, lead, and selenium were determined by Zeeman-corrected graphite-furnace atomic-absorption spectrometry. Dissolved concentrations of total arsenic, arsenite, total antimony, and antimonite were determined by hydride-generation atomic-absorption spectrometry using a flow-injection analysis system. Dissolved concentrations of total mercury and methyl

mercury were determined by cold-vapor atomic-fluorescence spectrometry. Concentrations of dissolved chloride, fluoride, nitrate, bromide, and sulfate were determined by ion chromatography. Concentrations of dissolved ferrous and total iron were determined by the FerroZine colorimetric method. Concentrations of dissolved nitrite were determined by colorimetry or chemiluminescence. Concentrations of dissolved ammonium were determined by ion chromatography, with reanalysis by colorimetry when separation of sodium and ammonia peaks was poor. Dissolved organic carbon concentrations were determined by the wet persulfate oxidation method. Hydrogen and oxygen isotope ratios were determined using the hydrogen and CO_2 equilibration techniques, respectively.

Introduction

Investigations into the water chemistry of hot springs, geysers, streams, and rivers in Yellowstone National Park (YNP) have been conducted by the U.S. Geological Survey (USGS) dating back to 1888. A list of publications that report results of these and several non-USGS investigations is presented in table 1. Waters at YNP have pH values ranging from less than 1 to 10, temperatures from ambient to about 93 degrees Celsius (°C; boiling at YNP's altitude; some pools are superheated), and high concentrations of silica, arsenic, hydrogen sulfide, and sulfate, and high alkalinity relative to many natural waters. Numerous redox reactions and mineral-precipitation reactions occur. In addition to being valuable natural resources and tourist attractions, active geothermal areas such as those in YNP provide insight into formation of mineral deposits, microbiological processes in extreme environments, and water-rock interactions.

Purpose and Scope

The purpose of this report is to: (1) provide water-quality data from numerous sample sites in YNP; (2) describe methods used to collect and analyze the samples; (3) describe quality-control procedures; and (4) supplement interpretive reports. The samples were collected during five field trips to YNP during May–June and September 2003, September 2004, and June and September 2005. The primary purpose of the field trips was to study and interpret the geochemical processes (including mineral precipitation) affecting redox species of antimony, arsenic, iron, nitrogen, and sulfur in mineral springs and geothermal waters, and in their drainages. The evolution and chemical composition of several newly developed hydrothermal features of the Ragged Hills area of Norris Geyser Basin and the occurrence and distribution of total dissolved mercury and methylmercury in geothermal waters also was studied during these field trips. Several papers have been published on earlier phases of this project and on other collaborative research efforts (Ball and others, 1998a; 1998b; 2001; 2002; McCleskey and others, 2004; Nordstrom and others, 2005; Xu and others, 1996; 1998; 2000; Xu and Schoonen, 1995).

Table 1. Publications describing investigations into the water chemistry of hot springs, geysers, ground waters, streams, and rivers in Yellowstone National Park

Authors	Abbreviated title	Publication Date
Gooch and Whitfield	Analyses of waters of the Yellowstone National Park	1888
Clarke	Water analyses from the laboratory of the USGS	1914
Allen and Day	Hot Springs of the Yellowstone National Park	1935
White, Hem, and Waring	Chemical composition of subsurface waters	1963
Cox	Water Resources of Yellowstone National Park	1969
Rowe, Fournier, and Morey	Chemical analysis of thermal waters in Yellowstone National Park	1973
Cox	Water Resources of Yellowstone National Park	1973
Thompson, Presser, Barnes, and Bird	Chemical analyses from Yellowstone National Park, 1965 to 1973	1975
Cox	Wastewater Movement in Yellowstone National Park	1978
Cox	Wastewater Movement in Yellowstone National Park	1979
Thompson and Yadav	Chemical analyses from Yellowstone National Park, 1974 to 1978	1979
Stauffer, Jenne, and Ball	Chemical studies of selected trace elements in hot spring drainages of Yellowstone National Park	1980
Thompson and Hutchinson	Chemical analyses from the Boundary Creek area, Yellowstone National Park	1981
Cox	Wastewater Movement in Yellowstone National Park	1986
White, Hutchinson, and Keith	Geology and thermal features of Norris Geyser Basin	1988
Fournier	Geochemistry and dynamics of the Yellowstone National Park hydrothermal system	1989
Kharaka, Mariner, Bullen, Kennedy, and Sturchio	Geochemical investigations at Corwin Springs and adjacent parts of Yellowstone National Park	1991
Rye and Truesdell	Recharge to geysers and hot springs of Yellowstone National Park	1993
Fournier, Thompson, and Hutchinson	Geochemistry of hot spring waters at Norris Geyser Basin	1994
Thompson and DeMonge	Chemical analyses from Yellowstone National Park	1996
Ball, Nordstrom, Jenne, and Vivit	Chemical analyses from Yellowstone National Park, 1974-1975 data	1998a
Ball, Nordstrom, Cunningham, Schoonen, Xu, and DeMonge	Chemical analyses from Yellowstone National Park, 1994-1995 data	1998b
Ball, Nordstrom, McCleskey, Schoonen, and Xu	Chemical analyses from Yellowstone National Park, 1996-1998 data	2001
Fournier, Weltman, Counce, White, and Janik	Chemical and isotopic monitoring of selected springs in Norris Geyser Basin	2002
Kharaka, Thordsen, and White	Isotope and chemical compositions of meteoric and thermal waters and snow, Yellowstone National Park region	2002
Ball, McCleskey, Nordstrom, Holloway, and Verplanck	Chemical analyses from Yellowstone National Park, 1999-2000 data	2002
McCleskey, Ball, Nordstrom, Holloway, and Taylor	Chemical analyses from Yellowstone National Park, 2001-2002 data	2004
Nordstrom, Ball, and McCleskey	Chemistry of thermal outflows in Yellowstone National Park	2005

During 2003–2005, 157 water samples were collected from ten areas of YNP (fig. 1): Terrace and Beryl Springs in the Gibbon Canyon area; Norris Geyser Basin; the West Nymph Creek thermal area; the area near Nymph Lake, Hazle Lake, and Frying Pan Spring; Lower Geyser Basin; Washburn Hot Springs; Mammoth Hot Springs; Potts Hot Spring Basin; the Sulphur Caldron area; and Lemonade Creek near the Solfatara Trail. Thirty-two analyses are reported for samples collected during May and June 2003, 24 analyses are reported for samples collected during September 2003; 48 analyses are reported for samples collected during September 2004; 39 analyses are reported for samples collected during June 2005; and 14 analyses are reported for September 2005. Many of the results reported here contain the most complete analytical data available for YNP geothermal waters. Constituents analyzed include dissolved concentrations of calcium (Ca), magnesium (Mg), strontium (Sr), barium (Ba), sodium (Na), potassium (K), lithium (Li), sulfate (SO_4), thiosulfate (S_2O_3), polythionate (S_nO_6), hydrogen sulfide (H_2S), alkalinity (as HCO_3), acidity, fluoride (F), chloride (Cl), bromide (Br), nitrate (NO_3), nitrite (NO_2), ammonium (NH_4), silica (SiO_2), boron (B), aluminum (Al), total iron (Fe(T)), ferrous iron (Fe(II)), manganese (Mn), copper (Cu), zinc (Zn), cadmium (Cd), chromium (Cr), cobalt (Co), total mercury (Hg(T)), methyl mercury (CH_3Hg), nickel (Ni), lead (Pb), beryllium (Be), vanadium (V), molybdenum (Mo), total antimony (Sb(T)), antimonite (Sb(III)), selenium (Se), total arsenic (As(T)), arsenite (As(III)), dissolved organic carbon (DOC), and isotopes of hydrogen (δD) and oxygen ($\delta^{18}O$).

Acknowledgments

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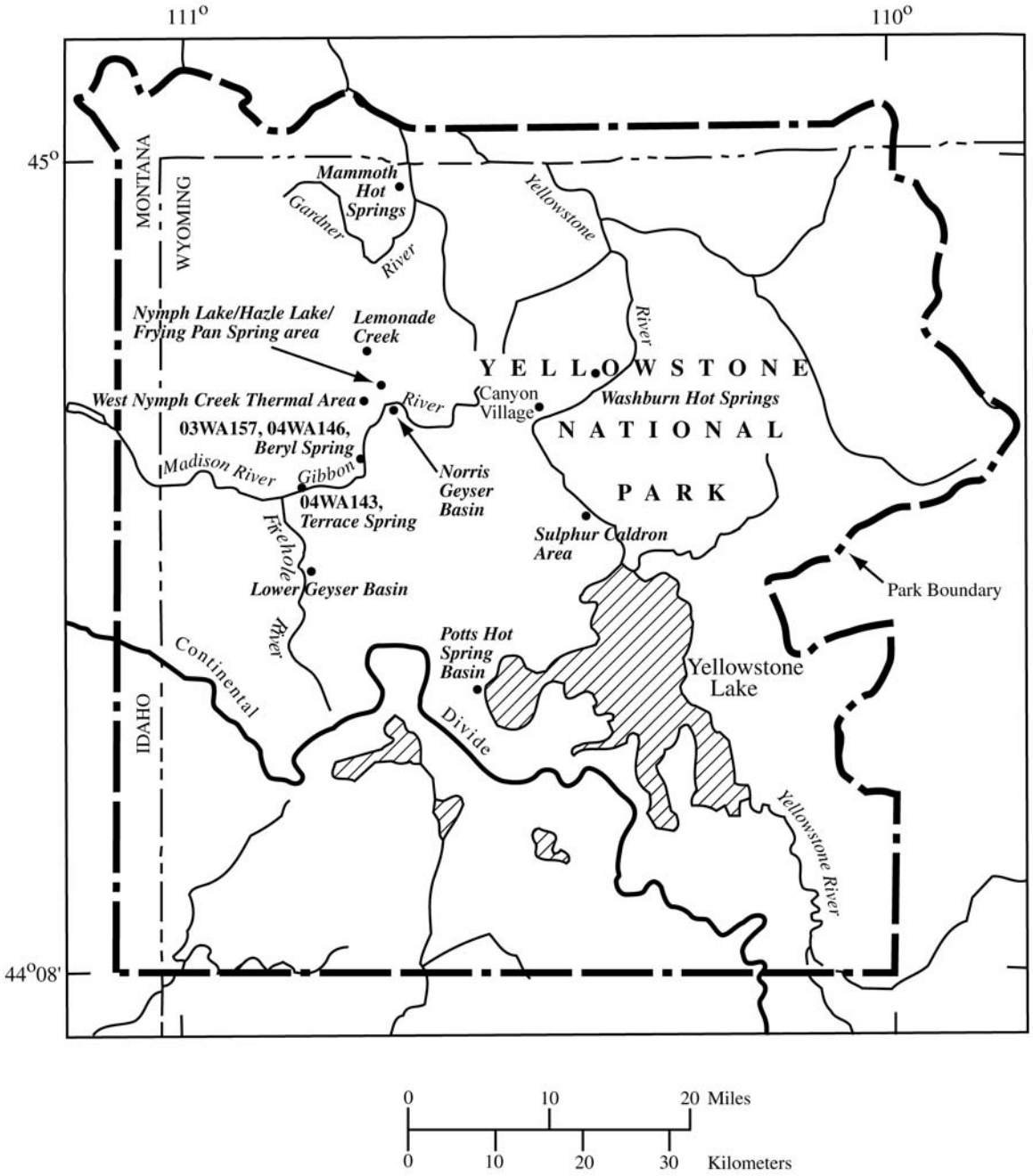


Base from Stauffer and others (1980)

Figure 1. Location of sampling areas in Yellowstone National Park, Wyoming.

Methods of Sample Collection, Preservation, and Analysis

Sample Locations

Because many geothermal features can be within meters of each other, it is critical that sample sites be accurately located and described. To this end, we have made every effort to include detailed maps (figs. 2–13), written descriptions, accurate latitude and longitude measurements (table 2), and photographs (Appendix) of all the sample sites for which analytical results are reported.

Sample locations for Terrace and Beryl Springs are shown on figure 1. Sample locations for the remaining nine areas sampled are shown on the following maps: Norris Geyser Basin (figs. 2–5), West Nymph Creek thermal area (fig. 6), Nymph Creek Springs, Nymph Creek, Hazle Lake, and other thermal features in the Nymph Lake area (fig. 7), Lower Geyser Basin (fig. 8), Washburn Hot Springs (fig. 9), Mammoth Hot Springs (fig. 10), Potts Hot Spring Basin (fig. 11), Sulphur Caldron Area (fig. 12), and Lemonade Creek near Solfatara Trail (fig. 13). Official names are taken from Whittlesey (1988). Several features that did not have official names were assigned names by the authors. Features named by the authors are in quotations in tables 2 and 6–14.

In the tables, "source" samples were collected at the origin of the spring, and "overflow channel" samples were collected at various distances downstream from the source. Series of transect samples were collected in the overflow channels from West Nymph Creek thermal area (04WA110B to 110D, Mound Spring (03WA133–T1 to T7 and 05WA112 to 117), Ojo Caliente Spring (05WA102 to 110), and Lemonade Creek (03WA159 to 162 and 05WA119 to 125). Latitudes and longitudes were acquired using a portable global positioning system (GPS, Garmin III+) with latitudes and longitudes referenced to the NAD27 datum (North American Datum of 1927).

Sample Collection and Preservation

Samples were collected from streams, tributaries, and overflow channels as close to the center of flow as possible and in areas that appeared to be well mixed. For springs and geysers, samples were collected as close to the discharge source as possible. Extreme care was taken to safely collect water samples from the larger geothermal sites, to protect fragile hot-spring mineral formations, and to minimize changes in temperature, pH, and water chemistry during sampling. Samples were collected from the middle of large pools and geysers by positioning the sample tubing intake using an insulated stainless-steel container as a flotation device attached to the end of an extendable aluminum pole. At more easily-accessible sites, the tubing intake was positioned in the source or channel by hand. A Teflon block attached to the end of the sampling tubing was used as a weight to keep the sample tubing in place (McCleskey and others, 2004). Grab samples also were collected from the source using the stainless-steel container or a syringe with Teflon tubing.

Samples were collected and filtered on-site by either or both of the following two techniques. The first technique consisted of pumping the water directly from the source with a battery-operated peristaltic pump fitted with medical-grade silicone tubing through a pre-cleaned 142-millimeter (mm) diameter all-plastic filter holder (Kennedy and others, 1976) containing a 0.1-micrometer (μm) pore size mixed-cellulose-ester filter membrane. The second technique consisted of filling a 60-milliliter (mL) syringe by suctioning from the source or with source water collected in the stainless-steel container and immediately forcing the water through a 25-mm disposable filter having a mixed-cellulose-ester membrane with a pore size of 0.2 or 0.45 μm.

Table 2. Detailed sample site descriptions, locations, and map, photograph, and chemical data table reference
[--, not measured or not photographed; cm, centimeters; m, meters]

Name and Site Description	Sample code number	North Latitude	West Longitude	Map (figure)	Chemical data (table)	Photograph (appendix)
Gibbon Canyon						
Beryl Spring	03WA157	44° 40' 43.5"	110° 44' 44.7"	1	6	1
Beryl Spring	04WA146	44° 40' 43.5"	110° 44' 44.7"	1	6	2
Terrace Spring	04WA143	44° 39' 00.8"	110° 50' 45.0"	1	6	3
Norris Geyser Basin (One Hundred Spring Plain area)						
Tantalus Creek at weir	03WA123	44° 44' 2.8"	110° 42' 54.5"	2, 3	7	4
Tantalus Creek at weir	03WA149	44° 44' 2.8"	110° 42' 54.5"	2, 3	7	5
Tantalus Creek at weir	04WA117	44° 44' 2.7"	110° 42' 54.5"	2, 3	7	6
Tantalus Creek at weir	05WA130	44° 44' 2.7"	110° 42' 54.6"	2, 3	7	7
Tantalus Creek at weir	05WA147	44° 44' 2.7"	110° 42' 54.6"	2, 3	7	8
Cinder Pool	03WA116	44° 43' 57.2"	110° 42' 35.6"	2, 3	7	9
Cinder Pool Side	03WA116B	44° 43' 57.2"	110° 42' 35.6"	2, 3	7	--
Cinder Pool	03WA150	44° 43' 57.2"	110° 42' 35.6"	2, 3	7	10
Cinder Pool	04WA115	44° 43' 57.5"	110° 42' 32.5"	2, 3	7	11
Cinder Pool	05WA129	44° 43' 57.5"	110° 42' 32.5"	2, 3	7	12
Cinder Pool	05WA140	44° 43' 57.5"	110° 42' 32.5"	2, 3	7	13
Norris Geyser Basin (Back Basin area)						
"Black Gassy Spring"	04WA130	44° 43' 36.6"	110° 42' 30.7"	2, 4	7	14, 15
Cistern Spring	03WA121	44° 43' 23.4"	110° 42' 14.8"	2, 4	7	16
Cistern Spring-Side	03WA121B	44° 43' 23.4"	110° 42' 14.8"	2, 4	7	--
Cistern Spring	03WA143	44° 43' 23.4"	110° 42' 14.8"	2, 4	7	17
Cistern Spring	04WA116	44° 43' 23.4"	110° 42' 14.8"	2, 4	7	18
Cistern Spring	05WA134	44° 43' 23.4"	110° 42' 14.8"	2, 4	7	19
Cistern Spring	05WA141	44° 43' 23.4"	110° 42' 14.8"	2, 4	7	20
Congress Pool	05WA152	44° 43' 40.3"	110° 42' 2.4"	2, 4	7	21
Constant Geyser	03WA141	44° 43' 43.7"	110° 42' 7.6"	2, 4	7	22
Echinus Geyser	03WA120	44° 43' 19.7"	110° 42' 4.6"	2, 4	7	23
Echinus Geyser	03WA144	44° 43' 19.7"	110° 42' 4.6"	2, 4	7	24
Pearl Geyser	05WA151	44° 43' 19.4"	110° 42' 22.9"	2, 4	7	25
Perpetual Spouter	04WA129	44° 43' 36.1"	110° 42' 30.1"	2, 4	7	26
Perpetual Spouter	05WA128	44° 43' 36.1"	110° 42' 30.1"	2, 4	7	27
Tantalus Creek upstream from Perpetual Spouter	04WA128	44° 43' 35.4"	110° 42' 29.9"	2, 4	7	28
Unnamed acid spring near Perpetual Spouter	04WA127	44° 43' 35.5"	110° 42' 33.1"	2, 4	7	29
Porkchop Geyser	03WA118	44° 43' 19.9"	110° 42' 29.3"	2, 4	7	30
Porkchop Geyser	03WA145	44° 43' 19.9"	110° 42' 29.3"	2, 4	7	31
Porkchop Geyser	04WA144	44° 43' 19.9"	110° 42' 29.3"	2, 4	7	32
"Second Eruptor" near Porkchop Geyser	03WA147	44° 43' 19.8"	110° 42' 24.4"	2, 4	7	33
"Second Eruptor" near Porkchop Geyser	04WA145	44° 43' 20.2"	110° 42' 24.5"	2, 4	7	34
"Second Eruptor" near Porkchop Geyser	05WA127	44° 43' 20.2"	110° 42' 24.5"	2, 4	7	35
"Second Eruptor" near Porkchop Geyser	05WA142	44° 43' 20.2"	110° 42' 24.5"	2, 4	7	36
Thermal discharge at base of Porkchop Geyser	03WA119	44° 43' 20.3"	110° 42' 26.5"	2, 4	7	37
Thermal discharge at base of Porkchop Geyser	03WA146	44° 43' 20.3"	110° 42' 26.5"	2, 4	7	38
Unnamed thermal feature near "Second Eruptor"	05WA126	44° 43' 20.3"	110° 42' 26.5"	2, 4	7	39
Steamboat Geyser	03WA142	44° 43' 24.8"	110° 42' 11.2"	2, 4	7	40
Norris Geyser Basin (Ragged Hills area)						
Crystal Spring	05WA131	44° 43' 43.6"	110° 42' 40.1"	2, 5	7	41
"Kaolin Spring"	03WA122	44° 43' 41.9"	110° 42' 48.2"	2, 5	7	42
"Kaolin Spring"	05WA132	44° 43' 41.8"	110° 42' 44.5"	2, 5	7	43
Unnamed 15-cm diameter pool with bright yellow precipitate, 6 m northwest of The Gap drainage	03WA124	44° 43' 45.3"	110° 42' 41.4"	2, 5	7	44
Unnamed 15-cm diameter pool with bright yellow precipitate, 6 m northwest of The Gap drainage	03WA140	44° 43' 45.2"	110° 42' 41.5"	2, 5	7	45
Unnamed 15-cm diameter pool with bright yellow precipitate, 6 m northwest of The Gap drainage	04WA118	44° 43' 45.3"	110° 42' 41.4"	2, 5	7	46

Table 2. Detailed sample site descriptions, locations, and map, photograph, and chemical data table reference—Continued

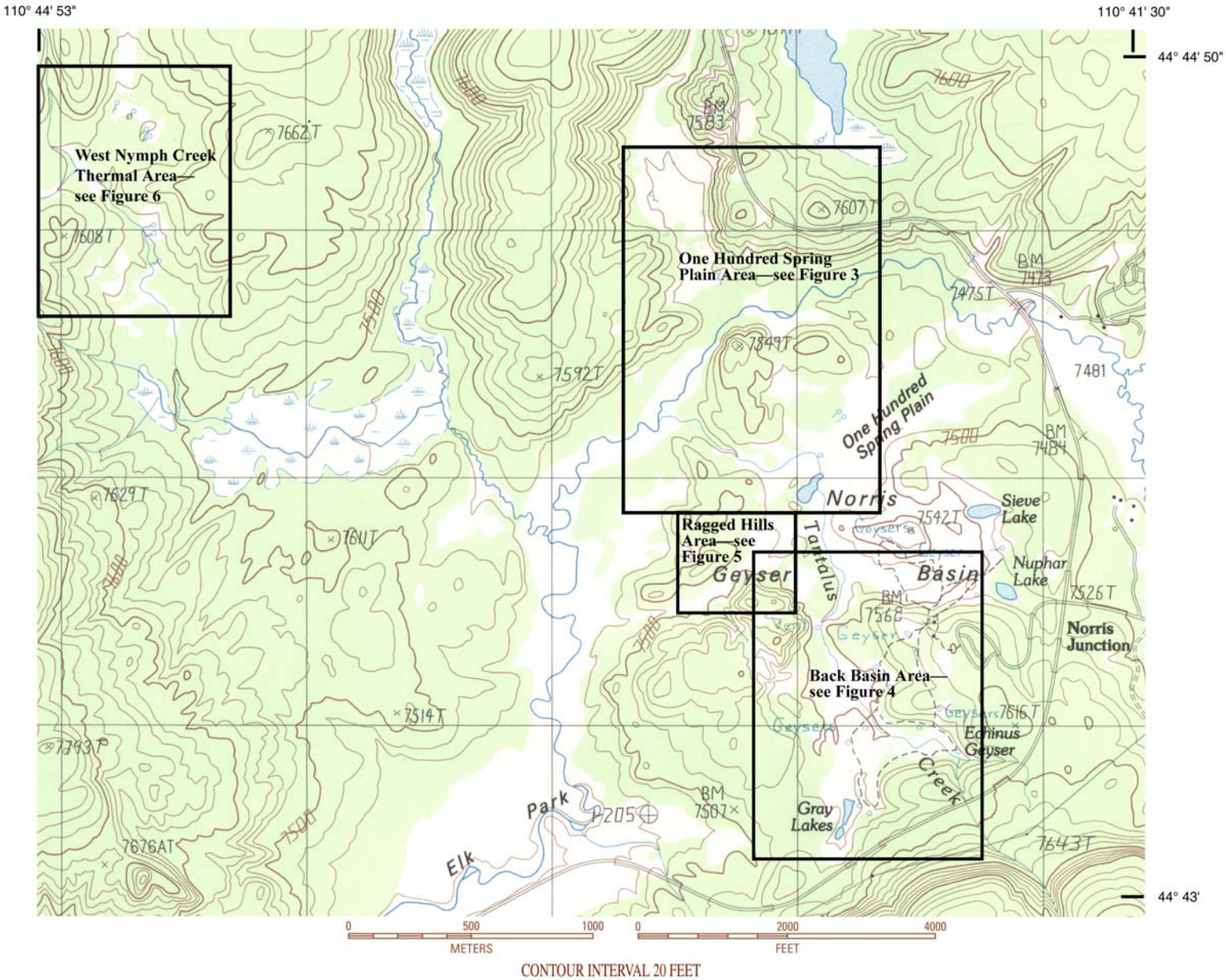
Name and Site Description	Sample code number	North Latitude	West Longitude	Map (figure)	Chemical data (table)	Photograph (appendix)
"Orpiment Puddle 2"	03WA151	44° 43' 44.7"	110° 42' 41.3"	2, 5	7	47
"Orpiment Puddle 2"	04WA119	44° 43' 44.5"	110° 42' 41.3"	2, 5	7	48
"Orpiment Puddle 2"	04WA119-0.45	44° 43' 44.5"	110° 42' 41.3"	2, 5	7	--
"Orpiment Puddle 3"	04WA120	44° 43' 44.4"	110° 42' 41.6"	2, 5	7	49
"Orpiment Puddle 4"	05WA133	44° 43' 44.2"	110° 42' 42.4"	2, 5	7	50
"Persnickety Geyser"	04WA123	44° 43' 40.1"	110° 42' 49.9"	2, 5	7	51
"Rainbow Growler"	03WA152	44° 43' 42.2"	110° 42' 44.1"	2, 5	7	52
"Rainbow Growler"	04WA126	44° 43' 42.0"	110° 42' 44.2"	2, 5	7	53
"Titanic Spring"	03WA117	44° 43' 40.0"	110° 42' 48.5"	2, 5	7	54
"Titanic Spring"	03WA139	44° 43' 40.0"	110° 42' 48.5"	2, 5	7	55
"Titanic Spring"	04WA122	44° 43' 40.0"	110° 42' 48.5"	2, 5	7	56
Unnamed pool southwest of "Lifeboat Spring"	04WA125	44° 43' 39.7"	110° 42' 49.9"	2, 5	7	57
Unnamed pool southwest of 04WA125	04WA124	44° 43' 39.5"	110° 42' 50.3"	2, 5	7	58
Unnamed thermal feature near "Orpiment Puddle 3"	04WA121	44° 43' 44.4"	110° 42' 41.5"	2, 5	7	59
West Nymph Creek thermal area						
Blue–green 15 by 25 m hot spring discharging to south	04WA105	44° 44' 44.7"	110° 44' 39.9"	2, 6	8	60
Yellow-green surging hot spring downslope of and receiving discharge from 04WA105	04WA106	44° 44' 43.1"	110° 44' 40.3"	2, 6	8	61
Turbid vigorously surging 10 by 75 m spring containing 4-mm-diameter yellow spherules	04WA107	44° 44' 40.9"	110° 44' 32.6"	2, 6	8	62
Steep-sided turbid dark brown gently surging 15–m–diameter hot spring adjacent to and elevated about 3 m above stream channel	04WA108	44° 44' 34.5"	110° 44' 40.8"	2, 6	8	63
Steep-sided gently surging blue-green hot spring	04WA109	44° 44' 23.9"	110° 44' 31.3"	2, 6	8	64
Quiescent hot spring with reddish algal mat covering most of bottom, discharge channel 30 m to stream, sampled from center of pool	04WA110	44° 44' 19.5"	110° 44' 31.7"	2, 6	8	65, 66
Quiescent hot spring with reddish algal mat, edge of pool	04WA110B	44° 44' 19.5"	110° 44' 31.7"	2, 6	8	--
Quiescent hot spring with reddish algal mat, drainage channel at pool exit	04WA110C	44° 44' 19.5"	110° 44' 31.7"	2, 6	8	--
Quiescent hot spring with reddish algal mat, drainage channel 13.7 m from pool exit	04WA110D	44° 44' 19.5"	110° 44' 31.7"	2, 6	8	67
Surface water drainage at south end of area	04WA111	44° 44' 18.3"	110° 44' 31.8"	2, 6	8	68
Pale blue-green 4 by 8 m violently surging hot spring, surges 0.2 to >1.5 m high	04WA112	44° 44' 21.2"	110° 44' 36.1"	2, 6	8	69
Vigorous spouter on steep slope about 4 m in elevation above stream bed adjacent to very loud fumarole	04WA113	44° 44' 32.7"	110° 44' 40.6"	2, 6	8	70
Brown turbid 5 by 8 m sunken pool with 1 major and 2 minor surging areas, sides composed of terraces of fine–grained mud	04WA114	44° 44' 40.5"	110° 44' 37.5"	2, 6	8	71
Nymph Lake area						
Frying Pan Spring near pool entrance, south side of highway	05WA136	44° 45' 8.0"	110° 43' 18.2"	7	9	72
Frying Pan Spring near pool entrance south side of highway (Chlorine isotope sample only)	05WA153	44° 45' 8.0"	110° 43' 18.2"	7	9	--
Frying Pan Spring near pool exit, south side of highway	05WA135	44° 45' 7.5"	110° 43' 18.7"	7	9	73
Hazle Lake, south side	03WA136	44° 45' 0.4"	110° 42' 39.9"	7	9	74
Hazle Lake, north side	03WA137	44° 45' 3.5"	110° 42' 40.8"	7	9	75
Nymph Creek Springs, new vent	04WA134	44° 45' 11.0"	110° 43' 24.0"	7	9	76
Nymphy Creek, upstream from and flowing into Nymph Lake	04WA132	44° 45' 12.6"	110° 43' 32.1"	7	9	77

Table 2. Detailed sample site descriptions, locations, and map, photograph, and chemical data table reference—Continued

Name and Site Description	Sample code number	North Latitude	West Longitude	Map (figure)	Chemical data (table)	Photograph (appendix)
Flood Creek (Nymph Lake discharge channel)	04WA133	44° 44' 58.3"	110° 43' 43.4"	7	9	78
Unnamed pool 50 m from road near Hazle Lake	04WA131	44° 45' 02.6"	110° 42' 53.0"	7	9	79
Unnamed pool 50 m from road near Hazle Lake, side of pool	04WA131B	44° 45' 02.6"	110° 42' 53.0"	7	9	--
Lower Geyser Basin						
Azure Spring	04WA139	44° 33' 39.7"	110° 49' 55.9"	8	10	80
Mound Spring	03WA133	44° 33' 53.9"	110° 51' 33.0"	8	10	81
Mound Spring overflow channel, 0.9 m downstream from pool exit	03WA133–T1	44° 33' 53.9"	110° 51' 33.0"	8	10	--
Mound Spring overflow channel, 6.4 m downstream from pool exit	03WA133–T2	44° 33' 53.8"	110° 51' 33.2"	8	10	--
Mound Spring overflow channel, 12.5 m downstream from pool exit	03WA133–T3	44° 33' 53.7"	110° 51' 33.5"	8	10	--
Mound Spring overflow channel, 17.1 m downstream from pool exit	03WA133–T4	44° 33' 53.7"	110° 51' 33.7"	8	10	--
Mound Spring overflow channel, 21.3 m downstream from pool exit	03WA133–T5	44° 33' 53.8"	110° 51' 33.9"	8	10	--
Mound Spring overflow channel, 26.2 m downstream from pool exit	03WA133–T6	44° 33' 53.7"	110° 51' 34.1"	8	10	--
Mound Spring overflow channel, 28.7 m downstream from pool exit	03WA133–T7	44° 33' 53.7"	110° 51' 34.1"	8	10	--
Mound Spring	04WA137	44° 33' 53.9"	110° 51' 33.0"	8	10	82
Mound Spring	05WA111	44° 33' 53.8"	110° 51' 33.2"	8	10	85
Mound Spring overflow channel, 0.6 m downstream from pool exit	05WA112	44° 33' 53.8"	110° 51' 33.2"	8	10	85
Mound Spring overflow channel, 5.8 m downstream from pool exit	05WA113	44° 33' 53.8"	110° 51' 33.3"	8	10	85, 86
Mound Spring overflow channel, 12.2 m downstream from pool exit	05WA114	44° 33' 53.7"	110° 51' 33.5"	8	10	87
Mound Spring overflow channel, 20.7 m downstream from pool exit	05WA115	44° 33' 53.8"	110° 51' 33.9"	8	10	87
Mound Spring overflow channel, 26.8 m downstream from pool exit	05WA116	44° 33' 53.7"	110° 51' 34.1"	8	10	87
Mound Spring overflow channel, 55 (±3) m downstream from pool exit	05WA117	44° 33' 53.4"	110° 51' 35.0"	8	10	88
Ojo Caliente Spring	04WA138	44° 33' 46.1"	110° 50' 16.9"	8	10	84
Ojo Caliente Spring	05WA101	44° 33' 47.1"	110° 50' 16.8"	8	10	93
Ojo Caliente Spring at pool exit, 12.2 m from source	05WA102	44° 33' 46.8"	110° 50' 16.9"	8	10	93, 94
Ojo Caliente Spring overflow channel, 16.5 m downstream from source	05WA103	44° 33' 46.7"	110° 50' 17.1"	8	10	94
Ojo Caliente Spring overflow channel, 19.5 m downstream from source	05WA104	44° 33' 46.5"	110° 50' 17.1"	8	10	--
Ojo Caliente Spring overflow channel, 23.3 m downstream from source	05WA105	44° 33' 46.4"	110° 50' 17.2"	8	10	89, 95
Ojo Caliente Spring overflow channel, 26.7 m downstream from source	05WA106	44° 33' 46.4"	110° 50' 17.2"	8	10	89, 95
Ojo Caliente Spring overflow channel, 30.0 m downstream from source	05WA107	44° 33' 46.3"	110° 50' 17.2"	8	10	90
Ojo Caliente Spring overflow channel, 34.3 m downstream from source	05WA108	44° 33' 46.2"	110° 50' 17.2"	8	10	90, 91
Ojo Caliente Spring overflow channel, 38.0 m downstream from source	05WA109	44° 33' 46.1"	110° 50' 17.2"	8	10	90, 91, 92
Ojo Caliente Spring overflow channel, 41.9 m downstream from source	05WA110	44° 33' 46.0"	110° 50' 17.2"	8	10	91, 92
Red Terrrace Spring/Queen's Laundry	03WA134	44° 33' 48.5"	110° 52' 9.9"	8	10	83

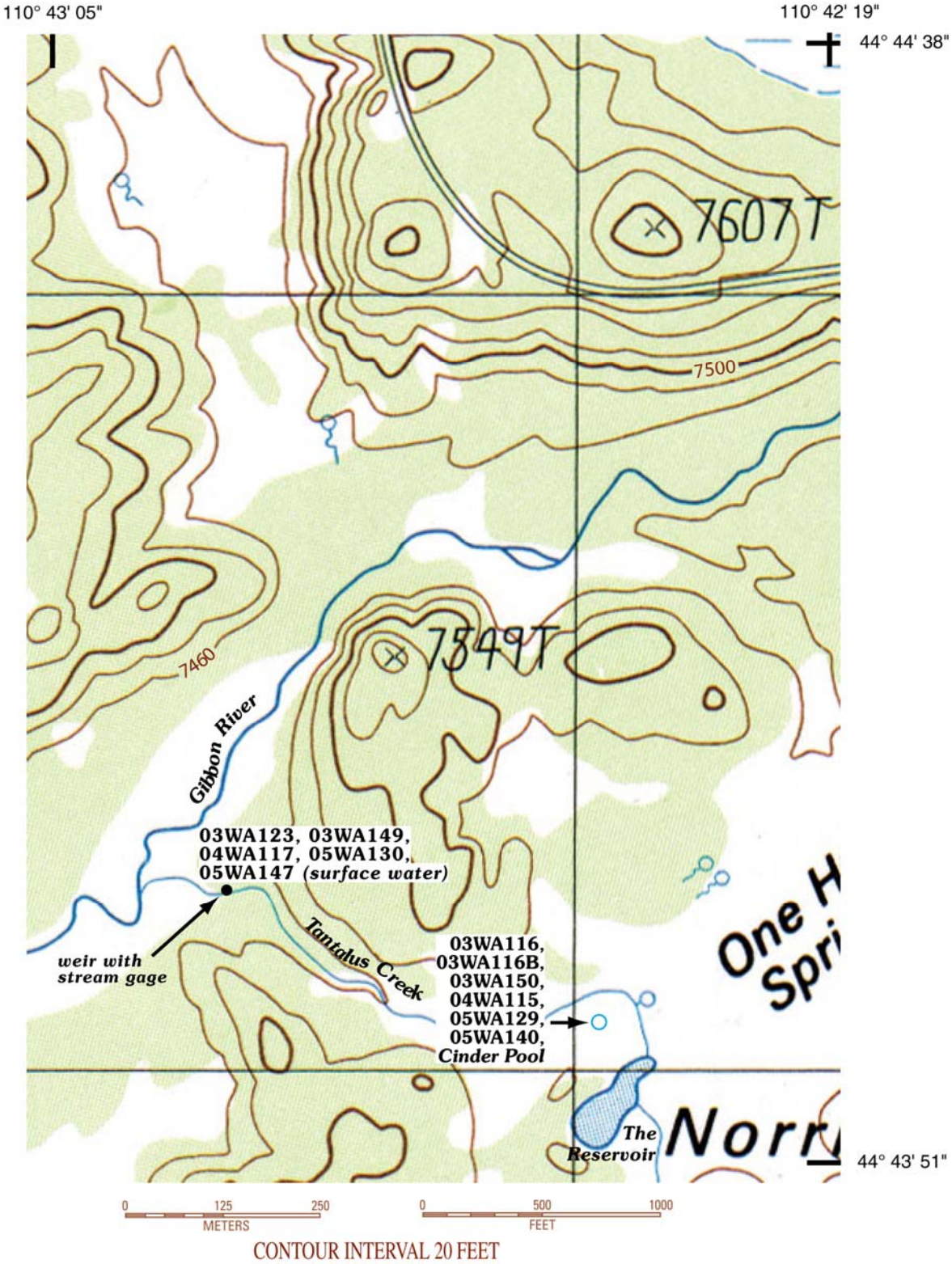
Table 2. Detailed sample site descriptions, locations, and map, photograph, and chemical data table reference—Continued

Name and Site Description	Sample code number	North Latitude	West Longitude	Map (figure)	Chemical data (table)	Photograph (appendix)
Steep Cone	03WA135	44° 34' 0.4"	110° 51' 44.8"	8	10	96
Steep Cone	04WA136	44° 34' 0.4"	110° 51' 44.8"	8	10	97
Steep Cone overflow channel	04WA136B	44° 34' 0.4"	110° 51' 44.8"	8	10	--
Unnamed small surging pool on bluff west of Firehole River	03WA138	44° 33' 33.6"	110° 49' 56.8"	8	10	98
Unnamed small surging pool on bluff west of Firehole River	04WA140	44° 33' 33.6"	110° 49' 56.8"	8	10	99
Mound Geyser, on bluff west of Firehole River	04WA141	44° 33' 34.1"	110° 49' 58.0"	8	10	100
Unnamed green pool west of Firehole River	04WA142	44° 33' 41.9"	110° 50' 07.3"	8	10	101
Washburn Hot Springs						
Inkpot #1	03WA127	44° 45' 53.1"	110° 25' 46.0"	9	11	102
Largest spring	03WA128	44° 45' 53.9"	110° 25' 46.2"	9	11	103
Inkpot #3	03WA129	44° 45' 53.5"	110° 25' 45.2"	9	11	104
Neutral mudpot	03WA130	44° 45' 52.2"	110° 25' 45.8"	9	11	104, 105
Mammoth Hot Springs						
Angel Terrace Spring	03WA125	44° 57' 54.7"	110° 42' 28.2"	10	5	106
Canary Spring	03WA126	44° 58' 1.1"	110° 42' 20.3"	10	5	107
Potts Hot Spring Basin						
Explosion Pool	03WA154	44° 25' 48.2"	110° 34' 41.7"	11	12	108
Jade Pool	03WA156	44° 25' 59.8"	110° 34' 53.2"	11	12	109
Pince Nez Spring	03WA153	44° 25' 59.3"	110° 34' 56.1"	11	12	110
Unnamed pool near Explosion Pool	03WA155	44° 25' 47.4"	110° 34' 42.1"	11	12	111
Sulphur Caldron area						
Mud Geyser	03WA132	44° 37' 23.2"	110° 25' 51.4"	12	13	112
Sulphur Caldron	03WA131	44° 37' 41.1"	110° 25' 55.8"	12	13	113
Sulphur Caldron	05WA139	44° 37' 41.5"	110° 25' 55.9"	12	13	114
Unnamed hot spring at lake shore	04WA135	44° 36' 40.4"	110° 26' 12.0"	12	13	115
Lemonade Creek area						
Uppermost thermal spring in drainage	03WA148	44° 48' 3.0"	110° 43' 40.6"	13	14	116
Middle thermal spring in drainage	03WA158	44° 48' 4.0"	110° 43' 40.9"	13	14	117, 119
Lowermost thermal spring in drainage	03WA159	44° 48' 4.2"	110° 43' 40.7"	13	14	118
Lemonade Creek, 2 m downstream from confluence with lowermost thermal vent overflow channel	03WA160	44° 48' 4.5"	110° 43' 41.2"	13	14	119
Lemonade Creek, 27 m downstream from confluence with thermal vent overflow channel	03WA161	44° 48' 5.7"	110° 43' 41.3"	13	14	--
Lemonade Creek, 140 m downstream from confluence with thermal vent overflow channel	03WA162	44° 48' 8.7"	110° 43' 42.0"	13	14	--
Thermal vent	05WA118	44° 48' 4.1"	110° 43' 40.7"	13	14	120, 121
Thermal vent overflow channel, 1 m downstream from source	05WA119	44° 48' 4.2"	110° 43' 40.9"	13	14	121
Thermal vent overflow channel, 1 m upstream from Lemonade Creek	05WA120	44° 48' 4.2"	110° 43' 41.2"	13	14	121, 122
Lemonade Creek upstream from confluence with thermal vent overflow channel	05WA121	44° 48' 4.4"	110° 43' 41.1"	13	14	121, 122
Lemonade Creek, 15 m downstream from confluence with thermal vent overflow channel	05WA122	44° 48' 5.3"	110° 43' 41.3"	13	14	123
Lemonade Creek, 27 m downstream from confluence with thermal vent overflow channel	05WA123	44° 48' 5.7"	110° 43' 41.1"	13	14	124
Lemonade Creek, 60 m downstream from confluence with thermal vent overflow channel	05WA124	44° 48' 6.4"	110° 43' 41.1"	13	14	124, 125
Lemonade Creek, 140 m downstream from confluence with thermal vent overflow channel	05WA125	44° 48' 8.9"	110° 43' 41.9"	13	14	126, 127



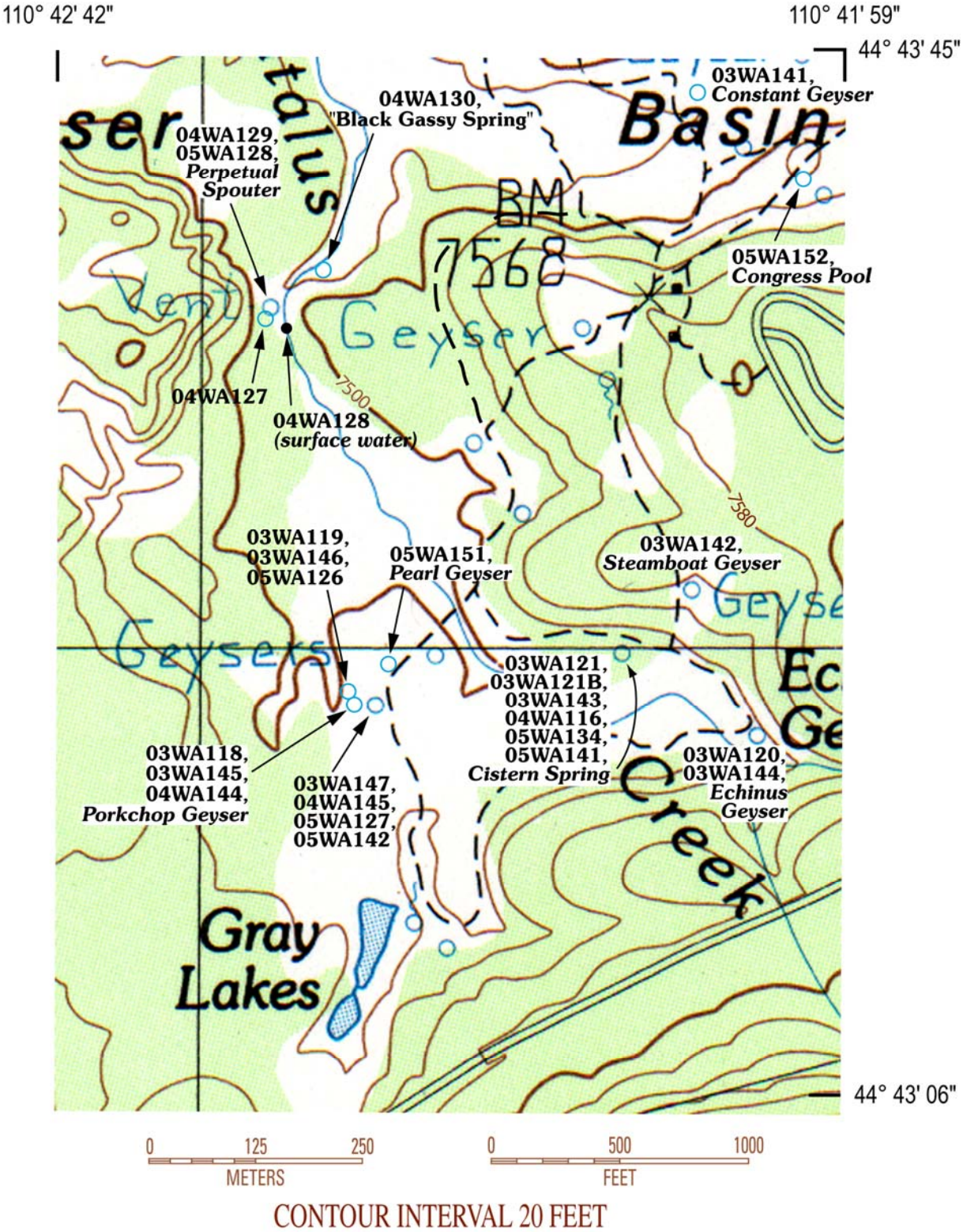
Base from U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 2. Sampling locations for hot springs, geysers, and surface waters at Norris Geyser Basin and West Nymph Creek thermal area, Yellowstone National Park, Wyoming.



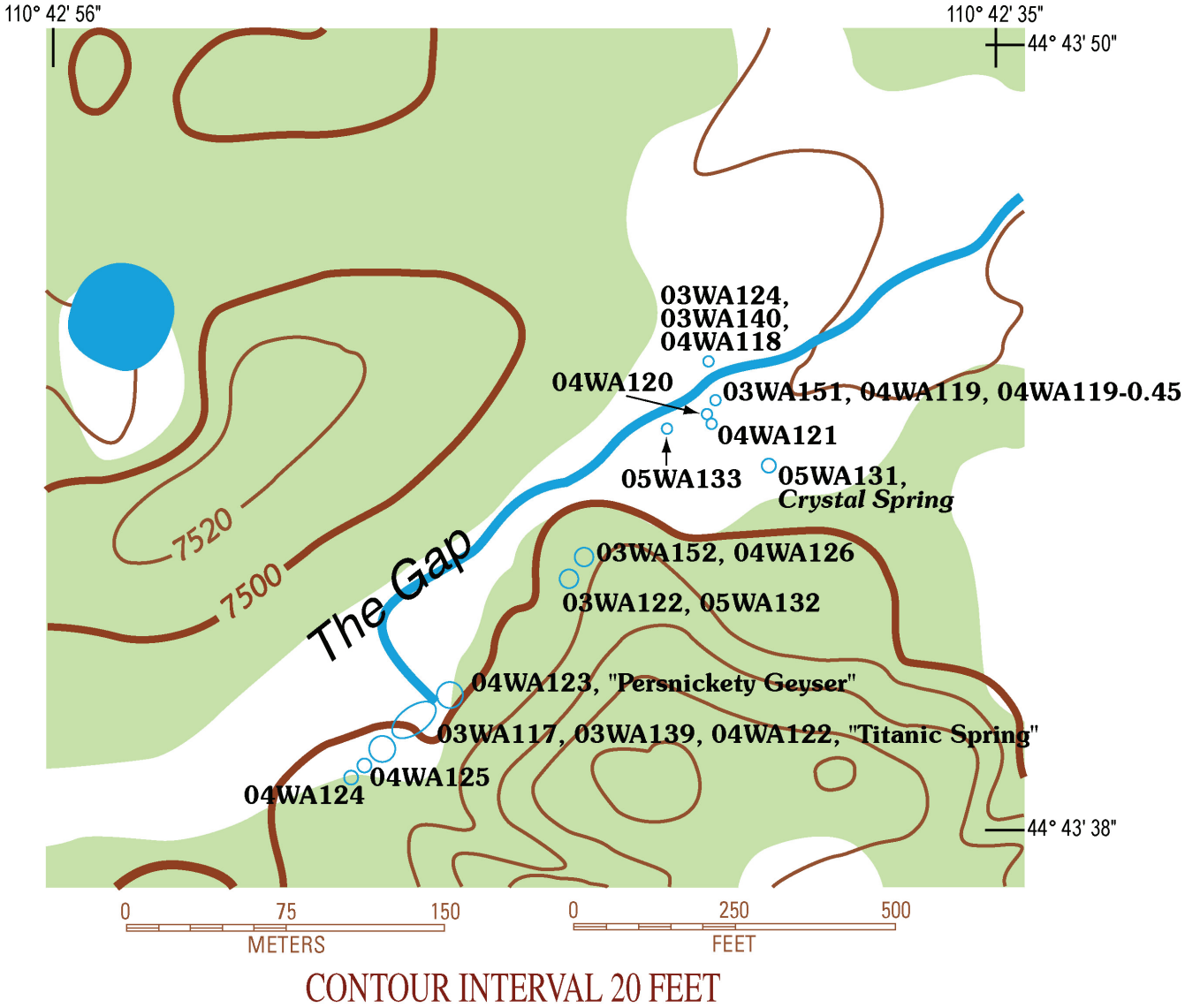
Base from U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 3. Sampling locations with sample code numbers for Cinder Pool and Tantalus Creek in the One Hundred Spring Plain area of Norris Geyser Basin, Yellowstone National Park, Wyoming (see figure 2).



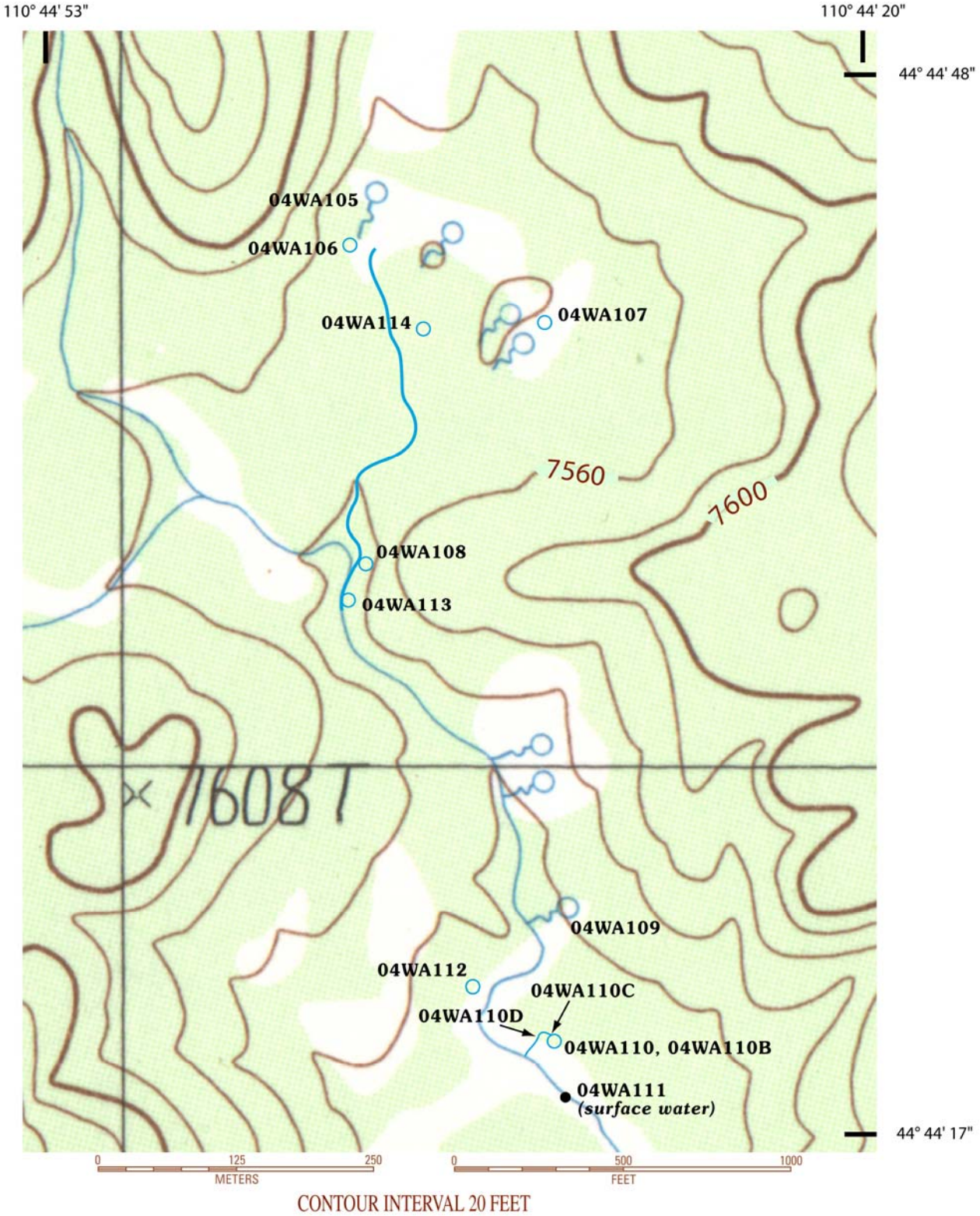
Base from U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 4. Sampling locations with sample code numbers for thermal features and one surface-water sample in the Back Basin area of Norris Geyser Basin, Yellowstone National Park, Wyoming (see figure 2).



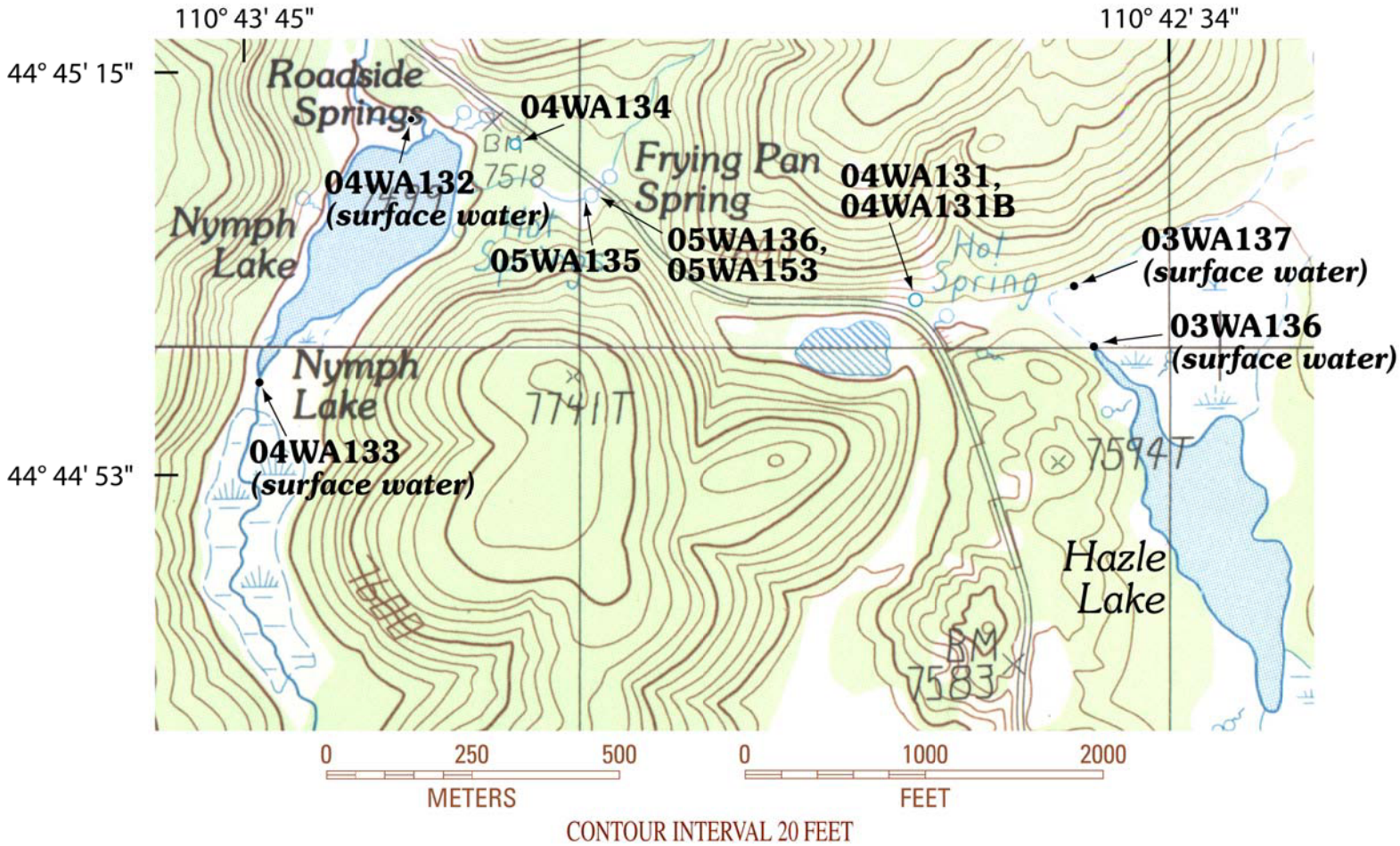
Sketch based on U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 5. Sampling locations with sample code numbers for thermal features in the Ragged Hills area of Norris Geyser Basin, Yellowstone National Park, Wyoming (see figure 2).



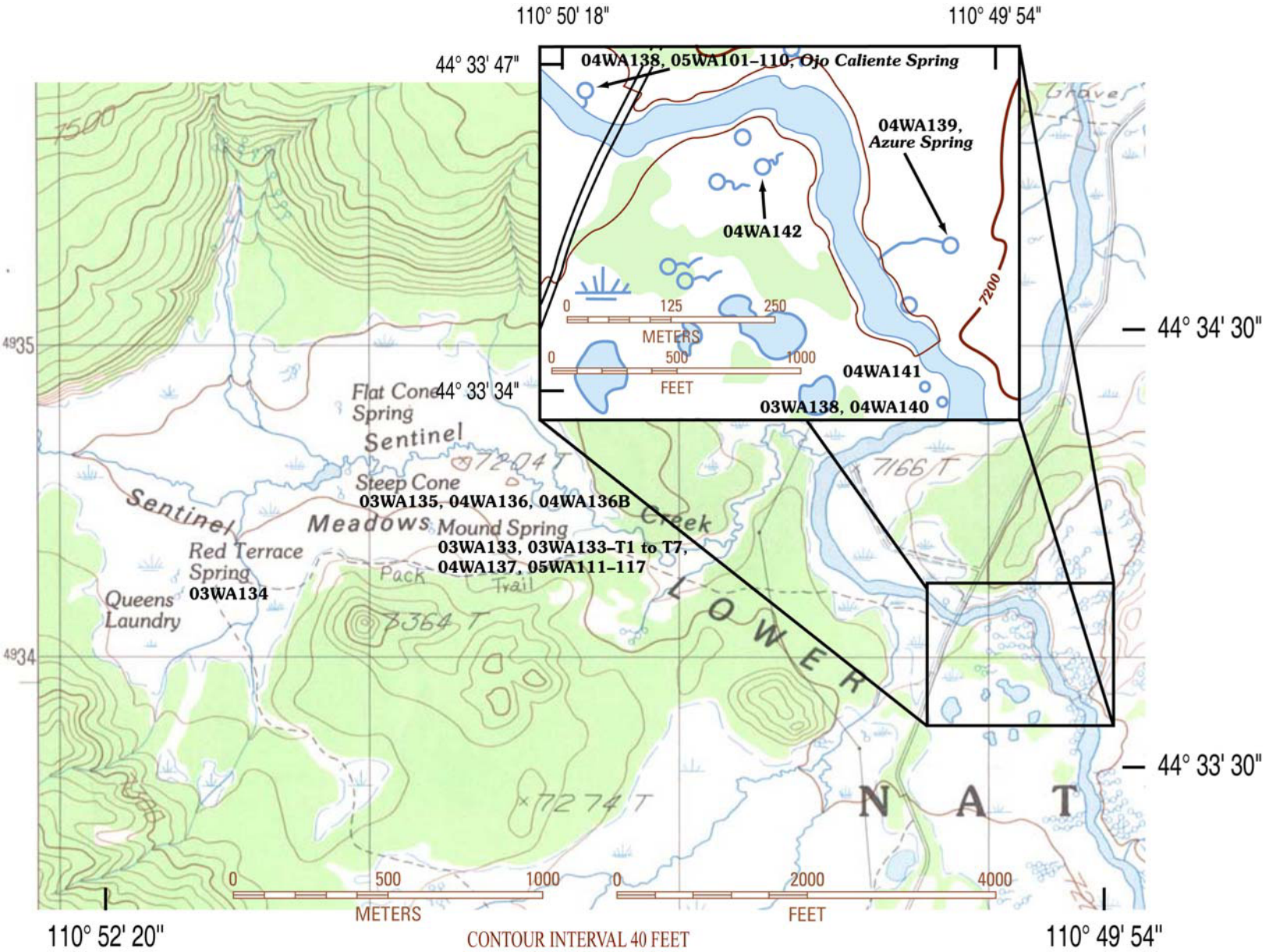
Base from U.S. Geological Survey Norris Junction quadrangle, 1:24,000 (1986)

Figure 6. Sampling locations with sample code numbers for thermal features and one surface-water sample in the West Nymph Creek thermal area, Yellowstone National Park, Wyoming (see figure 2).



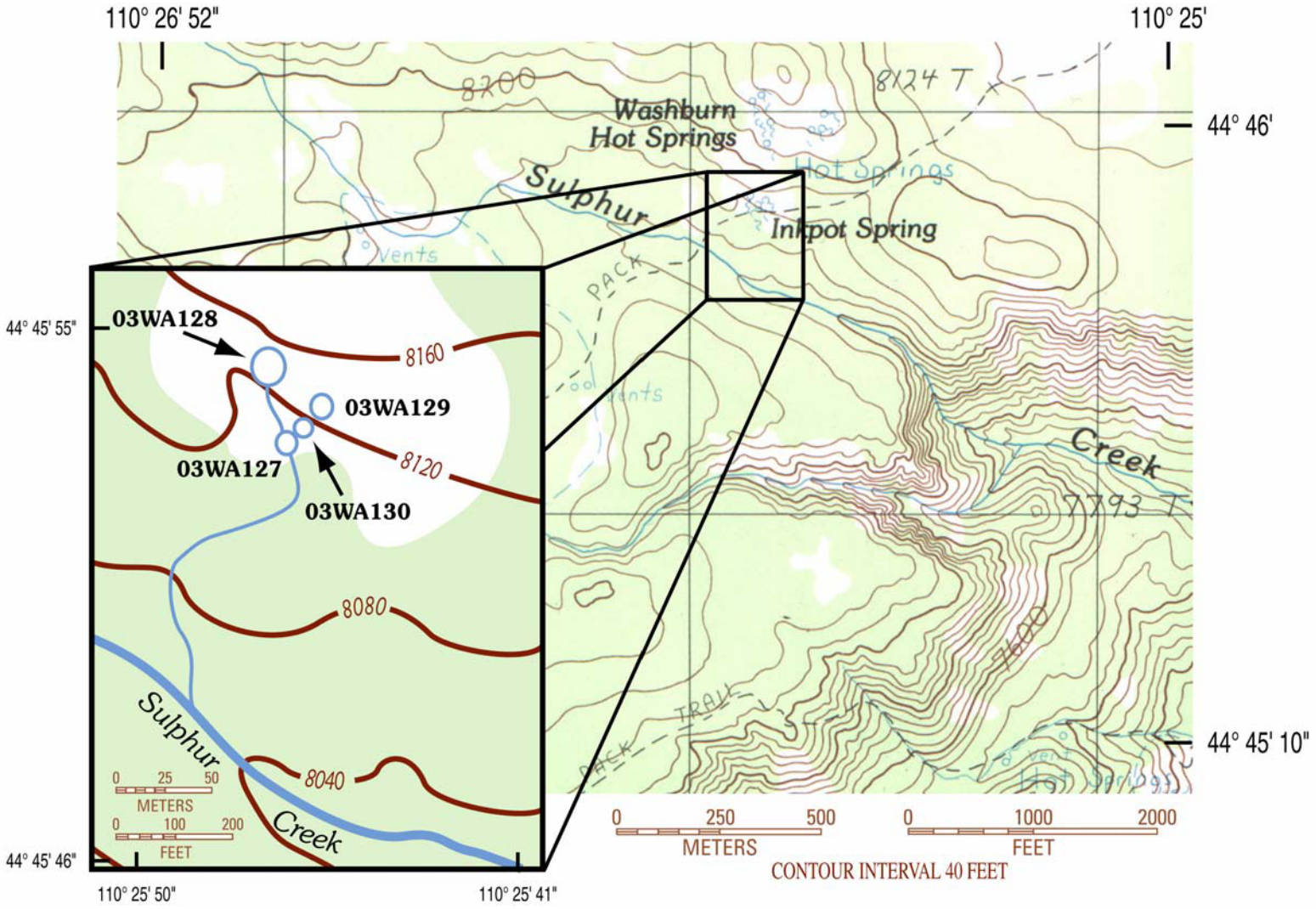
Base from U.S. Geological Survey Norris Junction and Obsidian Cliff quadrangles, 1:24,000 (1986)

Figure 7. Sampling locations with sample code numbers for Nymph Lake and Roadside Springs area, including Nymph Creek, Nymph Creek Springs, Hazle Lake, and Frying Pan Spring, Yellowstone National Park, Wyoming.



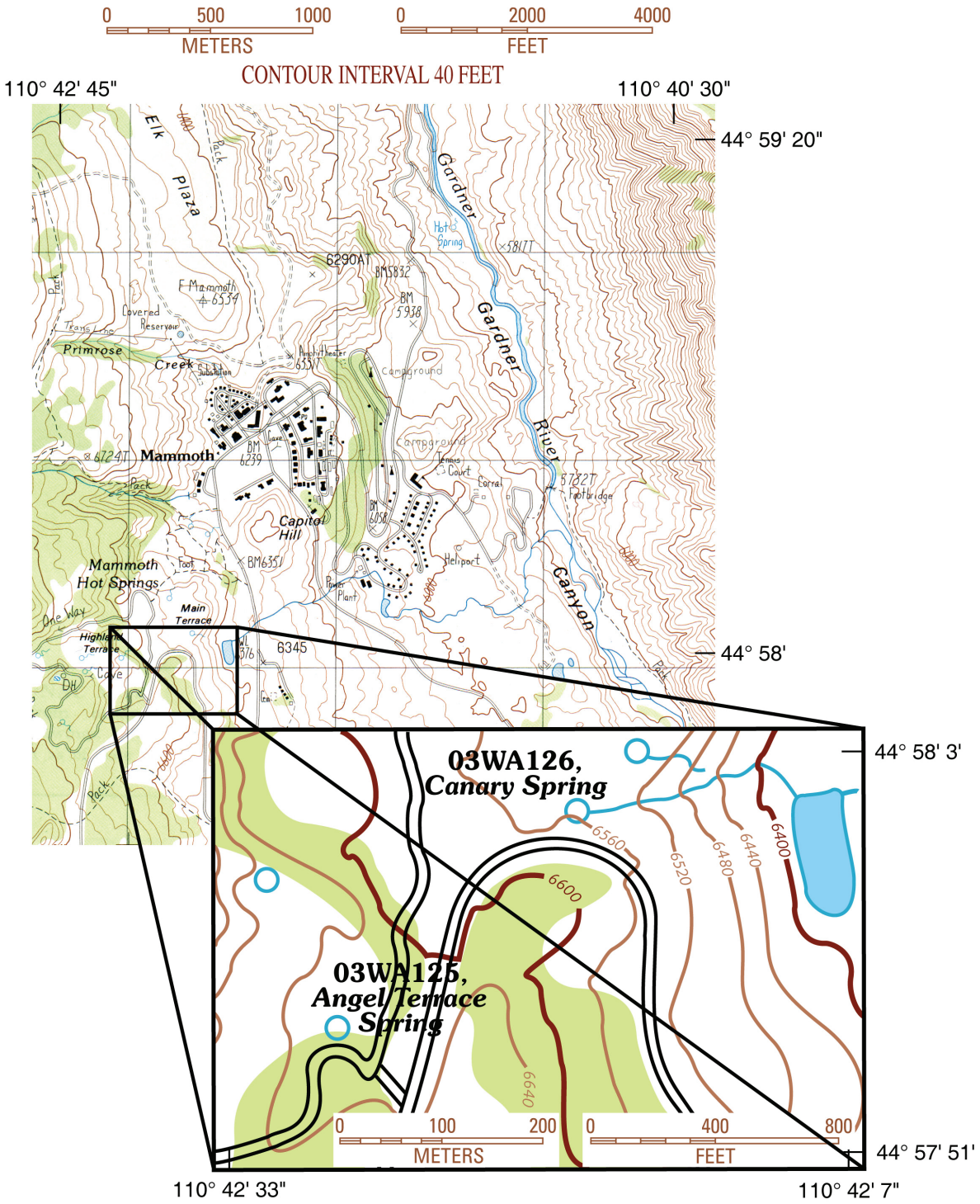
Base from U.S. Geological Survey Lower Geyser Basin Quadrangle, 1:24,000 (1986)

Figure 8. Sampling locations with sample code numbers for thermal features in Lower Geyser Basin, Yellowstone National Park, Wyoming.



Base from U.S. Geological Survey Mount Washburn Quadrangle, 1:24,000 (1986)

Figure 9. Sampling locations with sample code numbers for thermal features at Washburn Hot Springs, Yellowstone National Park, Wyoming.

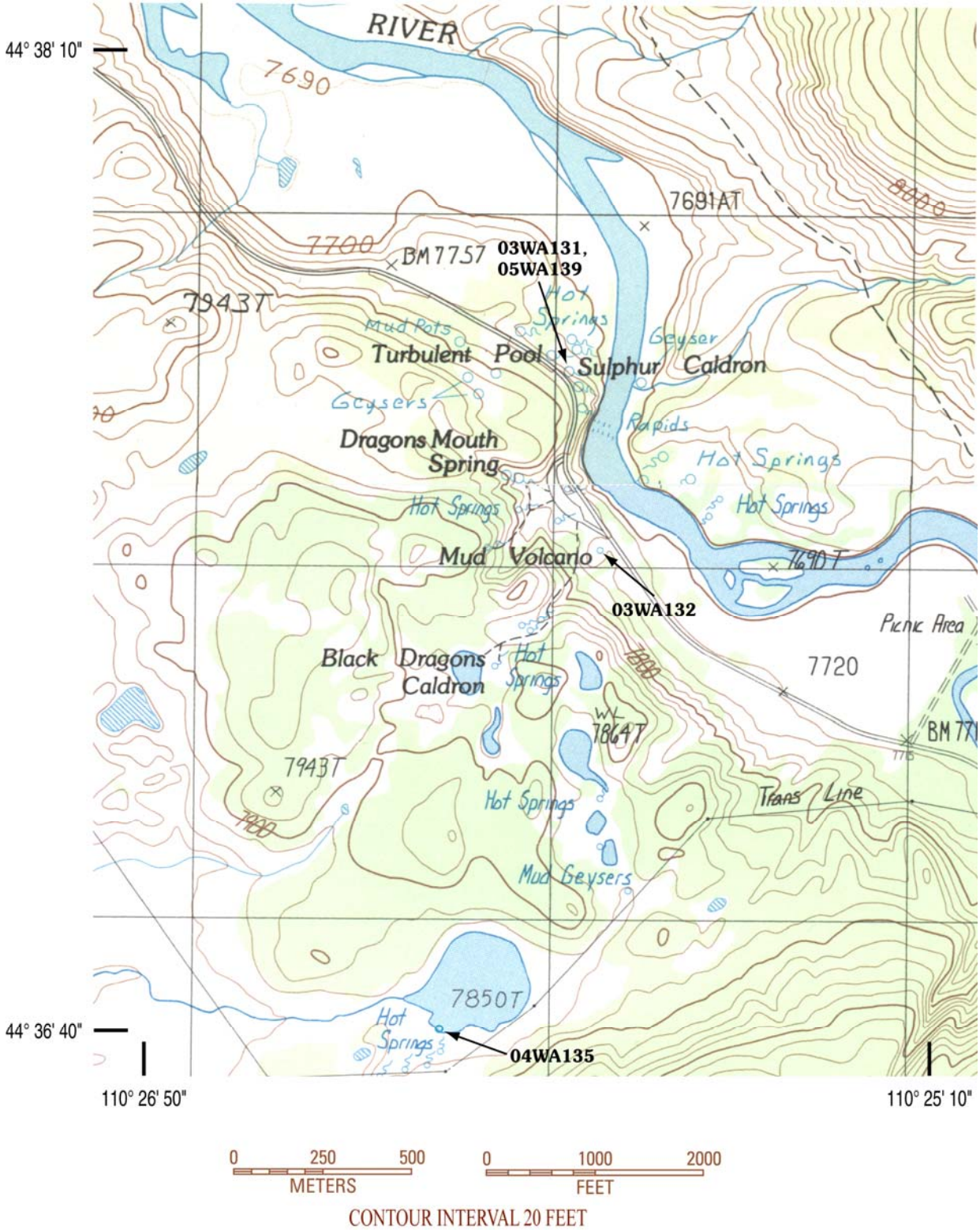


Base from U.S. Geological Survey Mammoth Quadrangle, 1:24,000 (1986)

Figure 10. Sampling locations with sample code numbers for thermal features at Mammoth Hot Springs, Yellowstone National Park, Wyoming.

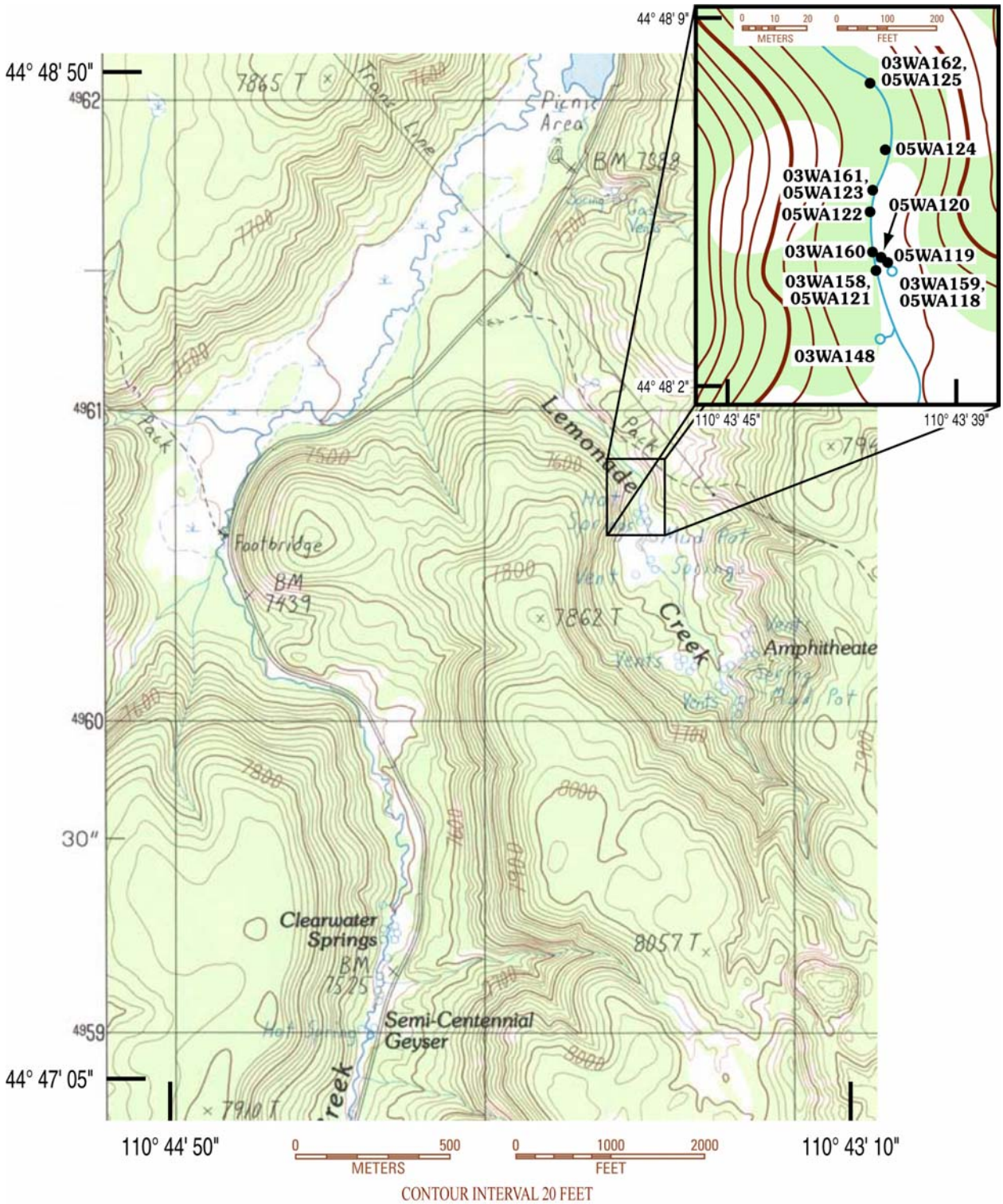
Base from U.S. Geological Survey West Thumb Quadrangle, 1:24,000 (1986)

Figure 11. Sampling locations with sample code numbers for thermal features at Potts Hot Spring Basin, Yellowstone National Park, Wyoming.



Base from U.S. Geological Survey Lake and Canyon Village Quadrangles, 1:24,000 (1986)

Figure 12. Sampling locations with sample code numbers for thermal features in the Sulphur Caldron Area, Yellowstone National Park, Wyoming.



Base from U.S. Geological Survey Obsidian Cliff Quadrangle, 1:24,000 (1986)

Figure 13. Sampling locations with sample code numbers for thermal features and surface-water samples in the Lemonade Creek area near Solfatara Trail, Yellowstone National Park, Wyoming.

Up to 11 sample bottles were filled at each site. Sequential aliquots were filtered into separate containers for the determination of inorganic constituents, redox species, stable hydrogen and oxygen isotopes of water, and dissolved organic carbon (DOC). Container preparation and storage and stabilization methods for filtered samples are summarized in table 3. Samples for the determination of major cations and trace metals (As, Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, SiO_2, Sr, V, and Zn), major anions (Br, Cl, F, NO_3, and SO_4), alkalinity (HCO_3), acidity, density, NH_4, NO_2, DOC , and water isotopes (δD and $\delta^{18}O$) were filtered and then stabilizing reagents, if needed, were added. Sample bottles were pre-rinsed with filtered water prior to sample collection. Stabilizing reagents for intermediate sulfur species were put into the sample bottle before the sample was collected; therefore, these bottles were not pre-rinsed. With the exception of the cation sample, all sample aliquots were chilled as soon as practical after sample collection.

To prevent over-estimation of S_2O_3 concentrations, S(-II) oxidation was minimized by adding zinc chloride ($ZnCl_2$). This technique caused the oxidation-resistant zinc sulfide (ZnS) species to precipitate. Polythionate was converted to thiocyanate (SCN) by the addition of potassium cyanide (KCN) to that sample split (Moses and others, 1984). For the analysis of dissolved SiO_2 in waters from hot springs and geysers, 1 mL of sample was diluted on-site to 25 mL with distilled water to prevent the precipitation of SiO_2 as the sample cooled. Samples for the determination of DOC were filtered through a 142-mm diameter all-plastic plate filter containing a 0.1-µm mixed-cellulose-ester filter membrane and collected in a glass bottle that had been baked at 600°C. At least 1 liter (L) of sample water was passed through the all-plastic plate-filter assembly before a DOC sample was collected. Samples for δD and $\delta^{18}O$ (water isotopes) determinations were filtered when the water filtered easily; otherwise water-isotope samples were not filtered.

Field and Laboratory Measurements

Analytical methods, typical precision, detection limits, equipment used, pertinent references, and comments are described briefly in table 4. Detection limits were equal to three times the standard deviation (s) of several dozen measurements of the constituent in a blank solution analyzed as a sample. Relative standard deviation for each analytical method is determined from the measurement of an analyte concentration at least ten times the detection limit. Techniques, general conditions, and variants from standard procedures are discussed in the following sections.

All reagents were equal to or more pure than the reagent-grade standards of the American Chemical Society. Double-distilled or de-ionized water and redistilled or trace-metal-grade acids were used in all preparations. Samples were diluted as necessary to bring the analyte concentration within the optimal range of the method. Each sample was analyzed at least twice for each dilution and for all constituents.

Table 3. Container preparation and stabilization methods for filtered samples

[°C, degrees Celsius; HCO_3, bicarbonate; HCl, hydrochloric acid; HNO_3, nitric acid; 1:9 H_2SO_4, one part sulfuric acid plus nine parts water; KCN, potassium cyanide; $K_2Cr_2O_7$, potassium dichromate; M, molar; mL, milliliter; N, normal; NaOH, sodium hydroxide; (S-II), sulfide; v/v, volume per volume; w/v, weight per volume; $ZnCl_2$, zinc chloride; %, percent]

Constituent(s) to be determined	Storage container and preparation	Stabilization treatment in addition to refrigeration
Major cations and trace metals (Al, B, Ba, Be, Ca, Cd, Co, Cr, Cu, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb(T), Sb(III), Se, SiO_2, Sr, V, and Zn)	Polyethylene bottles, soaked in 5% HCl and rinsed 3 times with distilled water	1% (v/v) concentrated redistilled HNO_3 added, samples were not chilled
Total mercury (Hg(T))	Borosilicate glass bottles, soaked with 5% HNO_3 and rinsed 3 times with deionized water	5 mL of concentrated redistilled HNO_3 (added in the field) + 0.04% w/v $K_2Cr_2O_7$ per 125 mL of sample (added in the laboratory)
Methyl Mercury (CH_3Hg)	Teflon bottles, double-bagged and transported containing about 100 mL 5% HCl	5 mL redistilled 6 M HCl added
Iron, arsenic, and antimony redox species (Fe(T), Fe(II), As(T), As(III), Sb(T), and Sb(III))	Opaque polyethylene bottles, soaked in 5% HCl and rinsed 3 times with distilled water	1% (v/v) redistilled 6 M HCl added
Major anions (Br, Cl, F, and SO_4), alkalinity as HCO_3, acidity, density, nitrate (NO_3), and nitrite (NO_2)	Polyethylene bottles filled with distilled water and allowed to stand for 24 hours, then rinsed 3 times with distilled water	None
Ammonium (NH_4)	Same as major cations and trace metals	1% (v/v) 1:9 H_2SO_4 added
Silica (SiO_2)	Same as major anions, alkalinity, and density	1 mL diluted to 25 mL with distilled water on site
Thiosulfate (S_2O_3) and polythionate (S_nO_6)	30-mL polyethylene bottle	1.7% (v/v) 0.6 M $ZnCl_2$ plus 1% (v/v) 1 M NaOH added; 1.7% (v/v) 1 M KCN also added to S_nO_6 bottle
Dissolved organic carbon (DOC)	Amber glass bottle baked at 600°C	None
Water Isotopes (δD and $\delta^{18}O$)	60-mL glass bottle	None (unfiltered sample collected when filtration was not possible)

Field Measurements

Measurements of temperature, pH, specific conductance, Eh, dissolved oxygen (DO), and H_2S were performed on-site. Measurements of pH and Eh were made on unfiltered sample water pumped from the source through an acrylic plastic flow-through cell which minimized sample contact with air. The flow-through cell contained a combination redox electrode, a combination pH electrode with integral thermistor, and test tubes containing buffer solutions for calibration of the pH electrode. All components were thermally equilibrated with the sample water before obtaining measurements. Where possible, temperature, specific conductance, and DO measurements were made by immersing probes directly into the source as close to the sampling point as possible. Otherwise, probes were immersed into an unfiltered sample collected in a stainless-steel insulated container, or into the flow-through cell. When sample temperatures were greater than the upper limit of the DO probe, DO was determined using the azide modification of the Winkler titration (American Public Health Association (APHA), 1971).

A mobile laboratory truck containing an ion chromatograph, ultraviolet-visible spectrophotometer, autotitrator, and reagent-grade water system was set up in a motel parking lot so that unstable intermediate sulfur-oxyanion species could be determined as soon as possible after sample collection. Iron redox species also were determined in the mobile laboratory from time to time to guide sampling strategies. Alkalinity and acidity titrations were performed before oxidation and hydrolysis reactions occurred.

pH Measurements

Field measurement of pH in geothermal waters is challenging because of the high water temperatures, complex sample matrices often supersaturated with CO_2, and surging water resulting from gas discharge that were frequently encountered. Because many pH electrodes perform poorly in near-boiling water, electrodes rated for boiling or near-boiling water temperatures were used. At each site, the flow-through cell, temperature probe, electrode, and calibration buffers were equilibrated to sample temperature prior to calibration and measurement. The system was calibrated using at least two bracketing standard buffers (chosen from among 1.68, 2.00, 4.01, 7.00, or 10.00) corrected to their values at the sample temperature. After calibration, the pH electrode was placed in the sample water in the flow-through cell and monitored until no change in temperature (± 0.1°C) or pH (± 0.01 standard unit) was detected for at least 30 seconds. Following sample measurement, the electrode was immersed in the standard buffer of pH closest to that of the sample and allowed to equilibrate. The entire calibration and measurement process was repeated as many times as necessary until the measured value for the buffer differed by no more than 0.05 standard units from its certified pH at the measured temperature.

Table 4. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references

[cm, centimeter; Cs, cesium; CVAFS, cold–vapor atomic–fluorescence spectrometry; °C, degrees Celsius; GFAAS, graphite-furnace atomic-absorption spectrometry; HGAAS, hydride-generation atomic-absorption spectrometry; IC, ion chromatography; ICP–OES, inductively coupled plasma-optical emission spectrometry; ISE, ion-selective electrode; KCl, potassium chloride; M, molar; $Mg(NO_3)_2$, magnesium nitrate; µg/L, micrograms per liter; mg/L, milligrams per liter; mM, millimolar; mN, millinormal; MS, mass spectrometry; N, normal; $NaHCO_3$, sodium bicarbonate; Na_2CO_3, sodium carbonate; ng/L, nanograms per liter; nm, nanometer; Pd, palladium; RSD, relative standard deviation; SLAP, standard light antarctic precipitation; TISAB, total ionic strength adjustment buffer; TOC, total organic carbon; VSMOW, Vienna standard mean ocean water; ≤, less than or equal to; %, percent]

Constituent	Analytical Technique	Typical RSD[1], detection limit (mg/L)	Equipment Used	Comments or Reference(s)
Field Measurements				
Temperature	Electronic sensor	Not applicable	Beckman 265 pH meter with Beckman temperature probe or Orion Research model 1230 multi-parameter meter with temperature sensor built into conductivity electrode	Temperatures were reported to the nearest 0.1 °C
pH	Potentiometry	0.02 pH units[2]	Beckman 265 pH meter with Orion Ross combination electrode or Orion Research model 1230 multi-parameter meter with pH triode	Two- or three-buffer calibration at sample temperature using 1.68, 2.00, 4.01, 7.00, and 10.00 pH buffers
Specific Conductance (SC)	Conductometry	0.5%	Orion Research model 1230 multi-parameter meter with conductivity electrode	Automatic temperature correction, calibration checked with 0.0100 N KCl
Eh	Potentiometry	10%	Orion Research model 96–78–00 combination redox electrode	Electrode checked using ZoBell's solution (ZoBell, 1946; Nordstrom, 1977)
Dissolved oxygen (DO)	Titration	1%	Burette and Erlenmeyer flask	Winkler Titration using manganous sulfate, alkaline iodide–azide, sulfamic acid, starch indicator, phenyl arsine oxide (APHA, 1971)
Hydrogen sulfide (H_2S)	Colorimetry	≤10%, *0.002*	Hach model DR–2000 ultraviolet – visible spectrometer and Hach method # 8131 reagents	Methylene Blue Method based on APHA (1985)
Laboratory Measurements				
Calcium (Ca)	ICP–OES	2%, *0.04*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 315.887 nm, view: radial
Magnesium (Mg)	ICP–OES	2%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 280.270 nm, view: axial
Sodium (Na)	ICP–OES	2%, *0.1*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 589.592 nm, view: radial

Table 4. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references—Continued

Constituent	Analytical Technique	Typical RSD[1], detection limit (mg/L)	Equipment Used	Comments or Reference(s)
Potassium (K)	ICP–OES	3%, *0.04*	Leeman Labs Direct Reading Echelle[3]	1,000 mg/L Cs ionization buffer, analytical wavelength: 766.490 nm, view: axial
Strontium (Sr)	ICP–OES	2%, *0.0007*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 421.611 nm, view: axial
Barium (Ba)	ICP–OES	2%, *0.0008*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 455.403 nm, view: axial
Lithium (Li)	ICP–OES	2%, *0.003*	Leeman Labs Direct Reading Echelle[3]	1,000 mg/L Cs ionization buffer, analytical wavelength: 670.784 nm, view: axial
Sulfate (SO_4)	IC	3%, *1.0*	Dionex model 100 or 600 ion chromatograph with AG14A guard and AS14A separator columns and Anion Self-Regenerating Suppressor-II	3.5 mM $NaHCO_3$ + 1.0 mM Na_2CO_3 eluent (Brinton and others, 1995)
Thiosulfate (S_2O_3)	IC	3%, *0.1*	Dionex model 100 or 600 ion chromatograph with two AG4A guard and an Anion Self-Regenerating Suppressor-II	0.028 M $NaHCO_3$ + 0.022 M Na_2CO_3 eluent (Moses and others, 1984)
Polythionate (S_nO_6)	IC	3%, *0.3*	Dionex model 100 or 600 ion chromatograph with two AG4A guard columns and an Anion Self-Regenerating Suppressor-II	0.028 M $NaHCO_3$ + 0.022 M Na_2CO_3 eluent (Moses and others, 1984)
Alkalinity (as HCO_3)	Titration	2%, *1.0*	Orion Research model 960/940 autotitrator, potentiometric detection, end-point determined by the first derivative technique	(Barringer and Johnsson, 1996; Fishman and Friedman, 1989)
Acidity (total / free H^+)	Titration	2%, *0.4 mM*	Orion Research model 960/940 autotitrator, potentiometric detection	(Barringer and Johnsson, 1996; Fishman and Friedman, 1989)
Fluoride (F)	ISE; IC	3%, *0.05*; 3%, *0.15*	Orion Research model 96–09 combination F^- electrode; Dionex model 100 or 600 ion chromatograph with AG14A guard and AS14A separator columns and Anion Self-Regenerating Suppressor-II	Sample mixed 1:1 with TISAB (Barnard and Nordstrom, 1980); 3.5 mM $NaHCO_3$ + 1.0 mM Na_2CO_3 eluent (Brinton and others, 1995)
Chloride (Cl)	IC	3%, *0.05*	Dionex model 100 or 600 ion chromatograph with AG14A guard and AS14A separator columns and an Anion Self-Regenerating Suppressor-II	3.5 mM $NaHCO_3$ + 1.0 mM Na_2CO_3 eluent (Brinton and others, 1995)

Table 4. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references—Continued

Constituent	Analytical Technique	Typical RSD[1], detection limit (mg/L)	Equipment Used	Comments or Reference(s)
Bromide (Br)	IC	3%, *0.03*	Dionex model 100 or 600 ion chromatograph with AG14A guard and AS14A separator columns and an Anion Self-Regenerating Suppressor-II	3.5 mM $NaHCO_3$ + 1.0 mM Na_2CO_3 eluent (Brinton and others, 1995)
Nitrate (NO_3)	IC; Chemiluminescence (2004 and 2005 samples)	3%, *0.1;* *2%, 0.001*	Dionex model 100 or 600 ion chromatograph with AG14A guard and AS14A separator columns and Anion Self-Regenerating Suppressor-II; Sievers 280 NO Analyzer	3.5 mM $NaHCO_3$ + 1.0 mM Na_2CO_3 eluent (Brinton and others, 1995); Chemiluminescence (Bateman and others, 2002) for concentrations <0.1 mg/L
Nitrite (NO_2)	Chemiluminescence	*2%, 0.0004*	Sievers 280 NO Analyzer	(Venkataraman and others, 2000)
Ammonium (NH_4)	Colorimetry	3%, *0.05*	Dionex model DX–300 ion chromatograph with CS12A IonPac column	22 mN H_2SO_4 eluent (Smith and others, 2006)
Silica (SiO_2)	ICP–OES	2%, *0.05*	Leeman Labs Direct Reading Echelle[3]	Sample diluted 25X in field, analytical wavelength: 251.611 nm, view: axial
Boron (B)	ICP–OES	2%, *0.01*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 249.678 nm, view: axial
Aluminum (Al)	ICP–OES; GFAAS	2%, *0.06*; 5%, *0.001*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 308.215 nm, view: axial; Analytical wavelength: 309.3 nm, modifier: 15 µg $Mg(NO_3)_2$, atomization temperature 2,300°C
Total dissolved iron (Fe(T))	Colorimetry	2%, *0.002*	Hewlett–Packard model 8452A diode array spectrometer with 1 and 5 cm cells	FerroZine method (Stookey, 1970; To and others, 1999)
Ferrous iron (Fe(II))	Colorimetry	2%, *0.002*	Hewlett–Packard model 8452A diode array spectrometer with 1 and 5 cm cells	FerroZine method (Stookey, 1970; To and others, 1999)
Manganese (Mn)	ICP–OES	3%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 257.610 nm, view: axial
Copper (Cu)	ICP–OES; GFAAS	2%, *0.003*; 3%, *0.0005*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 324.754 nm, view: axial; Analytical wavelength: 324.8 nm, modifier: 5 µg Pd + 3 µg $Mg(NO_3)_2$, atomization temperature: 2,000°C

Table 4. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references—Continued

Constituent	Analytical Technique	Typical RSD[1], detection limit (mg/L)	Equipment Used	Comments or Reference(s)
Zinc (Zn)	ICP–OES; GFAAS	2%, *0.004*; 3%, *0.0005*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 213.856 nm, view: axial; Analytical wavelength: 213.9 nm, modifier: 5 µg $Mg(NO_3)_2$, atomization temperature 1,800°C
Cadmium (Cd)	ICP–OES; GFAAS	2%, *0.001*; 5%, *0.0001*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 214.438 nm, view: axial; Analytical wavelength: 228.8 nm, modifier: 50 µg PO_4 + 3 µg $Mg(NO_3)_2$, atomization temperature: 1,500°C
Chromium (Cr)	GFAAS	5%, *0.0005*	Perkin–Elmer model 4110ZL	Analytical wavelength: 357.9 nm, modifier: 15 µg $Mg(NO_3)_2$, atomization temperature: 2,300°C
Cobalt (Co)	ICP–OES; GFAAS	2%, *0.004*; 5%, *0.0007*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 228.616 nm, view: axial; Analytical wavelength: 242.5 nm, modifier: 15 µg $Mg(NO_3)_2$, atomization temperature: 2,400°C
Total dissolved mercury (Hg(T))	CVAFS	2%, *0.4 ng/L*	PS Analytical, model Galahad, direct cold-vapor atomic fluorescence spectrometry	Taylor and others (1997), Roth and others (2001)
Methyl mercury (CH_3Hg)	CVAFS	2%, *0.04 ng/L*	Tekran Model 2500 CVAFS mercury detector	Distillation/ethylation/gas-phase separation method (Horvat and others, 1993; DeWild and others, 2002)
Nickel (Ni)	ICP–OES (2003); GFAAS (2004–2005)	2%, *0.002*; 3%, *0.0005*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 231.604 nm, view: axial; Analytical wavelength: 232.0 nm, atomization temperature: 2,300°C
Lead (Pb)	ICP–OES; GFAAS	5%, *0.008*; 5%, *0.0008*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 220.353 nm, view: axial; Analytical wavelength: 283.3 nm, modifier: 50 µg PO_4 + 3 µg $Mg(NO_3)_2$, atomization temperature: 1,600°C
Beryllium (Be)	ICP–OES	2%, *0.001*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 313.042 nm, view: axial
Vanadium (V)	ICP–OES	3%, *0.005*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 292.401 nm, view: axial
Molybdenum (Mo)	ICP–OES	3%, *0.007*	Leeman Labs Direct Reading Echelle[3]	Analytical wavelength: 277.540 nm, view: axial

Table 4. Analytical techniques, detection limits, typical precision, equipment used, and analytical method references—Continued

Constituent	Analytical Technique	Typical RSD[1], detection limit (mg/L)	Equipment Used	Comments or Reference(s)
Total dissolved antimony (Sb(T))	GFAAS	5%, *0.001*	Perkin–Elmer model 4110ZL	Analytical wavelength: 217.6 nm, modifier: 5 µg Pd + 3 µg $Mg(NO_3)_2$, atomization temperature: 1,900°C
Antimonite (Sb(III))	HGAAS	3%, *0.0005*	Perkin–Elmer AAnalyst 300 atomic absorption spectrometer with a FIAS–100 flow injection analysis system, quartz cell, and furnace	Analytical wavelength: 217.6 nm
Selenium (Se)	ICP–OES; GFAAS	5%, *0.04*; 5%, *0.001*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer model 4110ZL	Analytical wavelength: 196.026 nm, view: axial; Analytical wavelength: 196.0 nm, modifier: 5 µg Pd + 3 µg $Mg(NO_3)_2$, atomization temperature: 2,100°C
Total dissolved arsenic (As(T))	ICP–OES; HGAAS	5%, *0.04*; 2%, *0.0001*	Leeman Labs Direct Reading Echelle[3]; Perkin–Elmer AAnalyst 300 atomic absorption spectrometer with a FIAS–100 flow injection analysis system, quartz cell, and furnace	Analytical wavelength: 188.977 nm, view: axial; Pre–reduction of As(V) using KI + ascorbic acid + HCl (McCleskey and others, 2003)
Arsenite (As(III))	HGAAS	5%, *0.001*	Perkin–Elmer AAnalyst 300 atomic absorption spectrometer with a FIAS–100 flow injection analysis system, quartz cell, and furnace	(McCleskey and others, 2003)
Deuterium (δD)	MS	1 per mil[2]	V.G. Micromass model 602 mass spectrometer	Standardization against VSMOW (δD = 0 per mil) and SLAP (δD = -428 per mil) (Coplen and others, 1991)
Oxygen ($\delta^{18}O$)	MS	0.1 per mil[2]	DuPont model 21-491 mass spectrometer	Standardization against VSMOW ($\delta^{18}O$ = 0 per mil) and SLAP ($\delta^{18}O$ = -55.5 per mil) (Epstein and Mayeda, 1953)
Dissolved organic carbon (DOC)	TOC	2%, *0.1*	Oceanography International Model 700 TOC Analyzer	Wet oxidation method (Aiken, 1992)

[1]relative standard deviation expressed in percent (100 x standard deviation ÷ mean)

[2]these values are expressions of precision or range, rather than RSD

[3]dual view, sequential multi-element, inductively coupled plasma spectrometer. Hildebrand grid nebulizer and glass Scott spray chamber

Hydrogen Sulfide Determinations

Dissolved H_2S concentration was measured on-site using a battery-operated, portable ultraviolet-visible spectrophotometer and the methylene blue method (Hach, 1992; equivalent to Standard Method 4500–S^{2-} D for waste water; APHA, 1985). To minimize the inclusion of atmospheric air, samples for H_2S determination were either collected directly from the outflow of a thoroughly equilibrated 142-mm plastic filter with a 0.1-µm membrane filter, or drawn into a plastic syringe fitted with about 25 centimeters (cm) of Teflon tubing and flushed at least three times with sample fluid, then forced through a syringe-mounted 0.2-µm or 0.45-µm membrane filter. Samples were filtered directly into a measuring cuvette and color reagents were added immediately. After waiting for color development, the sample absorbance and the temperature of the solution were measured.

Thiosulfate, if present at concentrations exceeding 10 mg/L, can interfere with the colorimetric determination of H_2S by reacting with the color reagent and reducing or preventing color development (APHA, 1971). Although most S_2O_3 concentrations thus far encountered in Yellowstone geothermal waters are less than this value, 17 samples from 6 thermal features contained 11 to 52 mg/L S_2O_3. Hydrogen sulfide concentrations likely were underestimated in these cases. The dependence of the H_2S determination on temperature (McCleskey and others, 2004) and the order of reagent addition have been investigated further. Laboratory experiments were conducted to measure H_2S at temperatures of 12–15°C, 22°C, 47–49°C, and 64–70°C and H_2S concentrations of 0.05, 0.1, and 0.2 milligrams per liter (mg/L). Results of these experiments (fig. 14) demonstrated that (1) measurements at temperatures substantially lower than 20°C resulted in poor precision, (2) measurements of H_2S concentration at elevated temperatures are imprecise even under laboratory conditions, and (3) the algorithm presented in McCleskey and others (2004) to correct for temperature dependence was likely in error.

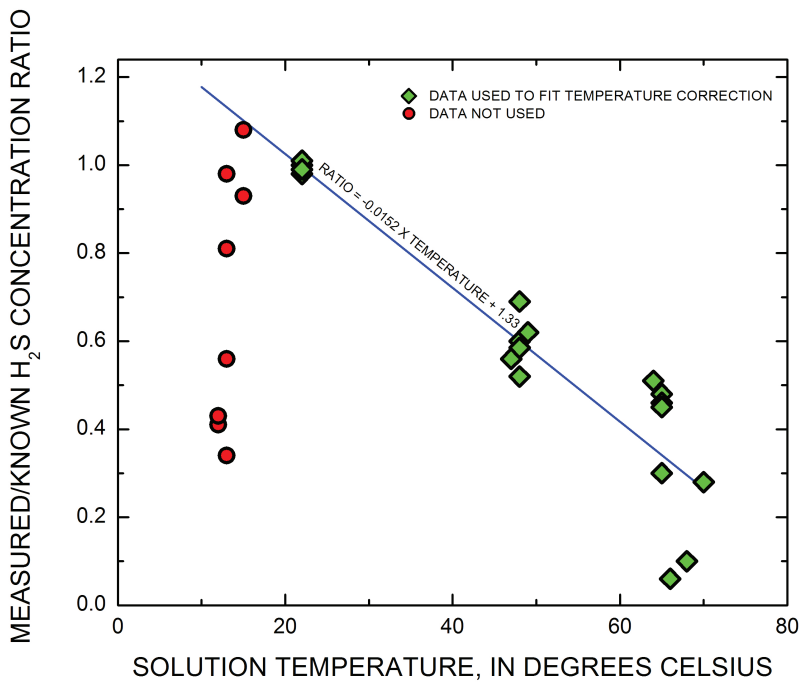


Figure 14. Temperature dependence of hydrogen sulfide (H_2S) measurement using the methylene blue method.

In a separate laboratory experiment, the Hach reagents 1 and 2 were either added sequentially to heated samples or mixed prior to their introduction. Those results (data not shown) represent strong circumstantial evidence that drastically reducing the pH of a hot sample before the introduction of color reagent creates a condition that favors rapid degassing of H_2S and consequent underestimation of its concentration. When Hach reagents 1 and 2 were mixed before their introduction into the hot sample, reduction of the H_2S concentration was not statistically significant.

Field experiments using numerous replicate determinations at several different dilutions, and therefore at varying temperatures (figs. 15 to 19), indicated that the best approach for obtaining the most accurate and precise H_2S concentrations was to dilute samples so that the solution temperatures were less than 30°C before adding the H_2S reagents. Figures 15A and 15B illustrate precision obtained for replicates obtained with a syringe and diluted 25×. Figures 15C and 15D illustrate precision obtained for undiluted samples and for samples diluted 2× to 5×. These figures demonstrate that the difference between measured and temperature–corrected H_2S is greater at higher temperature.

Figures 16A and 16B illustrate contrasting effects of residence time in the sampling apparatus on measured H_2S concentrations for Porkchop Geyser and Ojo Caliente Spring water. Because it contains considerable colloidal silica, water from Porkchop Geyser filters slowly, thus the residence time for water issuing from the plate filter is substantially longer than that of water in the flow-through cell. Consequently, at Porkchop Geyser, water issuing from the plate filter appears to contain less H_2S than water collected from the flow-through cell. In contrast, water from Ojo Caliente Spring filters rapidly, thus residence time for water in the plate filter is roughly equivalent to that for water in the flow-through cell. However, water in the plate filter is comparatively isolated from the atmosphere. Hence, at Ojo Caliente Spring, water issuing from the plate filter appears to contain substantially more H_2S than water collected from the flow-through cell. Figures 16C and 16D illustrate the temperature dependency, as the result of varying dilution factors, on the H_2S determination for Cistern Spring and Cinder Pool water. Figures 17A to 17D illustrate the variability of precision encountered for several sample types. Figures 18A to 18D, 19A, and 19B are examples of the precision that sometimes can be obtained regardless of dilution, sample source, or sampling method. Figures 19C and 19D illustrate the variability that may be introduced by sampling from varying sources or analyzing samples diluted by varying amounts, respectively.

The foregoing results illustrate the reduced precision that is encountered when determining an unstable species and the need for as many replicate determinations as possible given the constraints of available time in the field and quantities of analytical reagents. Because of new findings for the field analytical technique, the temperature-dependent corrections may be unnecessary and inappropriate. This problem is being pursued. Hydrogen sulfide concentrations presented in the tables of analytical results do not have any temperature corrections applied, and averages were computed excluding measurements that were determined to be outliers. Values listed are most likely minimum values, but are thought to be no lower than about 50 percent of true concentrations.

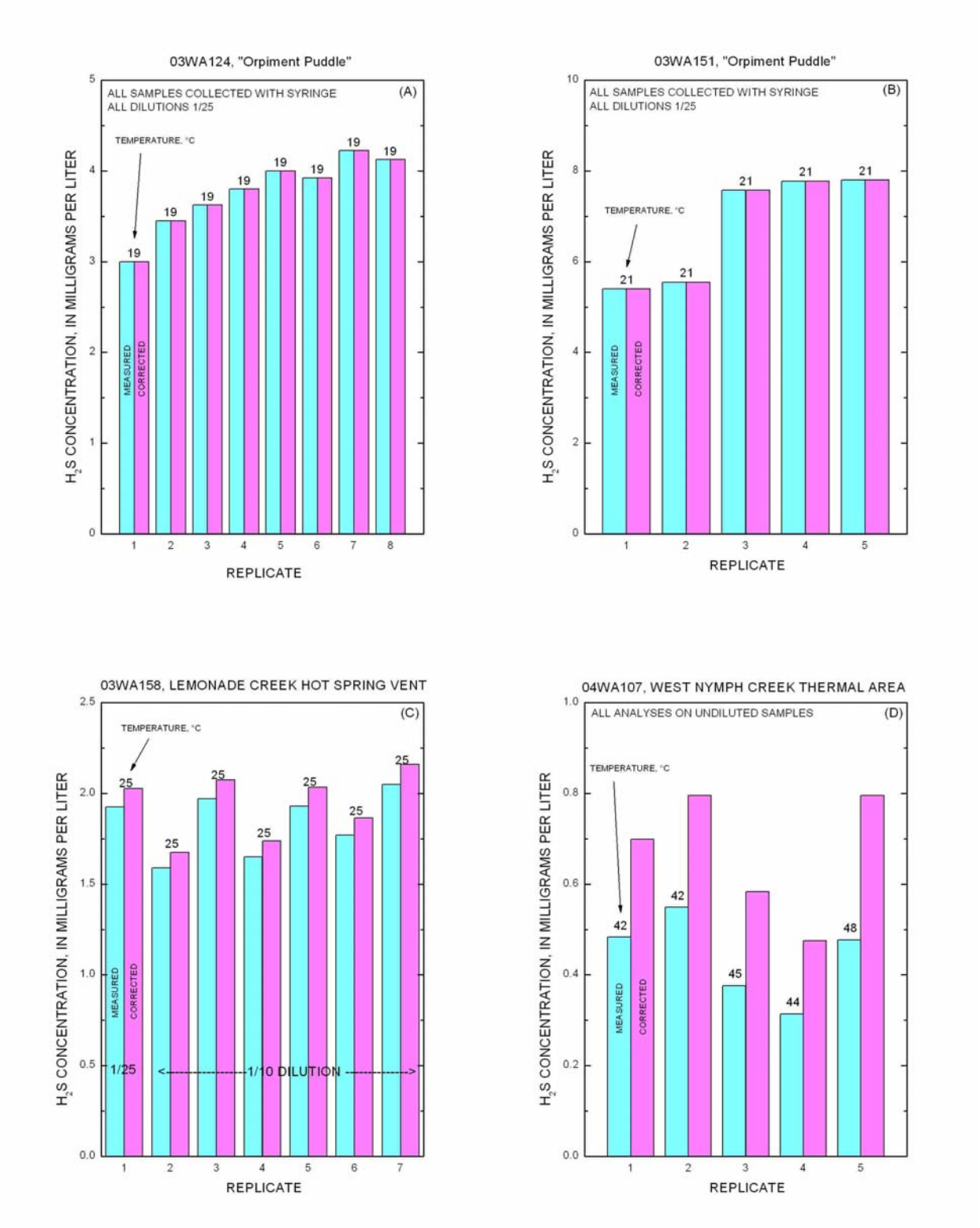


Figure 15. Replicate field determinations of hydrogen sulfide (H_2S) at varying dilutions and temperatures using the methylene blue method—results for samples 03WA124, 03WA151, 03WA158, and 04WA107.

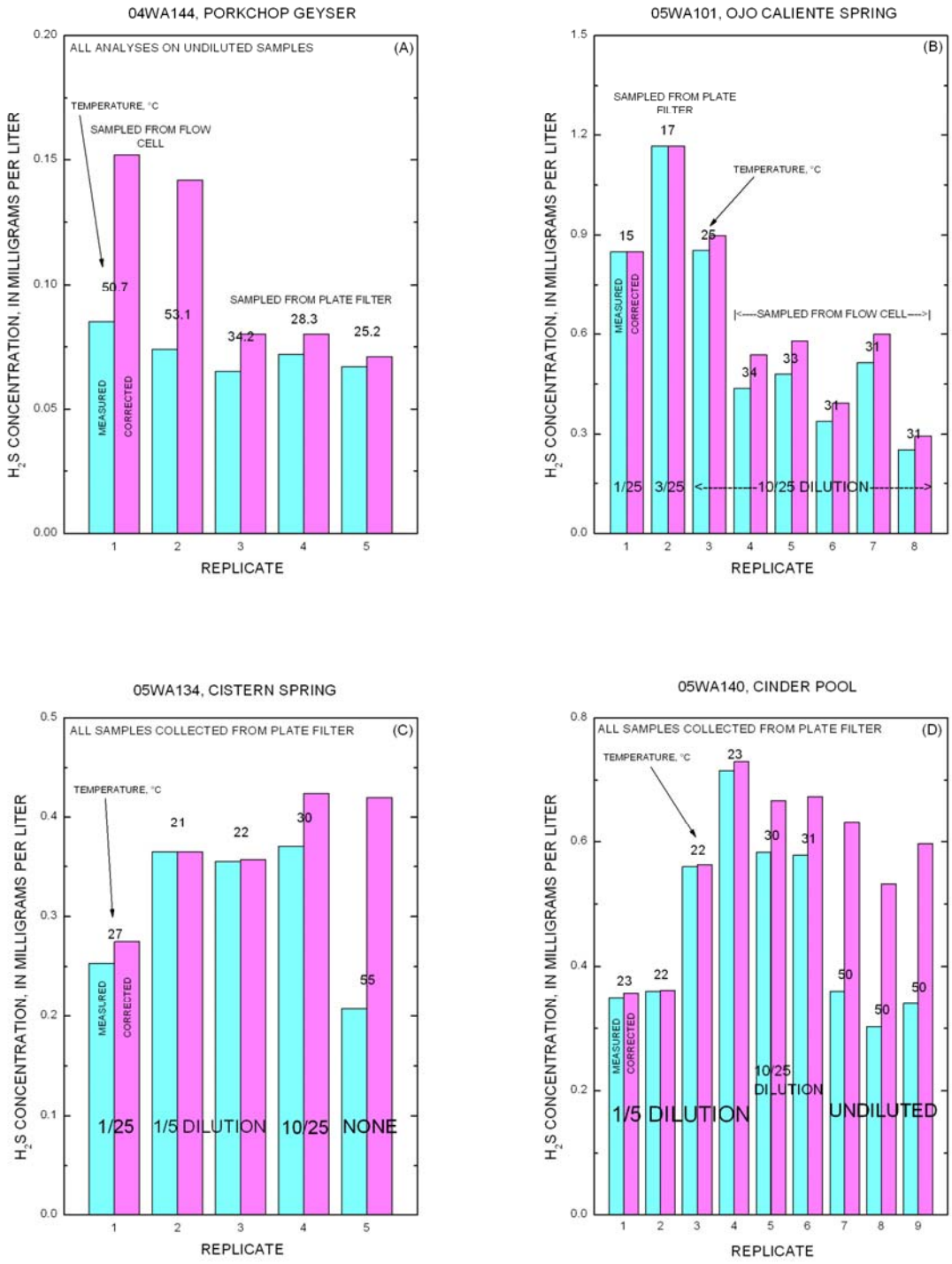


Figure 16. Replicate field determinations of hydrogen sulfide (H_2S) at varying dilutions and temperatures using the methylene blue method—results for samples 04WA144, 05WA101, 05WA134, and 05WA140.

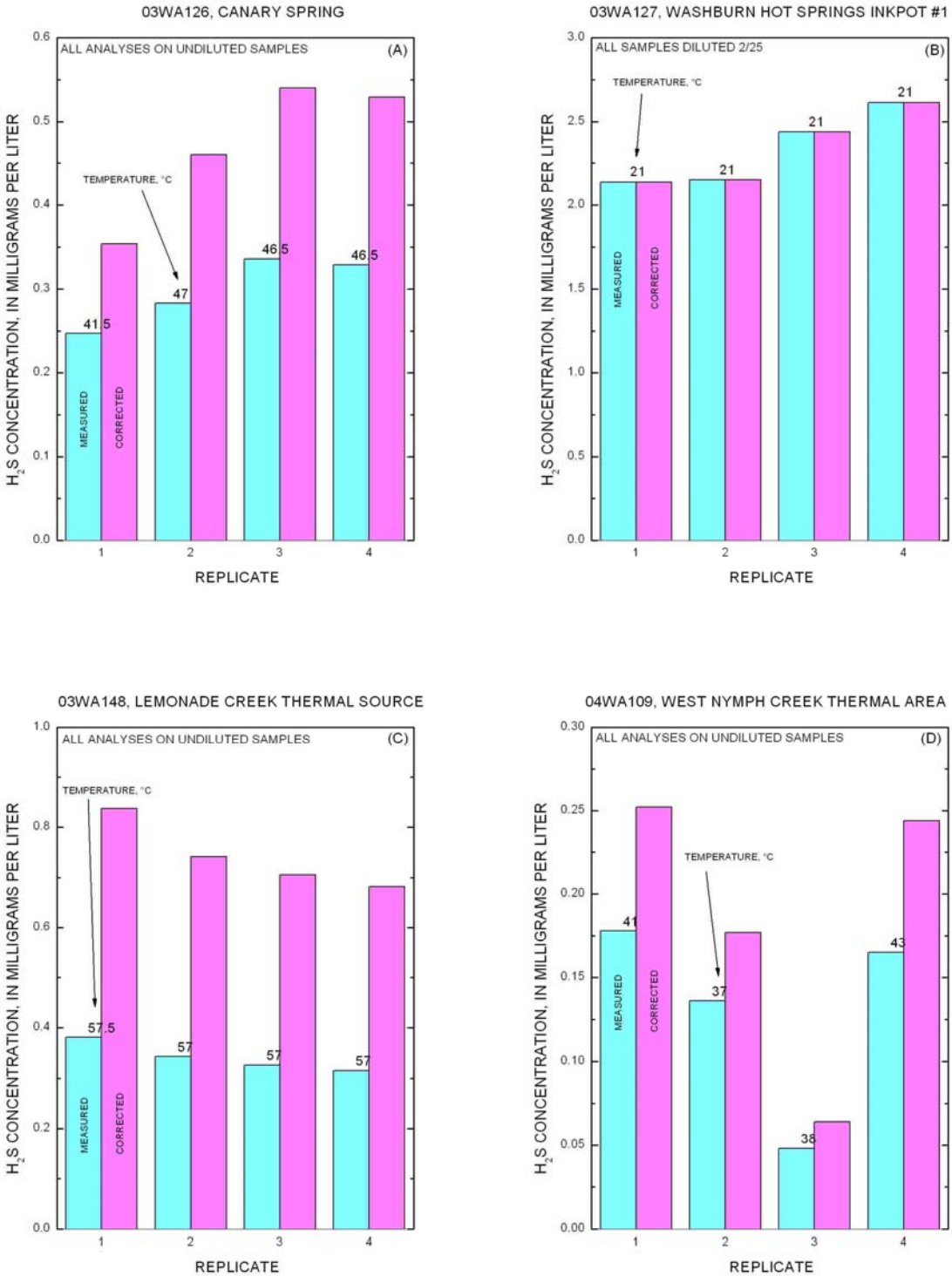


Figure 17. Replicate field determinations of hydrogen sulfide (H_2S) at varying dilutions and temperatures using the methylene blue method—results for samples 03WA126, 03WA127, 03WA148, and 05WA109.

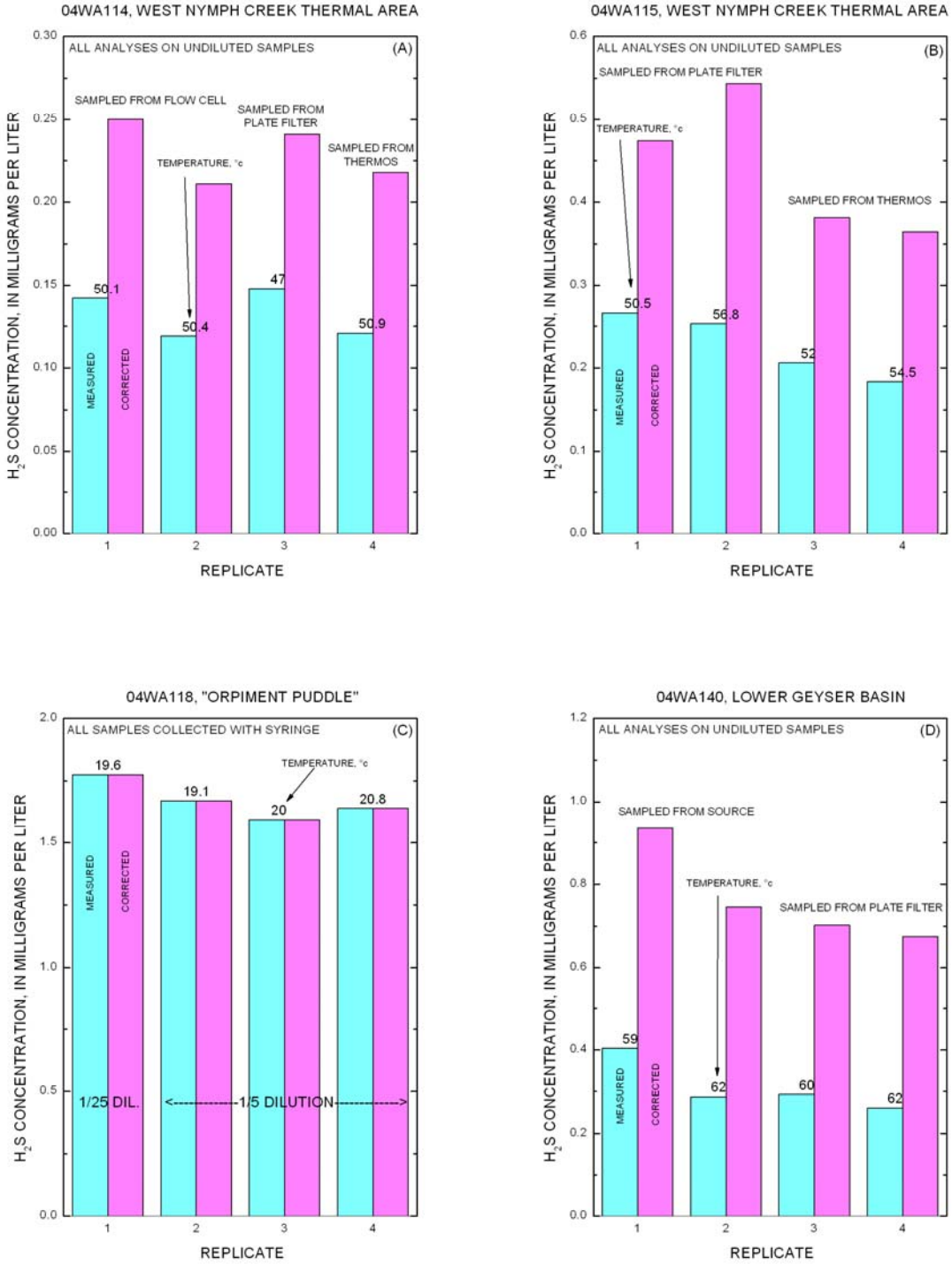


Figure 18. Replicate field determinations of hydrogen sulfide (H_2S) at varying dilutions and temperatures using the methylene blue method—results for samples 04WA114, 04WA115, 04WA118, and 04WA140.

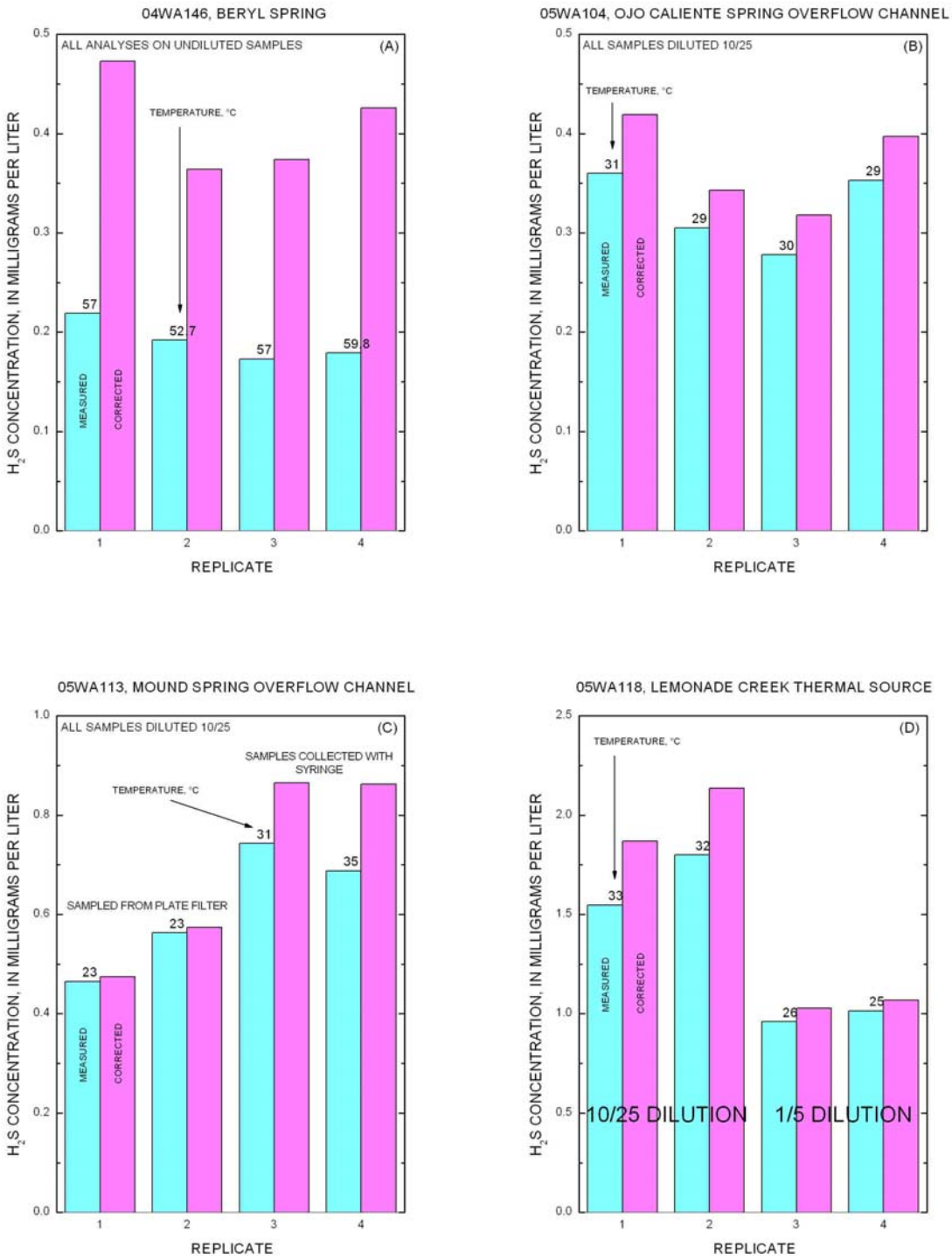


Figure 19. Replicate field determinations of hydrogen sulfide (H_2S) at varying dilutions and temperatures using the methylene blue method—results for samples 04WA146, 05WA104, 05WA113, and 05WA118.

Major Cation and Trace-Metal Determinations

Concentrations of major cations and trace metals were determined using inductively coupled plasma-optical emission spectrometry (ICP-OES) at the USGS laboratory in Boulder, Colorado. Major cations were analyzed using the radial plasma-viewing orientation while the axial plasma viewing orientation was used for trace metals. A cesium chloride ionization buffer was added to the samples for ICP-OES measurement of Li and K concentrations. Analytical wavelengths and plasma viewing orientations are specified in table 4.

Concentrations of Al, Sb(T), Cd, Cr, Co, Cu, Ni, Pb, Se, and Zn were measured using graphite-furnace atomic absorption spectrometry (GFAAS) with a transversely heated graphite atomizer (THGA) and Zeeman-effect background correction. Wavelengths, atomization temperatures, and matrix modifiers used are listed in table 4.

Hydride-generation atomic-absorption spectrometry was used to measure total dissolved arsenic (As(T)), dissolved arsenite (As(III)), total dissolved antimony (Sb(T)), and dissolved antimonite (Sb(III)) concentrations in HCl-acidified samples. A flow-injection analysis system (FIAS) was used to generate arsine (McCleskey and others, 2003) or stibine. Total dissolved-iron (Fe(T)) and ferrous-iron (Fe(II)) concentrations were determined in samples preserved with HCl using a modification of the FerroZine colorimetric method (Stookey, 1970; To and others, 1999).

Samples were analyzed for total dissolved Hg at the USGS laboratory in Boulder, Colorado. Samples were analyzed for methyl Hg (CH_3Hg) at the USGS Mercury Research Laboratory in Middleton, Wisconsin. Total dissolved Hg was determined by direct cold vapor atomic fluorescence spectroscopy (CVAFS) following oxidation with chromate, reduction by $SnCl_2$, and purge and trap of the evolved zero-valent Hg onto gold-coated glass-bead columns (Taylor and others, 1997; Roth and others, 2001). The method detection limit was 0.4 nanograms per liter (ng/L). Methyl Hg was analyzed using the distillation/ethylation/gas-phase separation method of Olson and DeWild (1999) and detection by CVAFS (Horvat and others, 1993). The method detection limit was 0.04 ng/L. All Hg samples were analyzed in duplicate and reanalyzed if the relative percent difference was greater than 10 percent. Analytical precision was about ±0.02 ng/L for the CH_3Hg method (DeWild and others, 2002).

Major Anion Determinations

Concentrations of Br, Cl, F, and SO_4 were determined at the USGS laboratory in Boulder, Colorado by ion chromatography (IC) (Brinton and others, 1995). Fluoride concentrations also were determined using an ion-selective electrode (ISE). Samples for F determination by ISE were mixed 1:1 with a total ionic strength adjustment buffer (TISAB) (Barnard and Nordstrom, 1980). Alkalinity was determined at the USGS laboratory in Boulder, Colorado by automated titration using standardized H_2SO_4 (Barringer and Johnsson, 1996).

Nutrient Determinations

Nutrient concentrations were determined at the USGS laboratory in Boulder, Colorado. Ammonium concentrations were determined by IC with 50 mN H_2SO_4 eluent. Nitrite concentrations were determined by chemiluminescence (Venkataraman and others, 2000). For the chemiluminescence NO_2 determination, a 1 percent solution of potassium iodide in glacial acetic acid was used to convert NO_2 to NO. The NO produced in this step reacted with ozone to form an excited state of NO_2 proportional to the amount of NO in the sample, and was quantified using a chemiluminescence detector. Nitrate was measured by IC with a 3.5 mM $NaHCO_3$ + 1.0 mM

Na_2CO_3 eluent (Brinton and others, 1995). Low concentrations (<0.1 mg/L) of NO_3 were determined by chemiluminescence for 2004 and 2005 samples (Bateman and others, 2002). In this method, NO_3 was reduced to NO in an acidic vanadium chloride solution (0.05 M vanadium(III) in 0.8 M HCl) at 90°C.

Water Isotope Determinations

Hydrogen and oxygen isotope ratios were determined at the USGS Reston Stable Isotope Laboratory in Reston, Virginia (http://isotopes.usgs.gov/). Hydrogen isotope ratios were determined using a hydrogen equilibration technique (Coplen and others, 1991; Revesz and Coplen, 2003a). Oxygen isotope ratios were determined using the CO_2 equilibration technique of Epstein and Mayeda (1953), which has been automated by Revesz and Coplen (2003b). The isotopic concentration is reported in "delta notation," which compares the isotope ratio of a sample to that of a reference standard. For the example of $^{18}O/^{16}O$ ratios, delta notation is:

$$\delta^{18}O‰ = \frac{{}^{18}O/{}^{16}O_{sample} - {}^{18}O/{}^{16}O_{standard}}{{}^{18}O/{}^{16}O_{standard}} \times 1000 \qquad (1)$$

where ‰ is per mil, which is equivalent to parts per thousand.

Oxygen and hydrogen isotopic results are reported relative to the standard VSMOW (Vienna Standard Mean Ocean Water) and normalized (Coplen, 1994) on scales such that the oxygen and hydrogen isotopic values of SLAP (Standard Light Antarctic Precipitation) are -55.5 per mil and -428 per mil, respectively.

Acidity Determinations

Total acidity was determined at the USGS laboratory in Boulder, Colorado by titrating samples having pH less than 5 to pH greater than 7 using an autotitrator and standardized sodium hydroxide (NaOH) solution. The NaOH titrant (0.01 to 0.05 M) was standardized daily by titrating a known quantity of potassium hydrogen phthalate ($KHC_8H_4O_4$). The titrator was programmed for 50- to 100-µL constant-volume additions or constant change in millivolts (mV), typically 10 mV per addition. Equivalence points were determined using a modified Gran's function (Barringer and Johnsson, 1996):

$$F_{acid} = (v_0 + v_{NaOH}) \times 10^{-pOH} \qquad (2)$$

where F_{acid} = the Gran function, v_0 = sample volume, v_{NaOH} = volume of NaOH titrant added, and pOH = 14 minus pH.

Acidity is commonly determined in acid mine waters, but not commonly in other waters. In addition to H^+, the principal components contributing to acidity are HSO_4^-, CO_2, and hydrolyzable metals (Kirby and Cravotta, 2005a; 2005b). The contributions of As and F also should be considered for geothermal waters, because their concentrations sometimes exceed Fe or Al concentrations under mildly acidic conditions (Ball and others, 2002; McCleskey and others, 2004). Arsenic(III) remains fully protonated in the acidic range and $pK = 7.16$ for the second hydrolysis for As(V), thus, of the As hydrolysis species, only the $H_2AsO_4^-$ intermediate hydrolysis species need be considered.

Although occasionally present at concentrations exceeding 500 mg/L in geothermal waters (McCleskey and others, 2004), NH_3 need not be considered because $pK = 9.25$ for the deprotonation of NH_4^+. Thus, the important reactions contributing to total acidity in geothermal waters are SO_4 hydrolysis, Fe oxidation and hydrolysis, Al hydrolysis, As(V) hydrolysis, and F hydrolysis, according to the following reactions (*p*K values from Nordstrom and Munoz, 1994; Nordstrom and Archer, 2003):

$$H^+ + SO_4^{2-} \leftrightarrow HSO_4^- \qquad (pK = 1.98) \qquad (3)$$

$$Fe^{2+} + 1/4O_2 + H^+ \leftrightarrow Fe^{3+} + 1/2H_2O \qquad (4)$$

$$Fe^{3+} + H_2O \leftrightarrow FeOH^{2+} + H^+ \qquad (pK_1 = 2.19) \qquad (5)$$

$$FeOH^{2+} + H_2O \leftrightarrow Fe(OH)_2^+ + H^+ \qquad (pK_2 = 3.48) \qquad (6)$$

$$Fe(OH)_2^+ + H_2O \leftrightarrow Fe(OH)_3^o + H^+ \qquad (pK_3 = 6.93) \qquad (7)$$

$$Al^{3+} + H_2O \leftrightarrow AlOH^{2+} + H^+ \qquad (pK_1 = 5.00) \qquad (8)$$

$$AlOH^{2+} + H_2O \leftrightarrow Al(OH)_2^+ + H^+ \qquad (pK_2 = 5.10) \qquad (9)$$

$$Al(OH)_2^+ + H_2O \leftrightarrow Al(OH)_3^o + H^+ \qquad (pK_3 = 6.70) \qquad (10)$$

$$H_3AsO_4^o \leftrightarrow H_2AsO_4^- + H^+ \qquad (pK_1 = 2.30) \qquad (11)$$

$$H_2AsO_4^- \leftrightarrow HAsO_4^{2-} + H^+ \qquad (pK_2 = 6.99) \qquad (12)$$

$$H^+ + F^- \leftrightarrow HF^o \qquad (pK_1 = 3.18) \qquad (13)$$

Because contributions from the above hydrolysis reactions must be subtracted from the total acidity, the value obtained for free H^+ acidity is model-dependent. For Fe(II) oxidation, equations (4) and (5) approximately cancel each other, because (4) consumes a proton and (5) generates one. Thus, assuming complete oxidation of Fe(II) during the acidity titration, dissolved Fe(II) can be treated as $FeOH^{2+}$ for the purpose of calculating H^+ acidity. Although usually less than about 2 mg/L at pH<3, F concentrations can approach 10 mg/L in mildly acidic geothermal waters (McCleskey and others, 2004). Although the concentration of the HF° aqueous complex becomes greater than that of free F^- at pH<3.2, the predominant F complexes typically are with Al.

Free H^+ was derived from the total acidity by subtracting the hydrogen ions produced by hydrolysis of SO_4, Fe, Al, As(V), and F, as calculated by PHREEQCi, a graphical-user-interface version (Charlton and others, 1997) of the program PHREEQC (Parkhurst and Appelo, 1999) incorporating the WATEQ4F database, as follows:

$$\text{Acidity}_{SO_4} = HSO_4^- \qquad (14)$$

$$\text{Acidity}_{Fe} = 3\left(Fe^{III}(tot) - FeOH^{2+} - Fe(OH)_2^+\right) + 2FeOH^{2+} + Fe(OH)_2^+ + 2Fe^{II}(tot) \qquad (15)$$

$$\text{Acidity}_{Al} = 3\left(Al(tot) - AlOH^{2+} - Al(OH)_2^+\right) + 2AlOH^{2+} + Al(OH)_2^+ \qquad (16)$$

$$\text{Acidity}_{As} = 2\left(As^{V}(tot) - H_2AsO_4^-\right) + H_2AsO_4^- \qquad (17)$$

$$\text{Acidity}_{F} = HF^o \qquad (18)$$

$$\text{Acidity}_{H^+} = \text{Acidity}_{Total} - \text{Acidity}_{SO_4} - \text{Acidity}_{Fe} - \text{Acidity}_{Al} - \text{Acidity}_{As} - \text{Acidity}_{F} \qquad (19)$$

Concentrations for the above equations are expressed in moles per kilogram of water. Sample pH from the acidity titration (acidity pH) was calculated by computing the product of the H^+ activity

coefficient (calculated by PHREEQCi) and the free H^+ molality (eq. 19, calculated using a spreadsheet) and computing the negative common logarithm of the resulting activity. This pH value was refined by repeating the PHREEQCi calculation and varying the input pH until the pH calculated from the PHREEQCi speciation was equal to the input pH. Graphs showing the relation between the pH used as input to PHREEQCi and that calculated using the solution speciation and total acidity are shown in figures 20 and 21, and a flow-chart illustrating the process for refining the acidity pH is shown in figure 22.

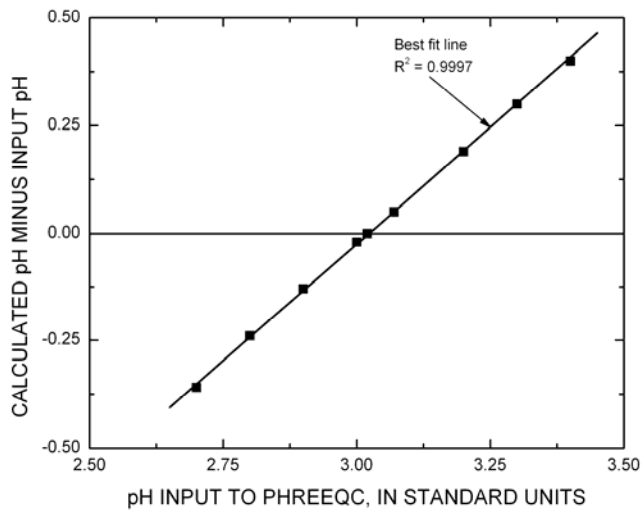


Figure 20. Example graph of pH difference as a function of input pH, for a sample illustrating a linear relation (R^2=correlation coefficient).

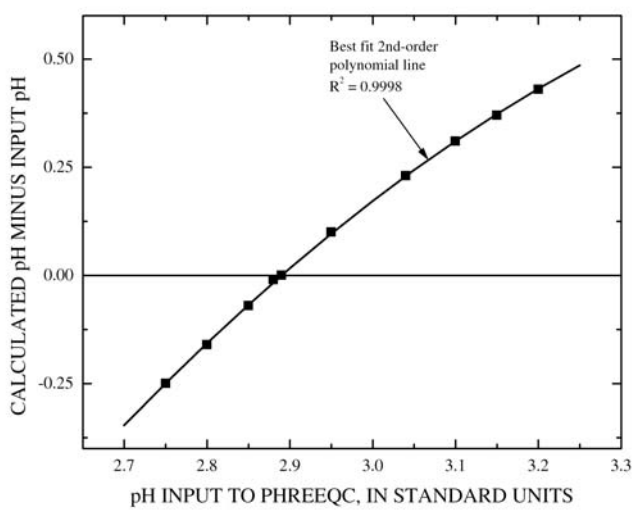


Figure 21. Example graph of pH difference as a function of input pH, for a sample illustrating a non-linear relation (R^2=correlation coefficient).

Water chemistries for two samples (03WA129 and 03WA144) that show a non-linear relation of delta-pH with respect to PHREEQCi input pH (see fig. 21) appear to share the characteristics of substantial concentrations of most or all the non-H^+ acidity components in conjunction with pH values in the range of 2.9 to 3.3.

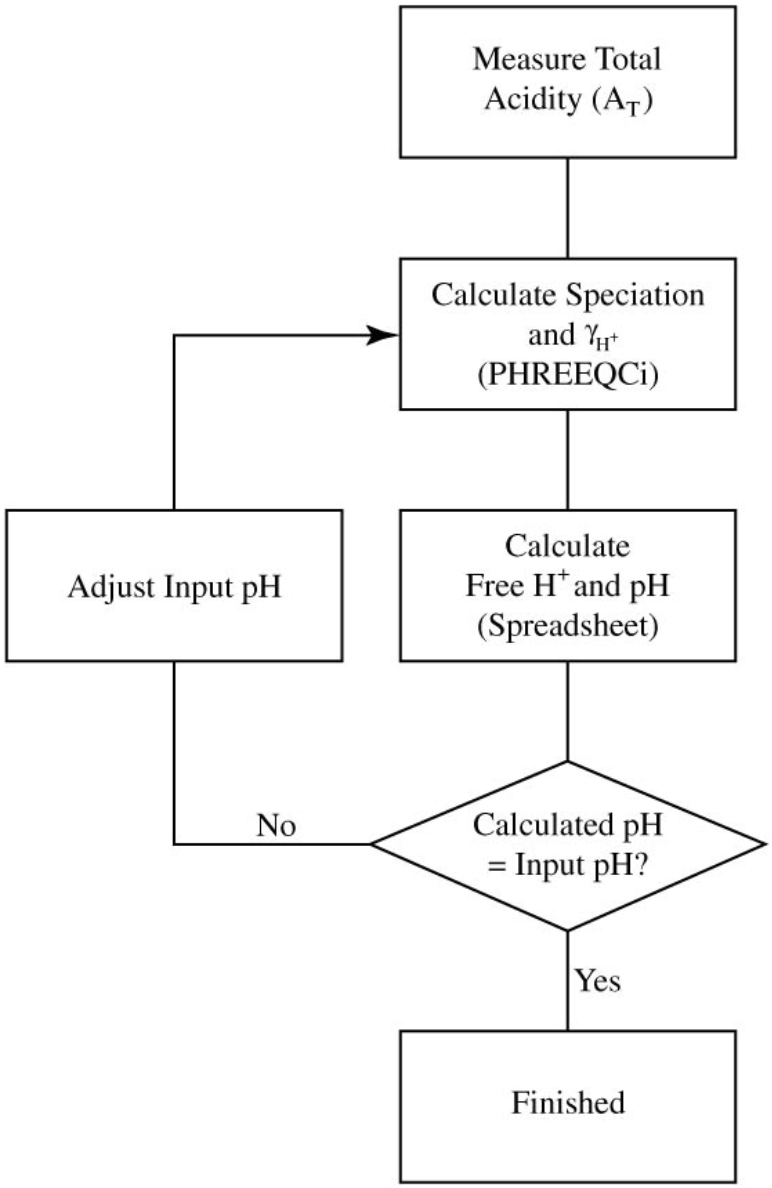


Figure 22. Flow chart illustrating the process for refining the acidity pH value.

Revised pH Measurements

Accurate measurement of pH is of primary importance for interpretation of aqueous chemical speciation. The free hydrogen ion (H^+) is usually the major cation in geothermal waters with pH less than 2.5 (Ball and others, 2002), is important in controlling geochemical reactions, and is critical in calculating the charge imbalance (C.I.) for waters with pH<3. For the subset of 51 samples with pH<5, pH values determined using four different techniques are shown in table 5: (1) pH measured in the field; (2) pH measured at the USGS laboratory in Boulder, Colorado; (3) pH calculated using total H^+ from the acidity titration, the free H^+ molality derived from the acidity titration data and the

PHREEQCi speciation results, and the H^+ activity coefficient calculated using PHREEQCi (acidity pH); and (4) pH calculated by adjusting the concentration of H^+ to yield a speciated C.I. of zero. Comparison of pH values from the four sources allows us to evaluate our measurements and estimate more accurate pH values.

A flow-chart showing the pH selection process is shown in figure 23. Field pH was considered to be the most accurate because pH measurements made in the laboratory may be biased from temperature changes and hydrolysis reactions, and the acidity pH calculation relies on measurements of Fe, Al, SO_4, As, and F, all of which are subject to analytical uncertainties.

Differences between field and laboratory pH values were found to be greatest for samples with initial pH values between 4 and 8 (fig. 24). Laboratory pH measurements typically are made at about 22°C which can be as much as 70°C less than the temperature at which the sample pH was measured. Differences in pH values between field and laboratory measurements are a function of the sample temperature and are greatest at pH>3.0 and higher sample temperatures (fig. 25). Many of the samples that had pH reductions most likely were poorly buffered, whereas samples that had pH increases likely were initially supersaturated with respect to atmospheric CO_2. Thus, positive differences, indicating laboratory pH values that are less than field pH values, likely are the result of Fe oxidation and hydrolysis (Nordstrom and Alpers, 1999) or oxidation of reduced S species, whereas negative values result from degassing of CO_2 (Nordstrom and others, 1990; fig. 26).

Charge imbalance variations also were found to be strong functions of temperature and pH. When comparing C.I. for samples calculated using pH measured in the field to C.I. for the same samples calculated using pH measured in the laboratory, the C.I. difference is seen to be greatest for samples with the lowest pH values. Figure 27 shows the difference between C.I. calculated at 22°C and C.I. calculated at field temperature as a function of field temperature. This difference can be attributed to the hydrolysis of SO_4 (equation 4), which is a function of both temperature and pH.

In this report, laboratory pH and pH calculated by using the concentration of H^+ to adjust the speciated C.I. to zero were used only as references because the laboratory pH measurement is confounded by temperature effects on the aqueous speciation for low-pH samples and by changes in P_{CO_2} for high-pH samples, and because C.I. pH relies on measurements of many parameters. Field pH was selected for all samples with pH greater than 3.5. For samples having a pH less than 3.5, field pH was selected unless the sample had a speciated C.I. greater than 10 percent. For samples with pH less than 3.5 and speciated C.I. greater than 10 percent using field pH, acidity pH was selected if the speciated C.I. was less than 10 percent. For samples with pH less than 3.5 and having field and acidity pH values that produced speciated C.I.s greater than 10 percent, the pH that produced the lower speciated C.I. was selected from among field and acidity pH.

Using the process described above and illustrated in figure 23, field pH was selected for all 157 samples. Values of field pH are found in the tables of chemical data (tables 6–14) along with the speciated C.I. calculated using the field pH and field temperature.

Table 5. Sample pH measured in the field and laboratory and calculated from acidity titration and speciated charge imbalance, for samples with pH less than 5
[WNCTA, West Nymph Creek thermal area]

Sample	pH, in standard units: Measured in the field	Measured in the laboratory	Calculated from acidity titration	Calculated from charge imbalance	Selected
03WA116, Cinder Pool	4.21	3.72	3.20	4.78	4.21
03WA117, "Titanic Spring"	3.28	3.21	3.21	3.31	3.28
03WA120, Echinus Geyser	3.58	3.41	3.30	3.50	3.58
03WA122, "Kaolin Spring"	2.87	2.63	2.61	2.77	2.87
03WA123, Tantalus Creek at weir	3.07	3.06	3.02	2.99	3.07
03WA124, "Orpiment Puddle"	3.33	3.28	2.97	2.96	3.33
03WA129, Washburn inkpot #3	3.04	2.74	2.89	7.11	3.04
03WA131, Sulphur Caldron	1.68	1.52	1.61	1.70	1.68
03WA132, Mud Geyser	1.93	1.87	1.90	2.00	1.93
03WA139, "Titanic Spring"	3.41	3.36	3.29	3.20	3.41
03WA140, "Orpiment Puddle"	3.28	3.27	3.23	7.02	3.28
03WA141, Constant Geyser	3.49	3.26	3.21	6.63	3.49
03WA144, Echinus Geyser	3.55	3.32	3.26	3.51	3.55
03WA148, Lemonade Creek	2.54	2.32	2.33	2.50	2.54
03WA149, Tantalus Creek at weir	2.95	2.93	2.94	4.73	2.95
03WA151, "Orpiment Puddle #2"	3.28	3.33	3.27	8.85	3.28
03WA152, "Rainbow Growler"	3.74	3.65	3.55	7.98	3.74
03WA156, Jade Pool	3.24	3.29	3.21	3.26	3.24
03WA158, Unnamed hot spring discharging into Lemonade Creek	2.30	2.23	2.20	2.28	2.30
04WA107, Unnamed hot spring with yellow spherules, WNCTA	2.52	2.42	2.32	2.55	2.52
04WA108, Unnamed pool adjacent to stream channel, WNCTA	2.25	2.17	2.09	2.26	2.25
04WA114, Unnamed dark brown surging turbid pool, WNCTA	2.40	2.32	2.26	2.41	2.40
04WA117, Tantalus Creek at weir	3.06	3.06	3.23	2.81	3.06
04WA118, "Orpiment Puddle"	3.23	3.22	2.95	3.01	3.23
04WA119, "Orpiment Puddle #2"	3.30	3.32	3.25	3.25	3.30
04WA120, "Orpiment Puddle #3"	2.74	2.74	2.70	2.71	2.74
04WA121, Unnamed pool adjacent to "Orpiment Puddle #3"	3.64	3.44	3.20	3.48	3.64
04WA122, "Titanic Spring"	3.45	3.33	3.27	2.82	3.45
04WA123, "Persnickety Geyser"	3.68	3.38	3.29	2.93	3.68
04WA124, Second unnamed pool west of "Lifeboat Spring"	3.27	3.16	3.14	0.71	3.27

Table 5. Sample pH measured in the field and laboratory and calculated from acidity titration and speciated charge imbalance, for samples with pH less than 5—Continued

Sample	pH, in standard units: Measured in the field	Measured in the laboratory	Calculated from acidity titration	Calculated from charge imbalance	Selected
04WA125, Third unnamed pool west of "Lifeboat Spring"	2.72	2.66	2.67	2.73	2.72
04WA126, "Rainbow Growler"	3.52	3.33	3.13	2.99	3.52
04WA127, Unnamed acid spring next to Perpetual Spouter	2.91	2.78	2.76	2.73	2.91
04WA128, Tantalus Creek upstream from Perpetual Spouter	3.11	3.09	3.16	3.60	3.11
04WA134, Nymph Creek Springs	2.86	2.80	2.76	2.79	2.86
05WA118, Unnamed thermal vent, Lemonade Creek area	2.27	2.17	2.20	2.30	2.27
05WA119, Unnamed thermal vent overflow channel, Lemonade Creek area	2.23	2.16	2.21	2.28	2.23
05WA120, Unnamed thermal vent overflow channel, Lemonade Creek area	2.20	2.14	2.23	2.25	2.20
05WA121, Lemonade Creek	2.22	2.25	2.30	2.31	2.22
05WA122, Lemonade Creek	2.20	2.22	2.25	2.29	2.20
05WA123, Lemonade Creek	2.20	2.20	2.23	2.26	2.20
05WA124, Lemonade Creek	2.20	2.20	2.24	2.27	2.20
05WA125, Lemonade Creek	2.24	2.20	2.23	2.24	2.24
05WA130, Tantalus Creek at weir	2.98	2.98	2.97	2.96	2.98
05WA132, "Kaolin Spring"	2.51	2.46	2.46	2.58	2.51
05WA133, "Orpiment Puddle #4"	2.85	2.87	2.88	2.82	2.85
05WA135, Frying Pan Spring	2.42	2.38	2.34	2.47	2.42
05WA139, Sulphur Caldron	1.85	1.76	1.77	1.92	1.85
05WA147, Tantalus Creek at weir	3.08	3.11	3.07	3.53	3.08

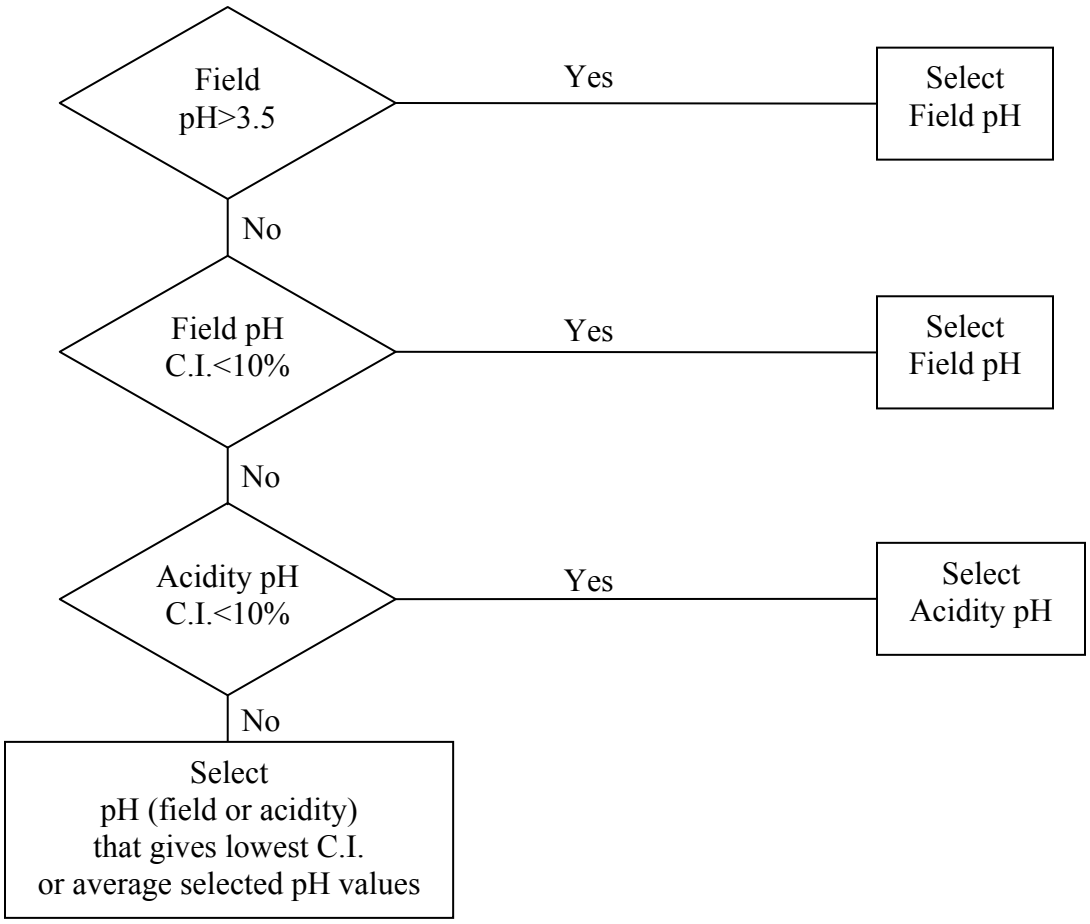


Figure 23. Flow chart showing the pH selection process.

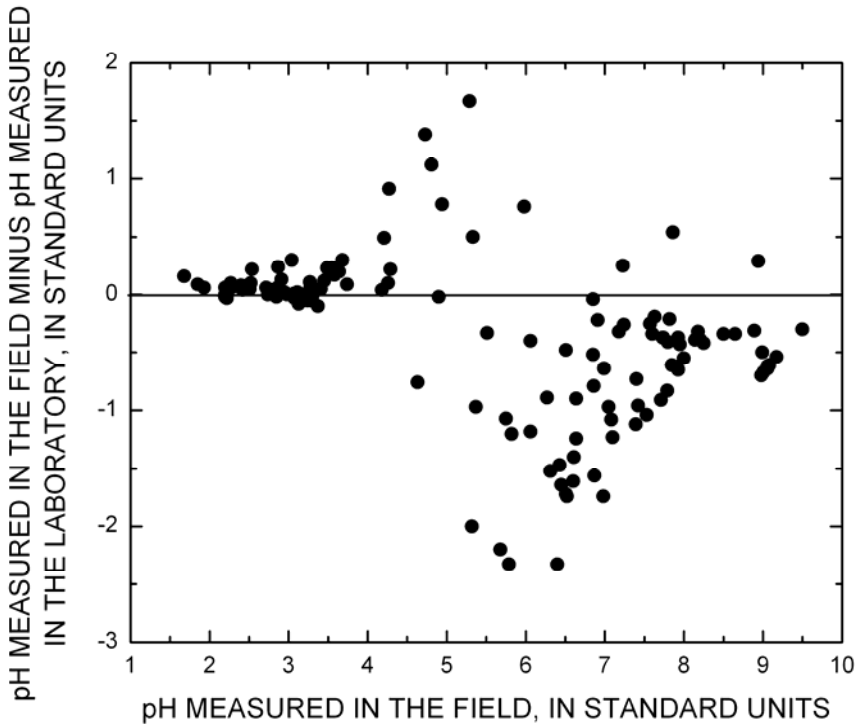


Figure 24. Difference between field and laboratory pH as a function of field pH.

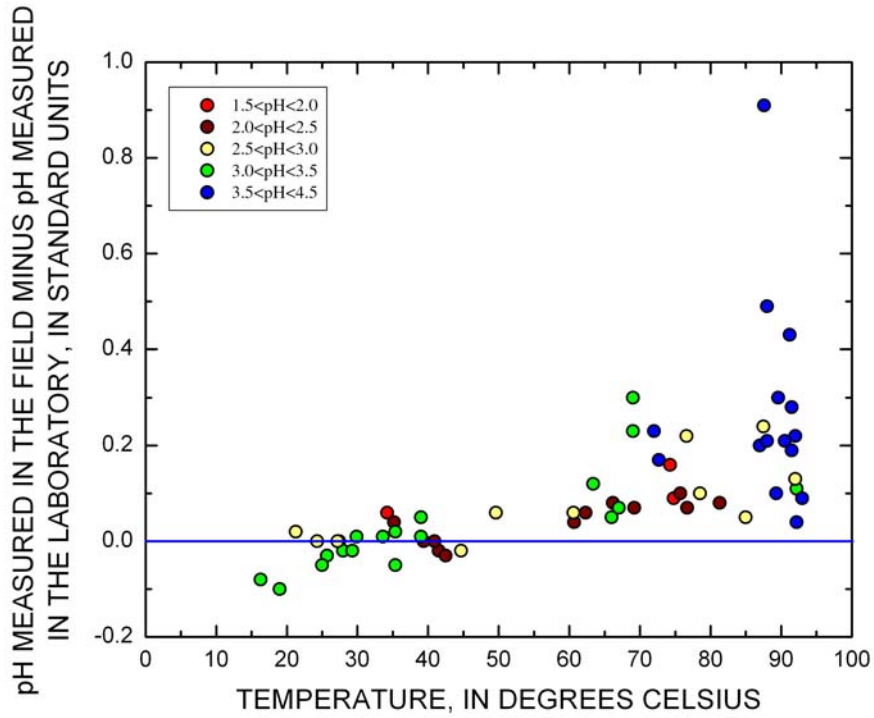


Figure 25. Difference between field and laboratory pH as a function of sample temperature.

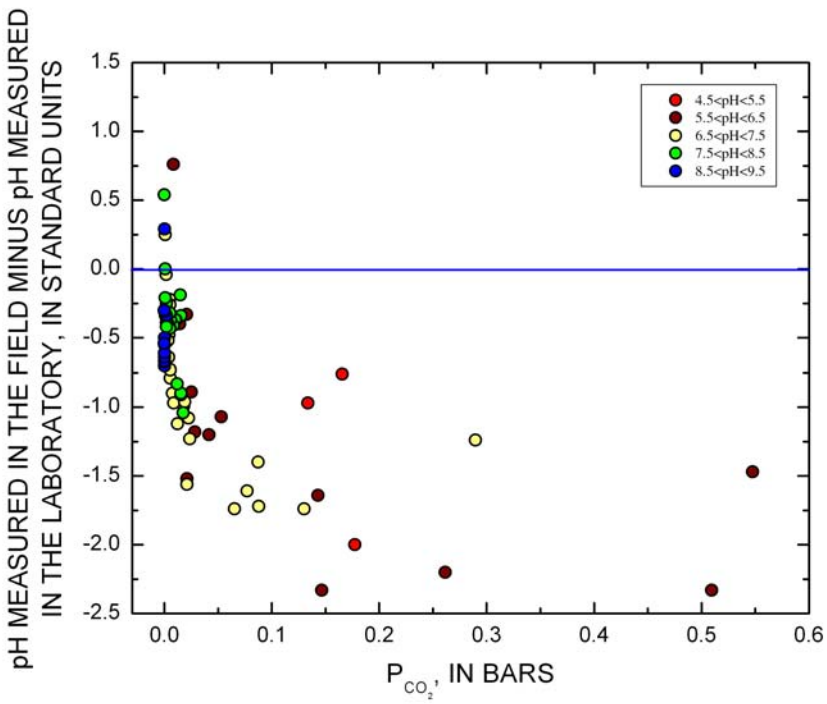


Figure 26. Difference between field and laboratory pH as a function of partial pressure of CO_2.

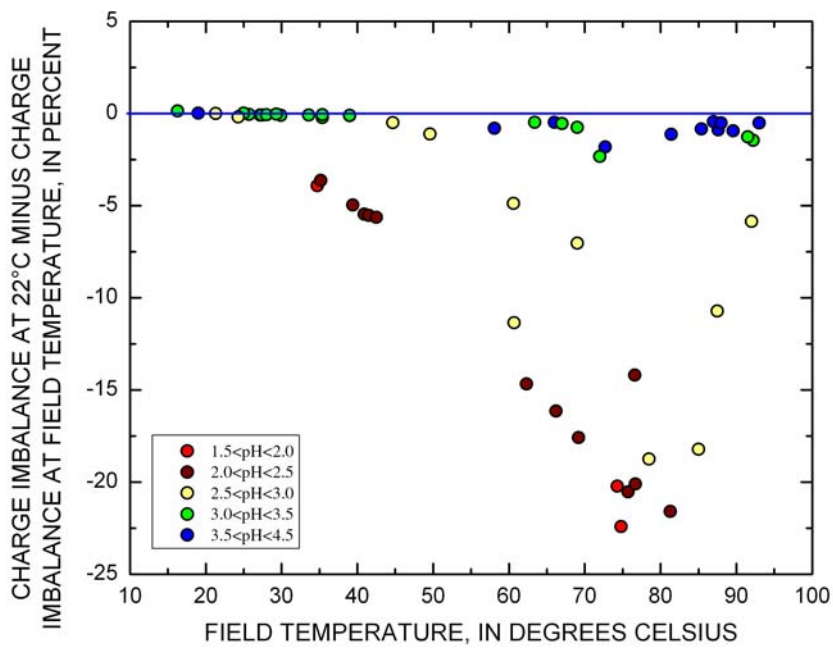


Figure 27. Difference between speciated charge imbalance at 22°C and speciated charge imbalance at field temperature in relation to field temperature.

Water-Chemistry Data

Site data and water analyses for YNP thermal features, their overflow drainages, and surface waters sampled in 2003, 2004, and 2005 are presented in tables 2 and 6–14. To organize presentation of the results, samples are sorted first alphabetically by sampling site, then by date of sample collection, and then by location along the overflow channel, if present. Photographs of most of the sample sites are in the Appendix.

Overflow Drainage Chemical Profiles

Samples were collected from the Mound Spring overflow channel on two occasions, once in 2003 and once in 2005, to investigate changes in S, Fe, As, Sb, and N redox species. One sampling site was added to the 2005 transect, making it about twice as long as the 2003 transect. Results are plotted on the same distance scale in figures 28 to 31 for comparison. The physical and chemical trends were similar in both transect studies. For these transect sampling events, sample temperature, pH, specific conductance, and concentrations of Cl, SO_4, alkalinity, Li, and B are plotted as a function of distance from the discharge source (figs. 28 A, B, C, and D for samples collected in 2003; figs. 30 A, B, C, and D for samples collected in 2005). Sample Eh and concentrations of H_2S, S_2O_3, As(T), and As(III) are plotted as a function of distance from the discharge source in figures 29 A, B, and C, for samples collected in 2003. Sample Eh and concentrations of H_2S, S_2O_3, dissolved oxygen, As(T), As(III), Sb(T), and Sb(III) are plotted as a function of distance from the discharge source in figs. 31 A, B, C, and D for samples collected in 2005. Specific conductance, pH, alkalinity, Li, B, Eh, and dissolved oxygen increased with distance, whereas temperature and concentrations of H_2S and Sb(III) decreased with distance. Arsenic(III) increased with distance for all but the most down-drainage 2005 sample. The oxidation of H_2S was rapid over the first few meters and the reduction in H_2S concentration with distance was similar for the two transects.

Data for N species for Mound Spring are presented in table 10 but are not plotted. For the 2003 transect, complete oxidation of NO_2 occurred within the first 0.9 meters, and NH_4 concentrations along the transect were 0.35 to 0.63 mg/L (table 10). For the 2005 samples, NH_4 concentrations (table 10) were less than the method detection limit.

Figures 32 A, B, and C, and 33 A, B, C, and D show physical and chemical profiles for the Lemonade Creek drainage near the Solfatara Trail for samples collected in 2003 and 2005. Dissolved oxygen concentration increased with distance from the thermal source to the Lemonade Creek confluence. The thermal source is about seven meters upstream from the confluence. Iron(T) and As(T) concentrations changed little upon mixing with the thermal source, and with distance downstream from the confluence. Temperature and concentrations of Fe(II), As(III), and Sb(III) decreased with distance. Iron and As began to oxidize within a few meters of the source. Most of the chemical and physical changes in the transect occurred between the thermal-outflow source and Lemonade Creek, whereas changes in Lemonade Creek were substantially less than the changes observed in the thermal outflow discharge channel.

Figures 34 A, B, C, and D illustrate changes in temperature, pH, specific conductance, and concentrations of Cl, SO_4, alkalinity, Li, and B along one drainage channel at Ojo Caliente Spring. Figures 35 A, B, C, and D illustrate changes in Eh and concentrations of H_2S, S_2O_3, As(T), As(III), Sb(T), and Sb(III) along the same Ojo Caliente Spring drainage channel. The source of thermal water is located near the northern edge of the main pool, about 10 meters from the pool's discharge point. The pH, Eh, specific conductance, and concentrations of dissolved oxygen, As(T), and Sb(T) increased along the drainage channel, whereas temperature and H_2S concentrations decreased.

Arsenic remained in the reduced As(III) state for the initial 30 meters and began to oxidize thereafter, while NO_2 concentrations (data not shown) remained generally constant for the first 12 meters, but decreased thereafter.

Mercury results, plotted on figures 36 A, B, and C, illustrate generally decreasing Hg(T) concentrations with distance. Mercury concentration in the 2005 Mound Spring transect decreased from 35 to 20 ng/L. Mercury concentration in the Lemonade Creek transect decreased from about 52 ng/L at the source to about 25 ng/L, one-half of the initial value, above the Lemonade Creek confluence, within about 7 meters of the source. Mercury concentrations in the Ojo Caliente Spring discharge channel decreased to about 70 ng/L, about one-third of the initial value of 205 ng/L at the source, over a distance of about 10 meters.

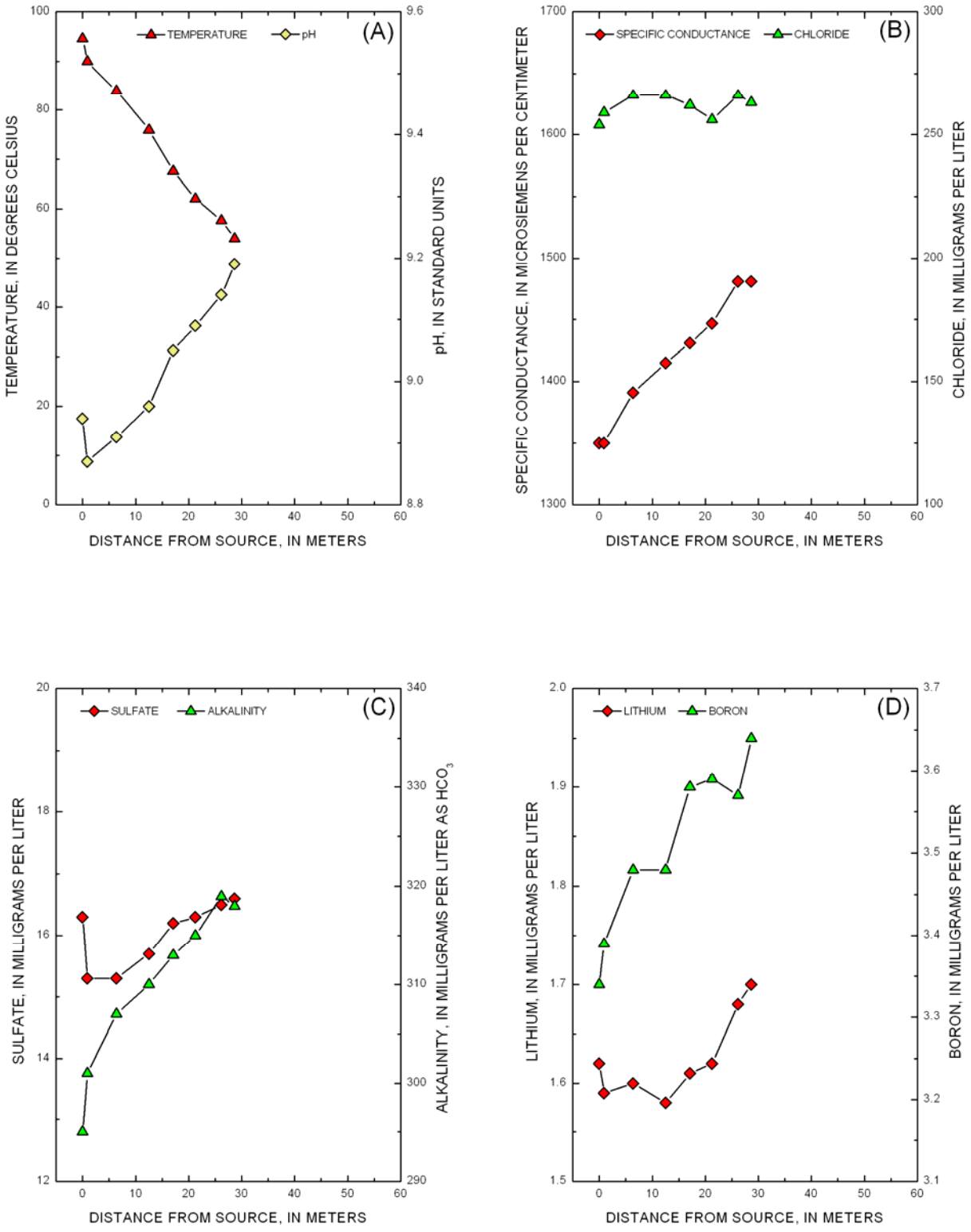


Figure 28. Graphs showing (A) sample temperature and pH, (B) specific conductance and concentration of chloride, (C) sulfate concentration and alkalinity, and (D) concentrations of lithium and boron as a function of drainage distance for Mound Spring and its overflow channel taken in 2003.

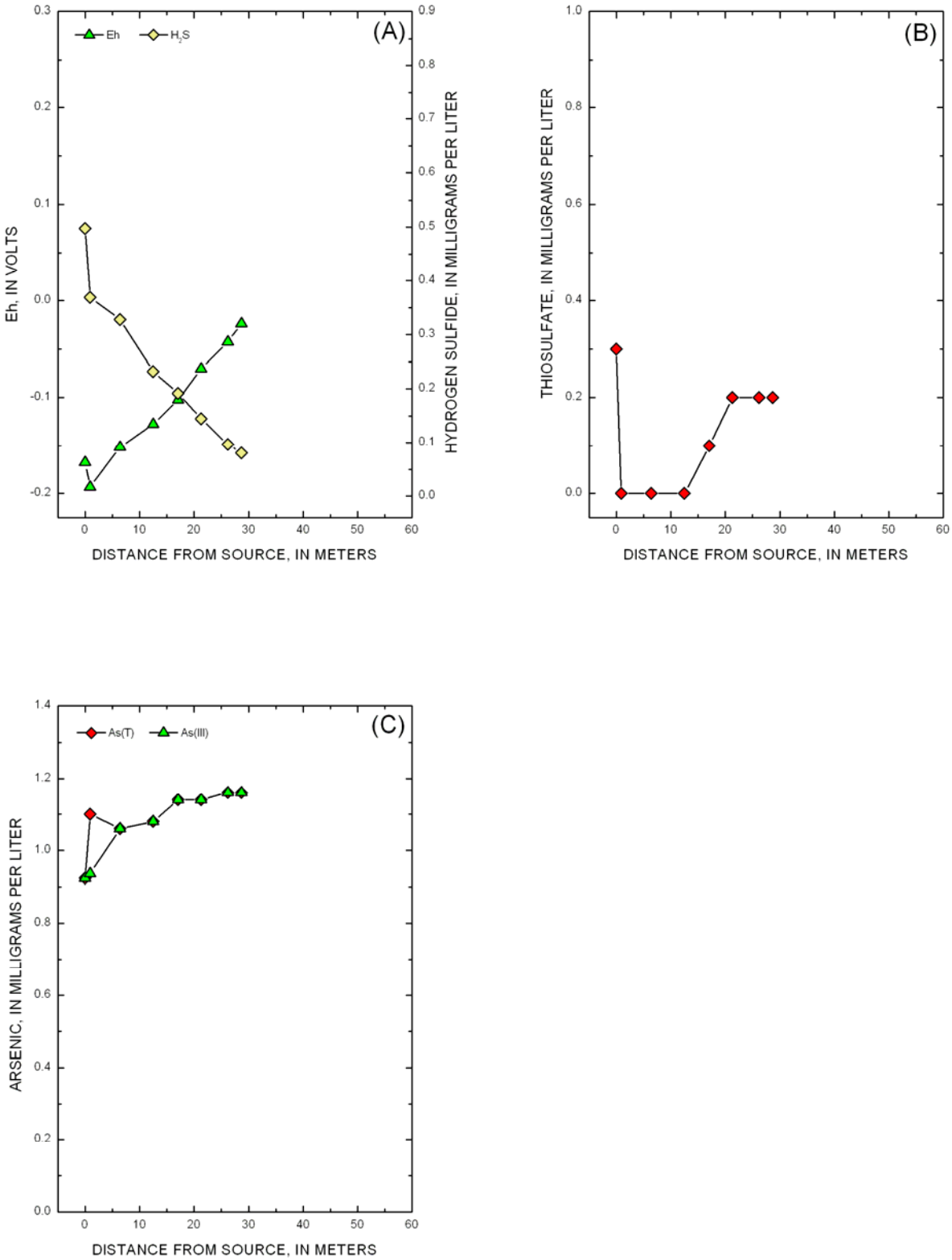


Figure 29. Graphs showing (A) sample Eh and concentration of H_2S, (B) thiosulfate concentration, and (C) concentrations of arsenic(total) and arsenic(III) as a function of drainage distance for Mound Spring and its overflow channel taken in 2003.

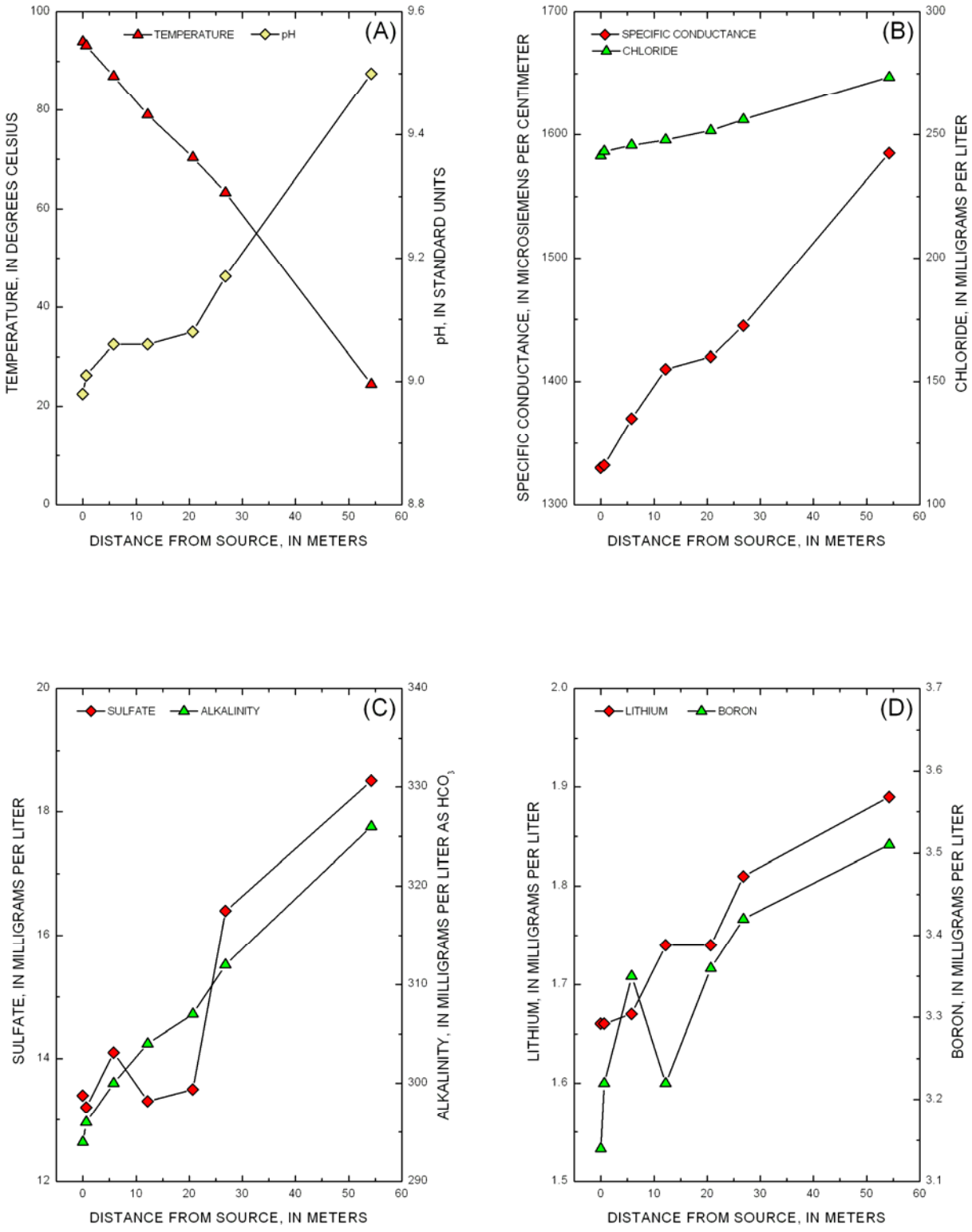


Figure 30. Graphs showing (A) sample temperature and pH, (B) specific conductance and concentration of chloride, (C) sulfate concentration and alkalinity, and (D) concentrations of lithium and boron as a function of drainage distance for Mound Spring and its overflow channel taken in 2005.

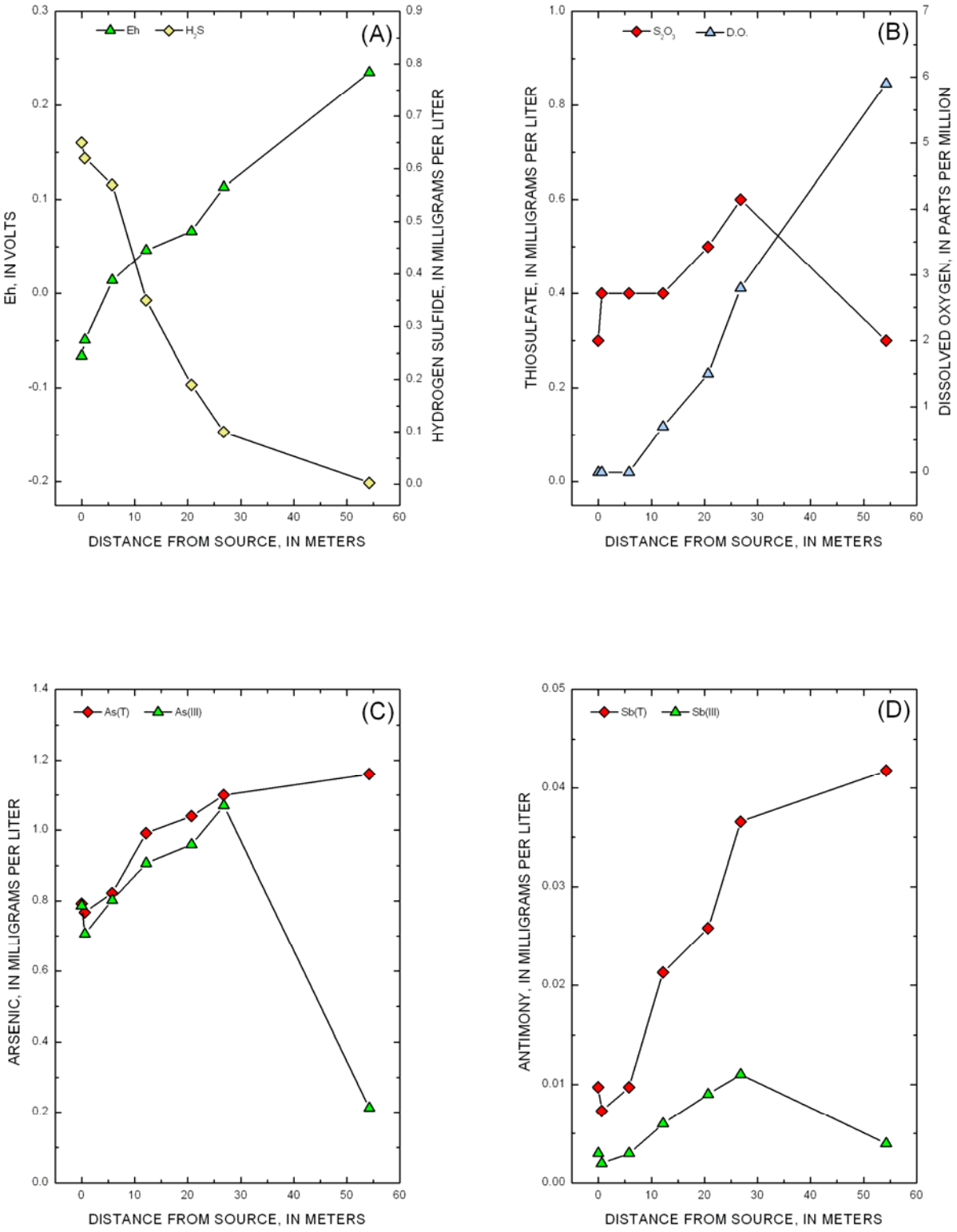


Figure 31. Graphs showing (A) sample Eh and concentration of H_2S, (B) thiosulfate and dissolved oxygen concentrations, (C) concentrations of arsenic(total) and arsenic(III), and (D) concentrations of antimony(total) and antimony(III) as a function of drainage distance for Mound Spring and its overflow channel taken in 2005.

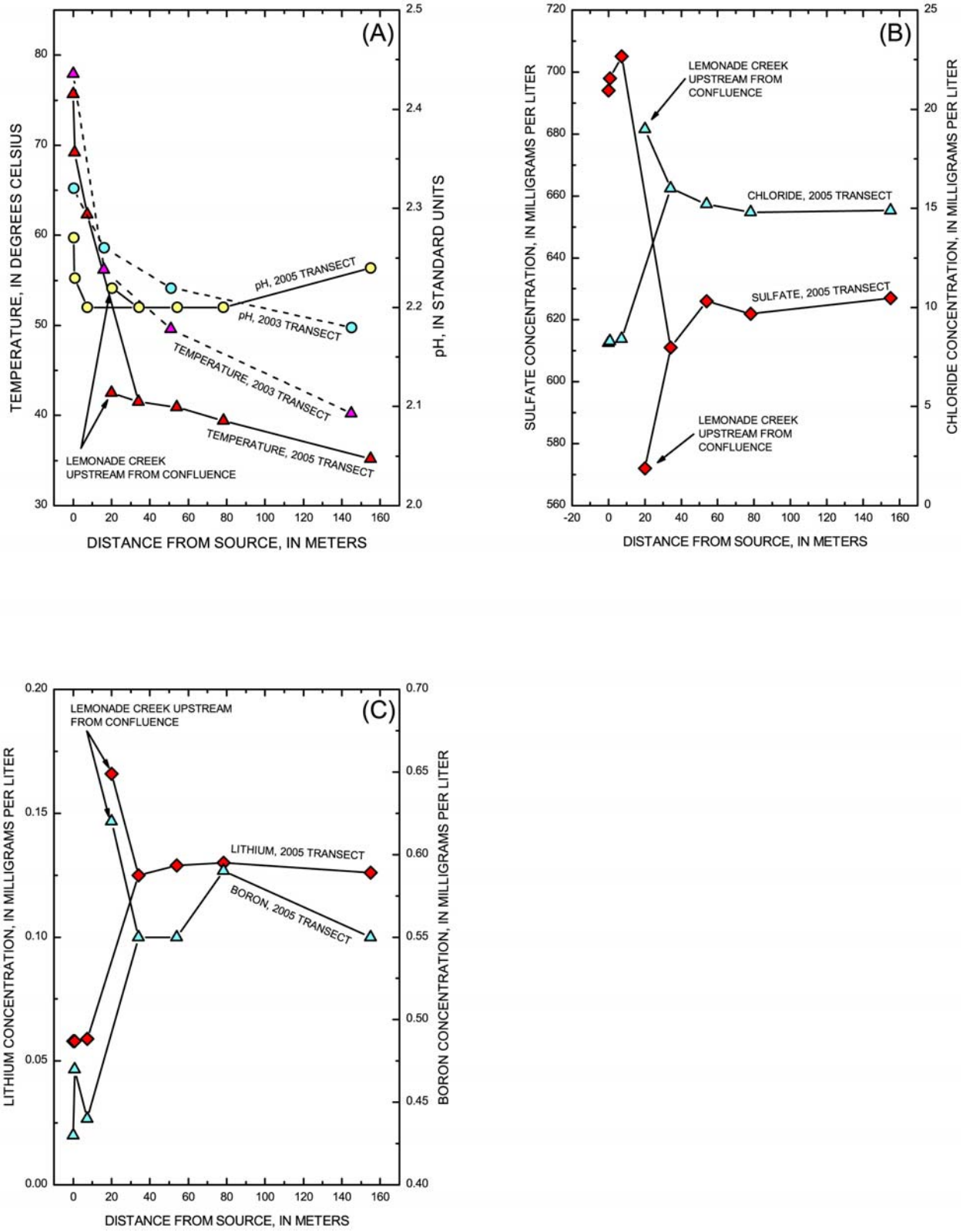


Figure 32. Graphs showing (A) sample temperature and pH, (B) concentrations of sulfate and chloride, and (C) concentrations of lithium and boron as a function of drainage distance for a thermal discharge near Lemonade Creek, its discharge channel, and Lemonade Creek, for 2003 and 2005 samples.

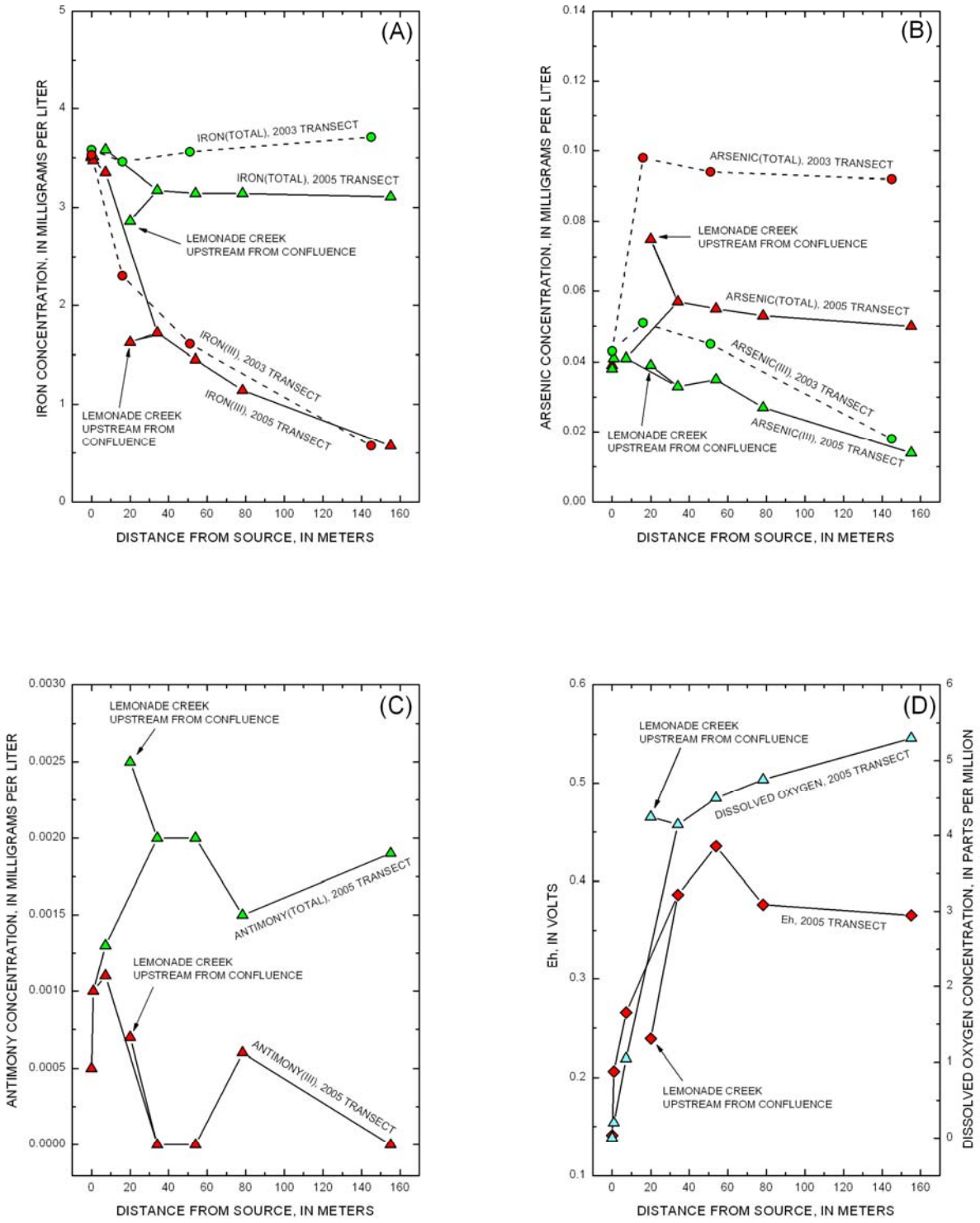


Figure 33. Graphs showing (A) concentrations of iron(total) and iron(II), (B) arsenic(total) and arsenic(III), (C) antimony(total) and antimony(III), and (D) sample Eh and dissolved oxygen concentration as a function of drainage distance for a thermal discharge near Lemonade Creek, its discharge channel, and Lemonade Creek, for 2003 and 2005 samples.

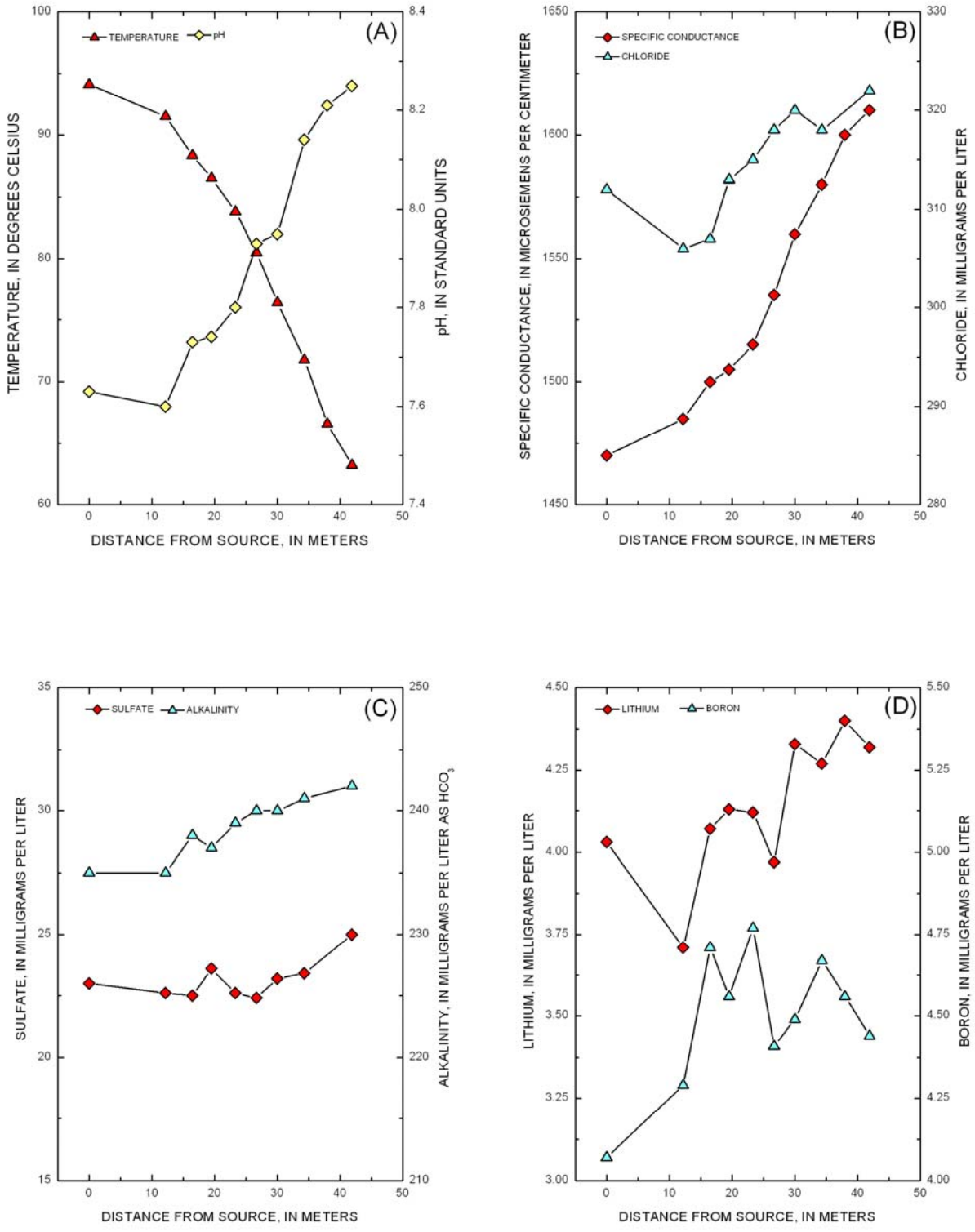


Figure 34. Graphs showing (A) sample temperature and pH, (B) specific conductance, and chloride concentration, (C) concentrations of sulfate and alkalinity, and (D) concentrations of lithium and boron as a function of drainage distance for Ojo Caliente Spring, for 2005 samples.

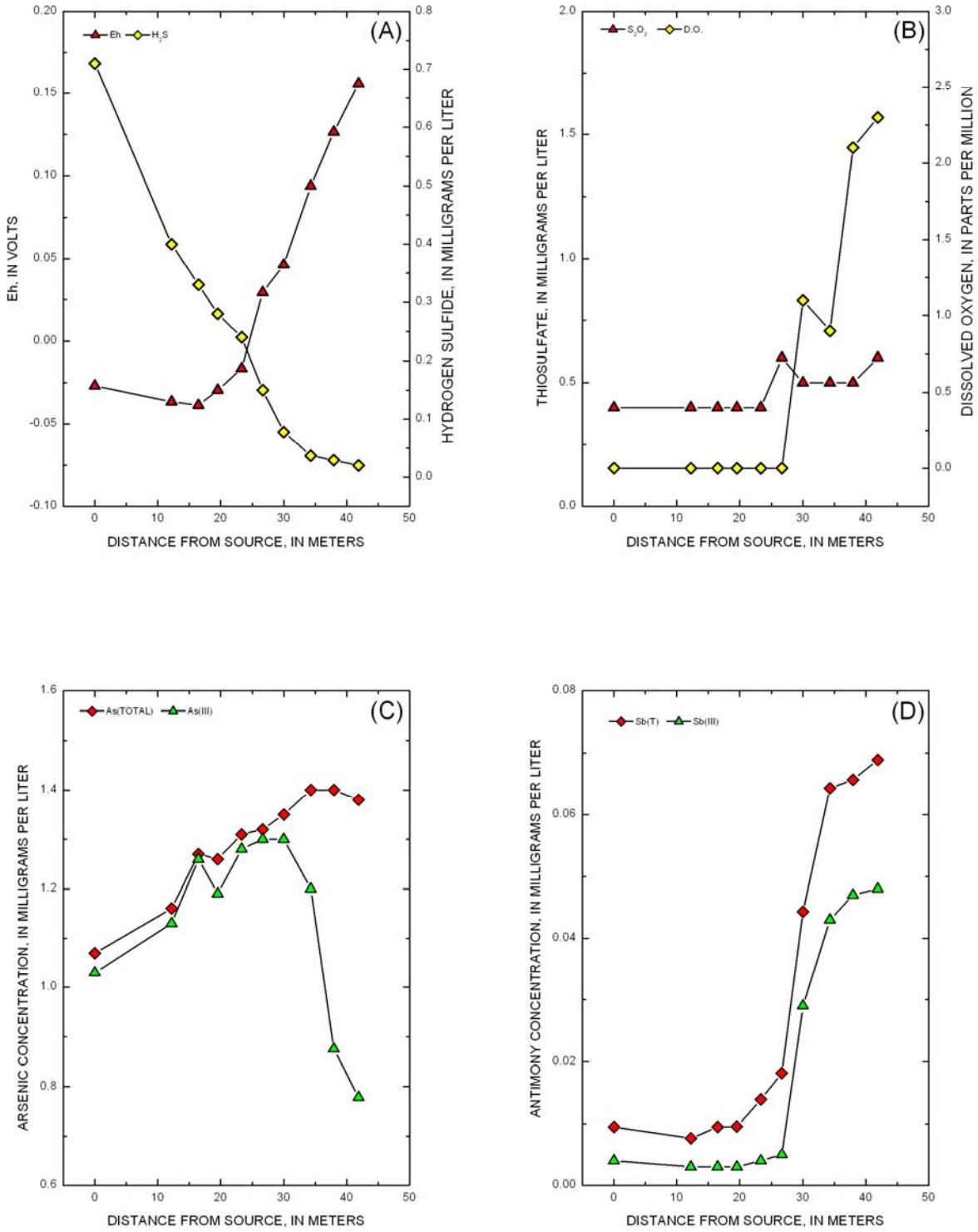


Figure 35. Graphs showing (A) sample Eh and concentration of hydrogen sulfide, (B) concentrations of thiosulfate and dissolved oxygen, (C) concentrations of arsenic(total) and arsenic(III), and (D) concentrations of antimony(total), and antimony(III) as a function of drainage distance for Ojo Caliente Spring, for 2005 samples.

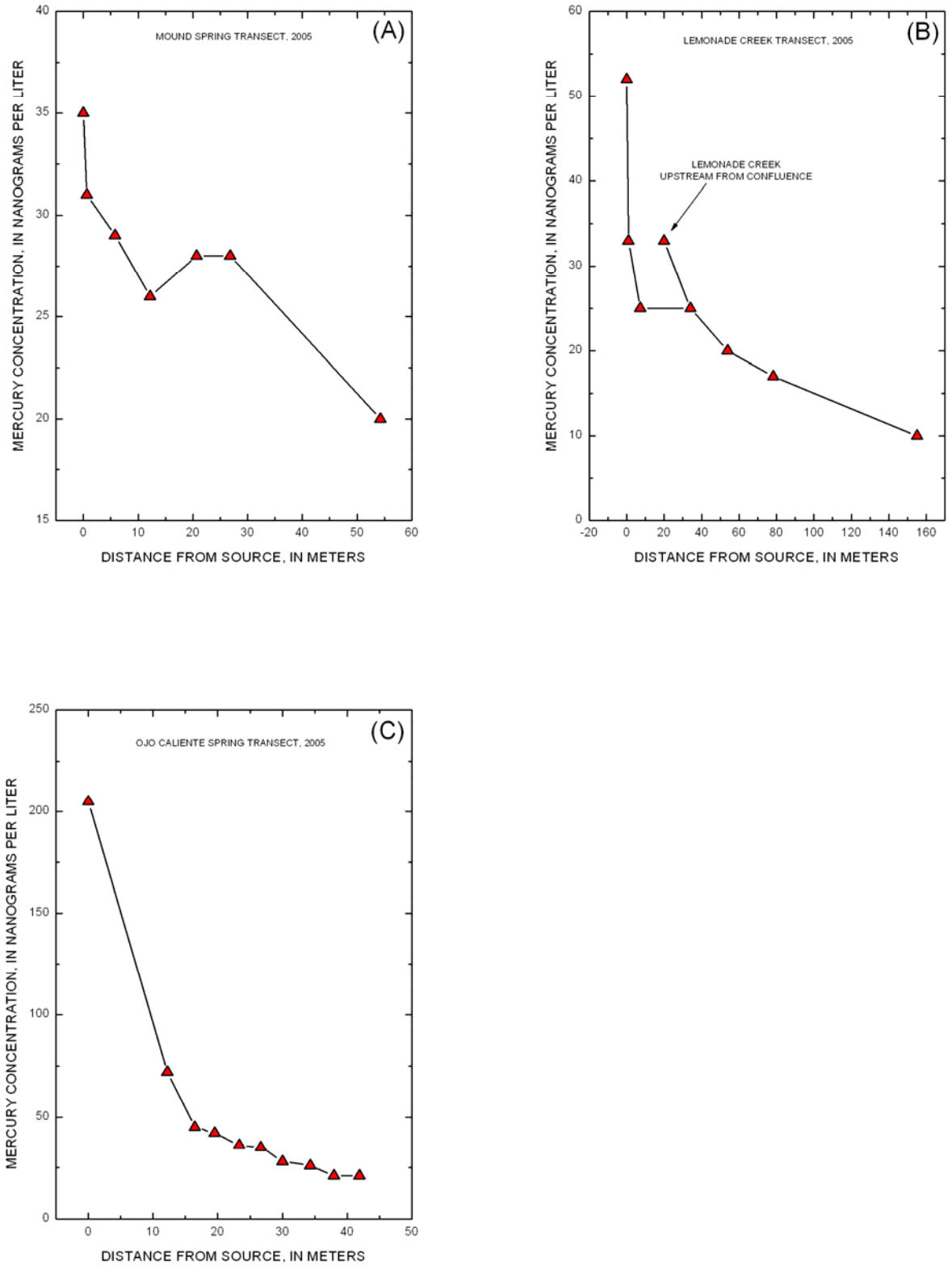


Figure 36. Graphs showing (A) concentrations of mercury(total) as a function of drainage distance for Mound Spring, (B) Lemonade Creek, and (C) Ojo Caliente Spring transects, for 2005 samples.

Table 6. Results of water analyses for Gibbon Canyon and Mammoth Hot Springs, 2003—2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Gibbon Canyon			Mammoth Hot Springs	
Location	**Beryl Spring**	**Beryl Spring**	**Terrace Spring**	**Angel Terrace Spring**	**Canary Spring**
Sample ID	03WA157	04WA146	04WA143	03WA125	03WA126
Collection Date / Time	9/7/03 9:15	9/10/04 14:05	9/9/04 19:00	6/2/03 13:00	6/2/03 15:00
Temperature, °C	92.0	92.6	58.5	73.5	70.0
pH (field / laboratory)	6.60 / 8.21	6.51 / 8.23	6.40 / 8.73	6.43 / 7.90	6.64 / 7.88
Specific conductance (field / laboratory), µS/cm	2040 / 2190	2030 / 2160	1365 / 1280	2230 / 1685	2260 / 1729
Eh, V	-0.076	-0.102	0.223	-0.060	-0.001
Density, g/mL at 20°C	0.9994	0.9993	0.9992	0.9994	0.9995
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	3.90	2.91	17.1	316	298
Magnesium (Mg)	0.014	<0.001	0.659	73.4	74.3
Sodium (Na)	405	407	287	136	134
Potassium (K)	21.9	17.2	23.6	50.2	42.9
Strontium (Sr)	0.007	0.006	0.031	1.61	1.55
Barium (Ba)	0.001	<0.0008	<0.0008	0.058	0.057
Lithium (Li)	3.96	5.53	0.590	1.64	1.54
Sulfate (SO_4)	71.7	69.0	11.4	546	564
Thiosulfate (S_2O_3)	<0.1	0.2	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.15	0.19	0.004	0.075	0.32
Alkalinity (HCO_3)	111	101	781	782	709
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	22.0	20.9	7.81	2.00	1.90
Chloride (Cl)	493	537	59.0	163	163
Bromide (Br)	1.60	1.83	0.180	0.610	0.588
Nitrate (NO_3)	<0.1	0.018	0.133	<0.1	<0.1
Nitrite (NO_2)	0.109	0.010	0.003	0.013	0.011
Ammonium (NH_4)	<0.05	0.40	<0.05	0.71	0.73
Silica (SiO_2)	455	292	130	51.0	50.0
Boron (B)	7.65	7.47	0.97	3.83	3.73
Aluminum (Al)	0.331	0.201	0.010	0.004	0.003
Iron total (Fe(T))	0.008	0.003	0.004	0.008	0.018
Ferrous iron (Fe(II))	0.007	0.003	<0.002	0.007	0.018
Manganese (Mn)	0.017	0.016	0.138	0.021	0.017
Copper (Cu)	0.0008	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	<0.004	0.010	0.005	<0.004	<0.004
Cadmium (Cd)	0.0002	0.0002	0.0006	0.0002	0.0002
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt (Co)	0.0008	<0.0007	<0.0007	<0.0007	0.0028
Mercury total (Hg(T)), ng/L	57	82	13	20	24
Methylmercury (CH_3Hg), ng/L	---	0.013	0.022	---	---
Nickel (Ni)	0.0020	0.0007	<0.0005	<0.002	<0.002
Lead (Pb)	0.0010	0.0019	0.0020	0.0010	<0.0008
Beryllium (Be)	0.001	0.001	0.012	0.001	0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.131	---	---	<0.007	<0.007
Antimony total (Sb(T))	0.0930	0.0724	<0.0005	0.0010	0.0020
Antimonite (Sb(III))	---	0.047	<0.0005	---	---
Selenium (Se)	<0.001	<0.001	<0.001	0.003	0.005
Arsenic total (As(T))	2.47	2.70	0.153	0.186	0.492
Arsenite (As(III))	2.47	2.70	0.003	0.186	0.492
Dissolved organic carbon (DOC)	0.4	0.5	---	---	---
δD, per mil	-139.98	-139.50	-147.30	-148.62	-147.76
$\delta^{18}O$, per mil	-14.53	-14.54	-18.81	-18.20	-18.15
sum cations, meq/L	18.9	19.1	14.0	23.8	22.8
sum anions, meq/L	18.3	19.3	15.0	23.4	22.7
Charge imbalance, percent	3.0	-1.3	-7.1	1.8	0.6

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	One Hundred Spring Plain area					
Location	**Cinder Pool**	**Cinder Pool Side**	**Cinder Pool**	**Cinder Pool**	**Cinder Pool**	**Cinder Pool**
Sample ID	03WA116	03WA116B	03WA150	04WA115	05WA129	05WA140
Collection Date / Time	5/30/03 11:30	5/30/03 11:30	9/4/03 10:30	9/4/04 15:30	6/7/05 11:00	9/19/05 14:10
Temperature, °C	88.0	---	92.0	87.6	92.2	89.3
pH (field / laboratory)	4.21 / 3.72	--- / ---	4.29 / 4.07	4.27 / 3.36	4.18 / 4.14	4.26 / 4.16
Specific conductance (field / laboratory), µS/cm	2060 / 2290	--- / ---	2140 / 2360	2080 / 2420	1935 / 2130	2080 / 2260
Eh, V	0.071	---	0.023	0.021	0.125	0.139
Density, g/mL at 20°C	0.9995	---	0.9994	0.9993	0.9993	0.9992
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	5.06	---	5.33	5.22	4.94	5.35
Magnesium (Mg)	0.025	---	0.032	<0.001	0.024	0.027
Sodium (Na)	364	---	349	361	348	408
Potassium (K)	35.8	---	41.6	49.4	53.1	46.6
Strontium (Sr)	0.016	---	0.017	0.017	0.016	0.016
Barium (Ba)	0.018	---	0.022	0.022	0.017	0.027
Lithium (Li)	3.16	---	3.60	4.57	4.22	4.15
Sulfate (SO_4)	71.8	---	84.9	68.5	77.2	82.0
Thiosulfate (S_2O_3)	12.3	---	5.5	17.3	11.8	8.3
Polythionate (S_nO_6), mg/L / n	1.1 / 5	---	<0.5	<0.5	0.7 / 4	<0.5
Hydrogen sulfide (H_2S)	0.27	0.20	0.25	0.26	0.68	0.46
Alkalinity (HCO_3)	---	---	---	<1	---	---
Acidity (free / total), mM	0.260 / 0.944	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	8.70	---	7.90	7.91	6.90	7.50
Chloride (Cl)	580	---	521	633	599	632
Bromide (Br)	1.96	---	1.96	2.23	1.90	2.00
Nitrate (NO_3)	<0.1	---	<0.1	0.028	0.027	0.014
Nitrite (NO_2)	0.0004	---	0.002	<0.0004	0.001	0.003
Ammonium (NH_4)	7.58	---	8.29	6.60	8.70	9.13
Silica (SiO_2)	405	---	550	366	387	371
Boron (B)	9.30	---	10.0	9.76	8.81	9.33
Aluminum (Al)	1.12	---	0.989	1.04	1.07	1.03
Iron total (Fe(T))	0.032	0.017	0.049	0.016	0.081	0.034
Ferrous iron (Fe(II))	0.032	0.015	0.049	0.016	0.081	0.034
Manganese (Mn)	0.004	---	0.006	0.008	0.005	0.004
Copper (Cu)	<0.0005	---	<0.0005	<0.0005	<0.0005	0.0005
Zinc (Zn)	<0.004	---	<0.004	0.003	0.005	0.014
Cadmium (Cd)	0.0005	---	0.0002	<0.0001	0.0004	0.0003
Chromium (Cr)	0.0007	---	0.0007	<0.0005	<0.0005	0.0008
Cobalt (Co)	<0.0007	---	0.0009	0.0012	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	240	---	280	290	52	130
Methylmercury (CH_3Hg), ng/L	0.074	---	---	---	---	---
Nickel (Ni)	0.0030	---	0.0040	0.0014	0.0012	<0.0005
Lead (Pb)	0.0026	---	<0.0008	0.0028	<0.0008	0.0020
Beryllium (Be)	<0.001	---	<0.001	<0.001	<0.001	<0.001
Vanadium (V)	<0.005	---	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.113	---	0.109	---	0.019	0.057
Antimony total (Sb(T))	---	---	0.0890	0.0117	0.0011	0.0010
Antimonite (Sb(III))	---	---	---	0.012	0.0011	0.0010
Selenium (Se)	<0.001	---	0.002	<0.001	<0.001	<0.001
Arsenic total (As(T))	2.11	2.31	1.86	2.70	1.06	2.16
Arsenite (As(III))	1.98	2.31	1.72	2.68	1.06	2.16
Dissolved organic carbon (DOC)	---	---	0.9	1.2	1.1	1.2
δD, per mil	-124.69	---	-125.38	-124.50	-125.20	-125.70
$\delta^{18}O$, per mil	-10.52	---	-10.84	-10.41	-10.84	-10.59
sum cations, meq/L	17.9	---	17.5	18.3	17.9	20.4
sum anions, meq/L	18.1	---	16.7	19.5	18.7	19.8
Charge imbalance, percent	-1.1	---	4.8	-6.6	-4.4	3.0

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	One Hundred Spring Plain area				
Location	**Tantalus Creek at weir**	**Tantalus Creek at weir**	**Tantalus Creek at weir**	**Tantalus Creek at weir**	**Tantalus Creek at weir**
Sample ID	03WA123	03WA149	04WA117	05WA130	05WA147
Collection Date / Time	6/1/03 13:00	9/3/03 16:15	9/5/04 11:10	6/7/05 11:55	9/20/05 15:20
Temperature, °C	29.9	21.3	27.4	27.2	25.7
pH (field / laboratory)	3.07 / 3.06	2.95 / 2.93	3.06 / 3.06	2.98 / 2.98	3.08 / 3.11
Specific conductance (field / laboratory), µS/cm	2100 / 2130	2330 / 2370	2280 / 2320	2050 / 2050	2310 / 2220
Eh, V	0.674	0.671	0.472	0.426	0.451
Density, g/mL at 20°C	0.9995	0.9993	0.9993	0.9993	0.9992
Dissolved oxygen (DO), mg/L	---	---	---	7.3	6.2
Constituent, mg/L[1]					
Calcium (Ca)	3.98	4.18	4.04	3.81	4.17
Magnesium (Mg)	0.279	0.307	0.230	0.267	0.226
Sodium (Na)	276	308	295	263	339
Potassium (K)	50.2	62.4	58.0	57.0	55.8
Strontium (Sr)	0.014	0.016	0.016	0.014	0.016
Barium (Ba)	0.079	0.098	0.086	0.078	0.084
Lithium (Li)	3.93	4.20	4.30	3.42	4.17
Sulfate (SO_4)	148	169	145	160	156
Thiosulfate (S_2O_3)	---	<0.1	---	<0.1	---
Polythionate (S_nO_6), mg/L / n	---	<0.5	---	<0.5	---
Hydrogen sulfide (H_2S)	---	---	---	---	---
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	0.965 / 1.52	1.30 / 1.81	1.08 / 1.08	1.20 / 1.67	0.930 / 1.39
Fluoride (F)	5.10	5.10	6.40	4.50	4.75
Chloride (Cl)	443	443	502	420	507
Bromide (Br)	1.52	1.57	3.90	1.30	1.65
Nitrate (NO_3)	0.143	<0.1	0.013	0.032	0.098
Nitrite (NO_2)	<0.0004	0.002	<0.0004	0.001	0.021
Ammonium (NH_4)	1.38	1.34	1.60	1.50	1.57
Silica (SiO_2)	354	378	350	323	401
Boron (B)	6.82	7.88	7.99	6.50	7.73
Aluminum (Al)	2.43	2.62	2.22	2.67	2.41
Iron total (Fe(T))	1.50	1.39	1.21	1.37	1.13
Ferrous iron (Fe(II))	0.742	0.553	0.432	0.523	0.535
Manganese (Mn)	0.073	0.087	0.092	0.079	0.073
Copper (Cu)	<0.0005	<0.0005	<0.0005	<0.0005	0.0035
Zinc (Zn)	0.012	0.012	0.009	0.010	0.011
Cadmium (Cd)	0.0005	0.0002	0.0001	0.0002	0.0003
Chromium (Cr)	0.0018	0.0013	<0.0005	<0.0005	<0.0005
Cobalt (Co)	<0.0007	0.0011	0.0016	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	44	49	29	40	25
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---
Nickel (Ni)	0.0030	0.0040	<0.0005	0.0019	0.0022
Lead (Pb)	0.0026	0.0019	0.0035	0.0057	0.0017
Beryllium (Be)	0.002	0.002	0.002	0.002	0.002
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.050	0.047	---	0.041	0.048
Antimony total (Sb(T))	0.0640	0.0710	0.0187	0.0242	0.0088
Antimonite (Sb(III))	---	---	0.0005	0.0008	<0.0005
Selenium (Se)	0.002	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.89	1.73	1.83	1.38	1.73
Arsenite (As(III))	0.068	0.055	0.070	0.273	0.055
Dissolved organic carbon (DOC)	---	1.0	1.1	1.3	8.3
δD, per mil	-128.75	-130.82	-131.00	-132.60	-132.40
$\delta^{18}O$, per mil	-13.15	-12.65	-13.03	-13.75	-12.85
sum cations, meq/L	15.2	17.2	16.3	14.9	18.1
sum anions, meq/L	15.5	15.9	17.2	15.1	17.5
Charge imbalance, percent	-2.1	8.3	-5.5	-0.7	3.4

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Back Basin area					
Location	**"Black Gassy Spring"**	**Cistern Spring**	**Cistern Spring-Side**	**Cistern Spring**	**Cistern Spring**	**Cistern Spring**
Sample ID	04WA130	03WA121	03WA121B	03WA143	04WA116	05WA134
Collection Date / Time	9/6/04 16:30	5/31/03 15:30	5/31/03 15:30	9/2/03 11:00	9/4/04 17:30	6/7/05 16:00
Temperature, °C	29.9	72.6[2]	---	81.4[2]	85.4	86.0
pH (field / laboratory)	6.51 / 6.99	5.75 / 6.82	--- / ---	4.73 / 3.35	5.29 / 3.62	4.90 / 4.92
Specific conductance (field / laboratory), µS/cm	2380 / 2508	1750 / 1915	--- / ---	1770 / 2070	1990 / 2190	1604 / 1590
Eh, V	-0.022	0.093	---	-0.001	-0.021	0.102
Density, g/mL at 20°C	0.9994	0.9996	---	0.9994	0.9994	0.9991
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	9.38	2.29	---	2.06	2.52	1.80
Magnesium (Mg)	0.104	0.105	---	0.076	0.112	0.146
Sodium (Na)	423	303	---	312	331	258
Potassium (K)	43.4	50.2	---	48.3	55.5	42.7
Strontium (Sr)	0.035	0.008	---	0.008	0.010	0.006
Barium (Ba)	0.018	0.019	---	0.018	0.022	0.015
Lithium (Li)	5.53	4.35	---	3.26	4.73	3.35
Sulfate (SO_4)	31.4	65.1	---	90.9	72.0	93.8
Thiosulfate (S_2O_3)	<0.1	13.2	13.7	14.4	17.7	51.7
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	0.7 / 4
Hydrogen sulfide (H_2S)	0.023	0.23	0.11	0.23	0.20	0.36
Alkalinity (HCO_3)	14.3	14.6	---	<1	<1	<1
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	8.20	6.90	---	5.90	7.39	5.10
Chloride (Cl)	751	482	---	439	567	374
Bromide (Br)	2.80	1.68	---	1.57	3.03	1.20
Nitrate (NO_3)	0.015	<0.1	---	<0.1	0.018	0.033
Nitrite (NO_2)	0.009	0.001	---	0.002	<0.0004	0.001
Ammonium (NH_4)	0.50	1.31	---	6.17	1.60	8.40
Silica (SiO_2)	277	527	---	520	557	398
Boron (B)	11.3	7.88	---	8.64	9.15	6.41
Aluminum (Al)	0.081	0.088	---	0.078	0.069	0.062
Iron total (Fe(T))	0.008	0.008	0.002	0.008	<0.002	0.024
Ferrous iron (Fe(II))	0.007	0.007	0.002	0.008	<0.002	0.024
Manganese (Mn)	0.066	0.043	---	0.040	0.064	0.112
Copper (Cu)	<0.0005	<0.0005	---	0.0005	<0.0005	<0.0005
Zinc (Zn)	0.003	<0.004	---	0.039	0.003	0.001
Cadmium (Cd)	0.0003	0.0004	---	0.0007	0.0002	0.0002
Chromium (Cr)	<0.0005	<0.0005	---	<0.0005	<0.0005	0.0006
Cobalt (Co)	<0.0007	<0.0007	---	0.0014	0.0018	<0.0007
Mercury total (Hg(T)), ng/L	31	69	---	370	130	440
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---	---
Nickel (Ni)	0.0009	0.0030	---	0.0060	<0.0005	0.0018
Lead (Pb)	0.0030	0.0019	---	0.0023	0.0027	<0.0008
Beryllium (Be)	<0.001	<0.001	---	<0.001	<0.001	<0.001
Vanadium (V)	<0.005	<0.005	---	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	0.102	---	0.110	---	0.125
Antimony total (Sb(T))	0.0850	0.0760	---	0.0840	0.0518	0.0170
Antimonite (Sb(III))	0.061	---	---	---	0.049	0.013
Selenium (Se)	<0.001	<0.001	---	<0.001	<0.001	<0.001
Arsenic total (As(T))	2.88	1.27	1.71	1.61	1.96	1.13
Arsenite (As(III))	2.87	1.27	1.68	1.61	1.94	0.924
Dissolved organic carbon (DOC)	0.6	---	---	0.7	0.7	1.3
δD, per mil	-141.90	-128.20	---	-122.22	-124.90	-123.50
$\delta^{18}O$, per mil	-15.25	-12.42	---	-9.48	-11.40	-11.25
sum cations, meq/L	20.8	15.3	---	15.7	16.7	13.3
sum anions, meq/L	22.5	15.5	---	14.5	17.9	12.7
Charge imbalance, percent	-8.0	-1.8	---	7.8	-6.8	4.7

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Back Basin area					
Location	**Cistern Spring**	**Congress Pool**	**Constant Geyser**	**Echinus Geyser**	**Echinus Geyser**	**Pearl Geyser**
Sample ID	05WA141	05WA152	03WA141	03WA120	03WA144	05WA151
Collection Date / Time	9/19/05 16:20	9/21/05 17:00	9/1/03 19:00	5/31/03 14:10	9/2/03 12:20	9/21/05 15:00
Temperature, °C	85.0	71.4	69.0	72.7[2]	72.0[2]	90.5
pH (field / laboratory)	5.37 / 6.34	6.06 / 7.24	3.49 / 3.26	3.58 / 3.41	3.55 / 3.32	7.93 / 8.58
Specific conductance (field / laboratory), µS/cm	1928 / 2060	2240 / 2330	1950 / 2200	1140 / 1279	1142 / 1319	2210 / 2380
Eh, V	0.118	0.406	0.154	0.432	0.255	0.088
Density, g/mL at 20°C	0.9992	0.9992	0.9994	0.9991	0.9991	0.9994
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	2.45	2.97	2.44	4.43	4.72	4.05
Magnesium (Mg)	0.123	0.012	0.118	0.484	0.526	0.009
Sodium (Na)	380	399	316	175	175	394
Potassium (K)	52.0	65.3	42.7	37.2	49.9	81.1
Strontium (Sr)	0.009	0.011	0.011	0.007	0.008	0.013
Barium (Ba)	0.020	0.005	0.126	0.054	0.064	0.009
Lithium (Li)	4.38	5.58	3.48	0.868	0.813	5.95
Sulfate (SO_4)	67.2	39.9	106	267	291	22.2
Thiosulfate (S_2O_3)	12.4	9.4	<0.1	<0.1	<0.1	0.9
Polythionate (S_nO_6), mg/L / n	1.1 / 4	<0.5	<0.5	<0.5	<0.5	0.7 / 4
Hydrogen sulfide (H_2S)	0.36	0.042	0.015	0.006	0.009	0.067
Alkalinity (HCO_3)	12.5	16.7	---	---	---	57.1
Acidity (free / total), mM	--- / ---	--- / ---	0.659 / 0.939	0.499 / 0.945	0.620 / 1.03	--- / ---
Fluoride (F)	6.50	6.10	5.40	6.70	6.20	6.80
Chloride (Cl)	576	673	462	144	136	692
Bromide (Br)	1.80	2.20	1.63	0.513	0.447	2.20
Nitrate (NO_3)	0.016	0.061	<0.1	<0.1	<0.1	0.080
Nitrite (NO_2)	0.008	0.030	0.005	0.002	0.007	0.046
Ammonium (NH_4)	1.80	0.86	1.19	1.05	0.73	0.45
Silica (SiO_2)	619	494	473	309	349	801
Boron (B)	8.79	10.3	8.41	2.57	2.56	9.73
Aluminum (Al)	0.064	0.012	0.930	1.97	2.20	0.015
Iron total (Fe(T))	0.004	<0.002	0.480	1.27	0.955	<0.002
Ferrous iron (Fe(II))	0.004	<0.002	0.448	0.972	0.674	<0.002
Manganese (Mn)	0.053	0.018	0.020	0.258	0.269	0.018
Copper (Cu)	<0.0005	<0.003	0.0014	<0.0005	<0.0005	<0.003
Zinc (Zn)	0.009	0.002	0.004	0.014	0.024	0.001
Cadmium (Cd)	0.0003	0.0004	0.0005	0.0003	0.0003	0.0003
Chromium (Cr)	<0.0005	<0.0005	<0.0005	0.0012	0.0012	<0.0005
Cobalt (Co)	<0.0007	<0.0007	<0.0007	<0.0007	0.0009	<0.0007
Mercury total (Hg(T)), ng/L	19	54	47	47	48	58
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---	---
Nickel (Ni)	0.0005	0.0019	0.0060	0.0030	0.0070	<0.0005
Lead (Pb)	0.0009	0.0009	0.0023	0.0011	0.0011	0.0012
Beryllium (Be)	<0.001	<0.001	<0.001	0.007	0.007	<0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.102	0.193	<0.007	<0.007	<0.007	0.222
Antimony total (Sb(T))	0.0022	0.0422	0.0740	0.0020	<0.001	0.0603
Antimonite (Sb(III))	0.002	0.042	---	---	---	0.043
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.32	2.40	1.85	0.084	0.052	2.49
Arsenite (As(III))	1.26	2.29	0.723	0.011	0.010	2.47
Dissolved organic carbon (DOC)	0.8	1.4	0.8	---	0.6	0.5
δD, per mil	-127.80	-137.60	-135.70	-140.06	-140.81	-141.60
$\delta^{18}O$, per mil	-12.15	-13.22	-13.96	-16.54	-16.66	-15.42
sum cations, meq/L	18.7	20.0	15.9	9.2	9.6	20.3
sum anions, meq/L	18.2	20.5	15.3	9.4	9.6	21.3
Charge imbalance, percent	2.8	-2.0	3.9	-1.9	-0.7	-4.9

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Back Basin area					
Location	**Perpetual Spouter**	**Perpetual Spouter**	**Tantalus Creek upstream from Perpetual Spouter**	**Unnamed acid spring near Perpetual Spouter**	**Porkchop Geyser**	**Porkchop Geyser**
Sample ID	04WA129	05WA128	04WA128	04WA127	03WA118	03WA145
Collection Date / Time	9/6/04 15:45	6/7/05 10:00	9/6/04 15:00	9/6/04 14:15	5/31/03 10:30	9/2/03 14:00
Temperature, °C	89.5	92.7	35.4	92.0	80.0	77.0
pH (field / laboratory)	7.23 / 6.98	6.85 / 6.89	3.11 / 3.09	2.91 / 2.78	7.24 / 7.50	7.18 / 7.50
Specific conductance (field / laboratory), µS/cm	2535 / 2700	2470 / 2680	2350 / 2310	1350 / 1932	2240 / 2420	2350 / 2520
Eh, V	-0.034	0.100	0.465	0.282	0.145	0.020
Density, g/mL at 20°C	0.9995	0.9995	0.9993	0.9990	0.9996	0.9996
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	9.91	10.7	4.11	2.90	4.50	4.65
Magnesium (Mg)	0.074	0.090	0.236	0.317	0.010	0.004
Sodium (Na)	487	471	337	160	399	419
Potassium (K)	48.8	56.9	65.8	55.2	63.8	76.6
Strontium (Sr)	0.036	0.036	0.014	0.015	0.014	0.015
Barium (Ba)	0.014	0.017	0.058	0.106	0.013	0.017
Lithium (Li)	6.24	6.25	4.63	1.06	4.78	5.06
Sulfate (SO_4)	34.6	44.8	159	220	26.3	31.6
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.018	0.002	0.002	0.008	0.060	0.040
Alkalinity (HCO_3)	11.1	7.42	---	---	49.1	42.5
Acidity (free / total), mM	--- / ---	--- / ---	0.940 / 1.23	2.05 / 2.40	--- / ---	--- / ---
Fluoride (F)	8.06	7.20	7.23	0.831	8.60	8.20
Chloride (Cl)	815	827	507	267	642	646
Bromide (Br)	2.84	2.50	2.01	0.799	2.21	2.19
Nitrate (NO_3)	0.037	0.073	0.019	0.009	<0.1	<0.1
Nitrite (NO_2)	0.046	0.028	0.001	0.002	0.014	0.067
Ammonium (NH_4)	0.50	0.62	1.90	3.10	0.34	<0.05
Silica (SiO_2)	276	293	458	351	589	641
Boron (B)	12.1	12.1	8.37	3.82	10.4	11.2
Aluminum (Al)	0.080	0.147	2.15	0.606	0.007	0.016
Iron total (Fe(T))	0.067	0.173	1.07	4.99	0.002	<0.002
Ferrous iron (Fe(II))	<0.002	0.020	0.630	4.89	<0.002	<0.002
Manganese (Mn)	0.044	0.055	0.103	0.100	0.018	0.011
Copper (Cu)	<0.0005	<0.0005	0.0005	0.0009	<0.0005	0.0010
Zinc (Zn)	0.003	0.001	0.009	0.054	0.233	1.47
Cadmium (Cd)	0.0002	0.0003	0.0003	0.0003	0.0039	0.0005
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt (Co)	<0.0007	<0.0007	0.0009	0.0012	<0.0007	0.0011
Mercury total (Hg(T)), ng/L	44	16	26	28	72	76
Methylmercury (CH_3Hg), ng/L	0.021	---	---	---	---	---
Nickel (Ni)	0.0012	<0.0005	0.0019	0.0022	0.0030	0.0050
Lead (Pb)	0.0028	0.0020	0.0035	0.0036	0.0032	0.0024
Beryllium (Be)	<0.001	<0.001	0.002	0.004	<0.001	<0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	0.087	---	---	0.220	0.308
Antimony total (Sb(T))	0.0949	0.115	0.0252	0.0158	0.192	0.224
Antimonite (Sb(III))	0.024	0.012	0.003	0.012	---	---
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	3.00	2.84	1.88	0.891	2.71	2.95
Arsenite (As(III))	1.70	0.585	0.144	0.610	2.04	1.84
Dissolved organic carbon (DOC)	0.5	1.1	1.9	0.6	---	0.6
δD, per mil	-142.00	-140.60	-132.50	-136.70	-140.70	-138.55
$\delta^{18}O$, per mil	-14.84	-14.82	-12.56	-15.46	-14.89	-13.62
sum cations, meq/L	23.9	23.4	18.2	10.3	19.9	21.2
sum anions, meq/L	24.4	24.8	17.6	11.4	20.0	20.1
Charge imbalance, percent	-2.2	-5.9	3.6	-9.8	-0.2	5.5

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Back Basin area					
Location	**Porkchop Geyser**	**"Second Eruptor" near Porkchop Geyser**	**"Second Eruptor" near Porkchop Geyser**	**"Second Eruptor" near Porkchop Geyser**	**"Second Eruptor" near Porkchop Geyser**	**Thermal discharge at base of Porkchop Geyser**
Sample ID	04WA144	03WA147	04WA145	05WA127	05WA142	03WA119
Collection Date / Time	9/10/04 10:30	9/2/03 16:45	9/10/04 11:30	6/6/05 17:00	9/19/05 17:40	5/31/03 12:00
Temperature, °C	90.0	91.0	90.0	58.5	89.2	92.0
pH (field / laboratory)	8.00 / 8.55	7.86 / 7.32	7.82 / 8.03	5.51 / 5.84	7.85 / 8.46	4.94 / 4.16
Specific conductance (field / laboratory), µS/cm	2210 / 2320	2370 / 2500	2250 / 2390	1630 / 1760	2220 / 2370	1960 / 2200
Eh, V	-0.109	-0.030	-0.046	0.071	0.047	0.104
Density, g/mL at 20°C	0.9996	0.9995	0.9995	0.9991	0.9994	0.9994
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	4.13	4.41	4.19	3.20	3.99	3.58
Magnesium (Mg)	<0.001	0.009	<0.001	0.014	0.010	0.056
Sodium (Na)	384	409	387	281	414	340
Potassium (K)	67.4	83.2	64.5	56.6	77.9	57.0
Strontium (Sr)	0.012	0.016	0.012	0.010	0.013	0.011
Barium (Ba)	0.006	0.020	0.007	0.008	0.009	0.020
Lithium (Li)	5.58	5.74	5.52	4.38	6.10	4.19
Sulfate (SO_4)	22.6	25.2	23.7	49.8	22.2	65.5
Thiosulfate (S_2O_3)	0.3	<0.1	2.0	10.7	0.6	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	0.7 / 4	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.073	0.097	0.12	---	0.13	0.041
Alkalinity (HCO_3)	55.5	46.3	48.5	4.14	56.7	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	8.36	8.10	8.44	5.50	6.80	7.70
Chloride (Cl)	678	633	672	480	683	559
Bromide (Br)	2.45	2.25	2.39	1.60	2.20	1.82
Nitrate (NO_3)	0.061	<0.1	0.051	0.018	0.112	6.16
Nitrite (NO_2)	0.010	0.224	0.015	0.006	0.052	0.002
Ammonium (NH_4)	0.30	<0.05	0.40	3.79	0.38	0.64
Silica (SiO_2)	521	673	442	369	796	389
Boron (B)	9.65	11.2	9.75	7.15	10.1	8.96
Aluminum (Al)	0.032	0.097	0.006	0.007	0.009	0.838
Iron total (Fe(T))	0.002	<0.002	0.004	0.005	<0.002	0.261
Ferrous iron (Fe(II))	0.002	<0.002	0.004	0.005	<0.002	0.259
Manganese (Mn)	0.002	<0.001	0.004	0.008	0.013	0.022
Copper (Cu)	<0.0005	0.0008	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	0.006	0.039	0.014	0.009	0.004	0.017
Cadmium (Cd)	0.0004	0.0002	0.0004	0.0003	0.0003	0.0005
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0013
Cobalt (Co)	0.0015	0.0012	<0.0007	<0.0007	0.0008	<0.0007
Mercury total (Hg(T)), ng/L	40	640	77	12	120	46
Methylmercury (CH_3Hg), ng/L	0.035	---	---	---	---	---
Nickel (Ni)	<0.0005	0.0070	0.0007	<0.0005	0.0008	0.0030
Lead (Pb)	0.0026	0.0012	0.0028	<0.0008	0.0016	0.0021
Beryllium (Be)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	0.253	---	0.185	0.221	0.135
Antimony total (Sb(T))	0.0850	0.169	0.0955	0.0719	0.0430	0.182
Antimonite (Sb(III))	0.048	---	0.054	0.030	0.039	---
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	2.58	2.63	2.61	1.98	2.47	2.55
Arsenite (As(III))	2.55	2.59	2.61	1.95	2.47	2.42
Dissolved organic carbon (DOC)	0.6	3.9	0.6	4.2	1.1	---
δD, per mil	-142.30	---	-138.60	-134.80	-139.70	-141.17
$\delta^{18}O$, per mil	-15.25	---	-13.64	-10.25	-15.32	-15.43
sum cations, meq/L	19.5	21.0	19.5	14.7	21.1	17.1
sum anions, meq/L	21.0	19.6	20.7	14.9	21.1	17.5
Charge imbalance, percent	-7.6	6.7	-6.1	-1.9	0.2	-2.7

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Back Basin area			Ragged Hills area		
Location	**Thermal discharge at base of Porkchop Geyser**	**Unnamed thermal feature near "Second Eruptor"**	**Steamboat Geyser**	**Crystal Spring**	**"Kaolin Spring"**	**"Kaolin Spring" discharge pool**
Sample ID	03WA146	05WA126	03WA142	05WA131	03WA122	03WA122B
Collection Date / Time	9/2/03 15:30	6/6/05 15:52	9/2/03 9:30	6/7/05 13:00	6/1/03 10:30	6/1/03 10:30
Temperature, °C	91.8	85.8	79.0	82.0	87.5	---
pH (field / laboratory)	5.98 / 5.22	7.57 / 7.82	6.27 / 7.16	5.33 / 4.83	2.87 / 2.63	--- / ---
Specific conductance (field / laboratory), µS/cm	2160 / 2440	2220 / 2410	1950 / 2130	2200 / 2350	1080 / 1756	--- / ---
Eh, V	0.042	-0.014	0.003	0.084	0.286	---
Density, g/mL at 20°C	0.9995	0.9995	0.9995	0.9994	0.9991	---
Dissolved oxygen (DO), mg/L	---	---	---	0.2	---	---
Constituent, mg/L[1]						
Calcium (Ca)	4.07	4.47	3.23	6.16	5.07	---
Magnesium (Mg)	0.044	0.009	0.207	0.010	0.867	---
Sodium (Na)	398	396	336	420	85.5	---
Potassium (K)	17.2	81.7	8.82	34.4	26.3	---
Strontium (Sr)	0.013	0.014	0.011	0.012	0.013	---
Barium (Ba)	0.020	0.010	0.027	0.007	0.044	---
Lithium (Li)	3.46	6.37	3.18	5.66	0.765	---
Sulfate (SO_4)	57.0	37.9	86.4	43.2	260	---
Thiosulfate (S_2O_3)	<0.1	1.2	<0.1	1.8	<0.1	---
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	---
Hydrogen sulfide (H_2S)	0.025	0.15	0.070	0.11	0.075	---
Alkalinity (HCO_3)	3.60	49.5	21.3	<1	---	---
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	2.91 / 4.01	--- / ---
Fluoride (F)	7.50	7.20	6.60	6.60	0.300	---
Chloride (Cl)	618	700	477	716	114	---
Bromide (Br)	2.21	2.10	1.67	2.20	0.474	---
Nitrate (NO_3)	<0.1	0.011	5.30	0.022	<0.1	---
Nitrite (NO_2)	0.041	0.005	0.008	0.002	0.001	---
Ammonium (NH_4)	0.46	0.54	1.08	1.00	1.36	---
Silica (SiO_2)	483	627	617	453	289	---
Boron (B)	10.7	10.1	8.90	10.4	1.80	---
Aluminum (Al)	0.379	0.018	0.133	0.382	5.45	---
Iron total (Fe(T))	0.133	<0.002	0.085	0.072	9.31	6.52
Ferrous iron (Fe(II))	0.131	<0.002	0.074	0.068	9.31	6.44
Manganese (Mn)	0.014	0.012	0.074	0.005	0.138	---
Copper (Cu)	<0.0005	<0.0005	0.0020	<0.0005	0.0011	---
Zinc (Zn)	<0.004	0.008	<0.004	0.001	0.050	---
Cadmium (Cd)	0.0003	0.0003	0.0005	0.0003	0.0004	---
Chromium (Cr)	<0.0005	<0.0005	0.0027	<0.0005	0.0048	---
Cobalt (Co)	<0.0007	0.0011	<0.0007	<0.0007	0.0007	---
Mercury total (Hg(T)), ng/L	67	62	140	53	490	---
Methylmercury (CH_3Hg), ng/L	---	---	---	---	0.222	---
Nickel (Ni)	0.0040	0.0010	0.010	0.0089	0.0050	---
Lead (Pb)	0.0028	0.0019	0.0023	0.0025	0.0013	---
Beryllium (Be)	<0.001	<0.001	0.001	<0.001	0.005	---
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	---
Molybdenum (Mo)	0.198	0.262	0.115	0.213	<0.007	---
Antimony total (Sb(T))	0.220	0.0937	0.0760	0.132	0.0020	---
Antimonite (Sb(III))	---	0.026	---	0.057	---	---
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	0.009	---
Arsenic total (As(T))	2.77	2.43	1.77	2.69	0.460	0.920
Arsenite (As(III))	1.38	2.36	1.73	2.45	0.214	0.372
Dissolved organic carbon (DOC)	2.7	0.6	1.6	0.6	---	---
δD, per mil	-141.43	-140.00	-129.08	-137.00	-132.50	---
$\delta^{18}O$, per mil	-15.28	-14.42	-13.39	-13.49	-12.21	---
sum cations, meq/L	18.5	20.5	15.5	20.3	6.9	---
sum anions, meq/L	19.1	21.8	16.0	21.4	7.5	---
Charge imbalance, percent	-3.2	-6.1	-3.2	-5.2	-9.4	---

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Ragged Hills area					
Location	**"Kaolin Spring"**	**"Orpiment Puddle 1"**	**"Orpiment Puddle 1"**	**"Orpiment Puddle 1"**	**"Orpiment Puddle 2"**	**"Orpiment Puddle 2"**
Sample ID	05WA132	03WA124	03WA140	04WA118	03WA151	04WA119
Collection Date / Time	6/7/05 14:40	6/1/03 14:00	9/1/03 17:00	9/5/04 12:15	9/4/03 12:00	9/5/04 13:10
Temperature, °C	85.0	39.0	39.0	33.6	35.4	29.3
pH (field / laboratory)	2.51 / 2.46	3.33 / 3.28	3.28 / 3.27	3.23 / 3.22	3.28 / 3.33	3.30 / 3.32
Specific conductance (field / laboratory), µS/cm	1070 / 1850	1450 / 1508	1445 / 1491	1470 / 1510	1395 / 1416	1440 / 1419
Eh, V	0.321	0.218	0.109	0.169	0.106	0.160
Density, g/mL at 20°C	0.9988	0.9990	0.9989	0.9987	0.9989	0.9988
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	3.21	2.64	2.62	2.01	3.00	2.83
Magnesium (Mg)	0.651	0.051	0.038	<0.001	0.049	<0.001
Sodium (Na)	31.8	211	212	197	205	206
Potassium (K)	16.3	18.2	23.2	20.4	26.3	22.3
Strontium (Sr)	0.008	0.010	0.011	0.010	0.010	0.011
Barium (Ba)	0.036	0.160	0.172	0.152	0.163	0.133
Lithium (Li)	0.403	2.39	2.33	2.24	2.62	2.46
Sulfate (SO_4)	314	71.4	65.8	65.6	64.2	63.0
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.051	3.4	3.2	1.7	7.7	4.3
Alkalinity (HCO_3)	---	---	---	---	---	---
Acidity (free / total), mM	4.27 / 5.23	0.558 / 1.50	0.572 / 0.974	0.677 / 1.56	0.503 / 0.916	0.514 / 0.951
Fluoride (F)	1.00	2.90	2.50	2.79	2.30	2.35
Chloride (Cl)	32.3	360	309	337	340	340
Bromide (Br)	0.100	1.20	1.09	1.10	1.06	1.58
Nitrate (NO_3)	0.023	0.110	<0.1	0.010	<0.1	0.007
Nitrite (NO_2)	0.001	---	0.003	<0.0004	0.004	0.001
Ammonium (NH_4)	1.20	0.86	0.22	1.50	0.15	0.60
Silica (SiO_2)	268	152	156	147	145	118
Boron (B)	0.62	5.29	5.61	4.99	5.16	4.86
Aluminum (Al)	7.47	2.49	2.60	2.33	2.63	2.60
Iron total (Fe(T))	0.894	0.271	0.185	0.192	0.415	0.458
Ferrous iron (Fe(II))	0.490	0.268	0.184	0.192	0.404	0.459
Manganese (Mn)	0.089	0.008	0.007	0.010	0.012	0.015
Copper (Cu)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	0.037	<0.004	<0.004	0.004	0.006	0.006
Cadmium (Cd)	0.0002	0.0003	0.0003	<0.0001	0.0004	<0.0001
Chromium (Cr)	0.0007	0.0009	<0.0005	<0.0005	0.0008	<0.0005
Cobalt (Co)	<0.0007	0.0090	<0.0007	0.0008	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	180	6.0	1.6	13	7.2	7.9
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---	---
Nickel (Ni)	0.0036	<0.002	0.0020	<0.0005	<0.002	<0.0005
Lead (Pb)	<0.0008	0.0013	0.0010	0.0014	0.0020	0.0017
Beryllium (Be)	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	<0.007	<0.007	<0.007	---	<0.007	---
Antimony total (Sb(T))	0.0008	<0.001	<0.001	<0.0005	<0.001	<0.0005
Antimonite (Sb(III))	0.0008	---	---	<0.0005	---	<0.0005
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Arsenic total (As(T))	0.023	0.076	0.201	0.257	0.055	0.091
Arsenite (As(III))	0.006	0.076	0.201	0.257	0.042	0.091
Dissolved organic carbon (DOC)	1.2	---	---	0.5	0.7	0.5
δD, per mil	-129.80	-144.66	-144.64	-144.60	-147.53	-146.70
$\delta^{18}O$, per mil	-11.02	-16.84	-16.79	-16.81	-17.09	-16.73
sum cations, meq/L	5.9	10.8	11.0	10.4	10.9	10.8
sum anions, meq/L	5.8	11.6	10.1	10.9	10.9	10.9
Charge imbalance, percent	1.8	-7.1	9.3	-4.6	-0.1	-0.9

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Ragged Hills area					
Location	**"Orpiment Puddle 2"**	**"Orpiment Puddle 3"**	**"Orpiment Puddle 4"**	**"Persnickety Geyser"**	**"Rainbow Growler"**	**"Rainbow Growler"**
Sample ID	04WA119-0.45	04WA120	05WA133	04WA123	03WA152	04WA126
Collection Date / Time	9/5/04 13:10	9/5/04 13:50	6/7/05 14:50	9/5/04 17:00	9/4/03 13:30	9/6/04 12:15
Temperature, °C	---	24.3	44.7	89.6	93.0	91.5
pH (field / laboratory)	--- / ---	2.74 / 2.74	2.85 / 2.87	3.68 / 3.38	3.74 / 3.65	3.52 / 3.33
Specific conductance (field / laboratory), µS/cm	--- / ---	1120 / 1160	2090 / 2250	1985 / 2270	1940 / 2170	1620 / 1860
Eh, V	---	0.271	0.229	---	0.133	0.160
Density, g/mL at 20°C	---	0.9986	0.9992	0.9993	0.9993	0.9992
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	---	<0.04	3.94	5.67	4.79	4.81
Magnesium (Mg)	---	<0.001	0.255	0.127	0.149	0.274
Sodium (Na)	---	35.7	273	327	348	250
Potassium (K)	---	14.0	48.4	49.3	45.4	41.1
Strontium (Sr)	---	0.007	0.015	0.018	0.016	0.018
Barium (Ba)	---	0.112	0.149	0.067	0.081	0.066
Lithium (Li)	---	0.517	2.97	5.27	3.73	3.57
Sulfate (SO_4)	---	156	161	99.5	78.5	124
Thiosulfate (S_2O_3)	---	<0.1	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	---	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	---	0.84	1.0	---	0.010	0.004
Alkalinity (HCO_3)	---	---	---	---	---	---
Acidity (free / total), mM	--- / ---	2.18 / 2.80	1.53 / 1.99	0.511 / 0.906	0.259 / 0.628	0.510 / 1.28
Fluoride (F)	---	0.638	2.30	6.59	5.10	4.04
Chloride (Cl)	---	52.0	450	575	505	424
Bromide (Br)	---	0.129	1.50	2.04	1.81	1.66
Nitrate (NO_3)	---	0.006	0.085	0.011	<0.1	0.006
Nitrite (NO_2)	---	0.001	0.001	<0.0004	0.002	0.002
Ammonium (NH_4)	---	<0.05	1.47	1.30	0.67	1.80
Silica (SiO_2)	---	279	310	396	618	389
Boron (B)	---	0.86	6.63	9.16	9.09	6.09
Aluminum (Al)	---	0.908	2.19	1.53	1.87	1.51
Iron total (Fe(T))	0.431	9.70	4.36	1.16	1.96	5.36
Ferrous iron (Fe(II))	0.431	9.74	4.25	1.16	1.89	5.37
Manganese (Mn)	---	0.014	0.069	0.040	0.038	0.069
Copper (Cu)	---	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	---	0.006	0.048	0.013	0.009	0.024
Cadmium (Cd)	---	0.0001	0.0004	0.0002	0.0004	0.0004
Chromium (Cr)	---	<0.0005	<0.0005	<0.0005	0.0015	<0.0005
Cobalt (Co)	---	<0.0007	<0.0007	<0.0007	0.0027	0.0007
Mercury total (Hg(T)), ng/L	---	3.8	42	90	11	15
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---	0.029
Nickel (Ni)	---	0.0024	0.0027	0.0013	0.0020	0.0018
Lead (Pb)	---	<0.0008	0.0018	0.0029	0.0019	0.0031
Beryllium (Be)	---	<0.001	0.003	0.002	0.002	0.003
Vanadium (V)	---	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	---	<0.007	---	0.153	---
Antimony total (Sb(T))	0.0011	0.0014	<0.0005	0.0600	0.141	0.0781
Antimonite (Sb(III))	0.0011	0.0014	<0.0005	0.029	---	0.056
Selenium (Se)	---	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	0.096	1.19	2.07	1.91	2.01	1.70
Arsenite (As(III))	0.096	1.19	1.78	1.46	2.01	1.67
Dissolved organic carbon (DOC)	---	0.9	1.5	---	0.7	1.1
δD, per mil	---	-134.80	-139.70	-136.90	-138.58	-135.50
$\delta^{18}O$, per mil	---	-14.00	-15.00	-13.74	-14.84	-14.44
sum cations, meq/L	---	4.3	15.6	16.9	17.4	13.3
sum anions, meq/L	---	4.5	15.8	18.3	15.9	14.4
Charge imbalance, percent	---	-3.7	-1.0	-8.4	9.1	-8.3

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 7. Results of water analyses for Norris Geyser Basin, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

	Ragged Hills area					
Location	"Titanic Spring"	"Titanic Spring"	"Titanic Spring"	Unnamed pool southwest of "Lifeboat Spring"	Unnamed pool southwest of 04WA125	Unnamed thermal feature near "Orpiment Puddle 3"
Sample ID	03WA117	03WA139	04WA122	04WA125	04WA124	04WA121
Collection Date / Time	5/30/03 15:00	9/1/03 14:00	9/5/04 16:20	9/6/04 11:30	9/6/04 10:50	9/5/04 14:30
Temperature, °C	67.0	66.0	63.4	49.6	92.2	87.0
pH (field / laboratory)	3.28 / 3.21	3.41 / 3.36	3.45 / 3.33	2.72 / 2.66	3.27 / 3.16	3.64 / 3.44
Specific conductance (field / laboratory), µS/cm	2110 / 2300	1865 / 2370	2200 / 2370	2350 / 2600	1120 / 2110	2250 / 2480
Eh, V	0.605	0.562	0.482	0.663	0.149	0.097
Density, g/mL at 20°C	0.9995	0.9995	0.9994	0.9992	0.9991	0.9994
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	5.42	5.43	5.83	4.09	3.38	6.45
Magnesium (Mg)	0.184	0.131	0.151	0.727	0.318	0.100
Sodium (Na)	329	346	335	275	279	406
Potassium (K)	54.3	10.9	47.5	37.2	37.6	37.4
Strontium (Sr)	0.017	0.016	0.018	0.016	0.014	0.024
Barium (Ba)	0.075	0.070	0.070	0.060	0.188	0.202
Lithium (Li)	3.68	3.69	5.15	2.94	3.62	5.50
Sulfate (SO_4)	111	104	109	242	119	69.1
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.003	---	<0.002	<0.002	0.048	0.039
Alkalinity (HCO_3)	---	---	---	---	---	---
Acidity (free / total), mM	0.664 / 1.00	0.507 / 0.900	0.571 / 0.960	2.58 / 3.59	0.795 / 1.45	0.405 / 1.16
Fluoride (F)	5.90	6.10	6.75	3.26	5.29	6.76
Chloride (Cl)	531	527	588	423	492	672
Bromide (Br)	1.85	1.85	2.11	1.74	1.90	2.46
Nitrate (NO_3)	<0.1	<0.1	0.009	0.011	0.008	0.017
Nitrite (NO_2)	0.003	0.008	0.002	0.001	0.001	0.001
Ammonium (NH_4)	1.16	0.84	0.90	1.90	2.40	1.80
Silica (SiO_2)	492	468	467	330	314	260
Boron (B)	8.24	9.46	8.85	6.29	7.59	9.80
Aluminum (Al)	1.41	1.63	1.61	5.73	2.47	3.07
Iron total (Fe(T))	1.72	1.16	1.34	5.74	7.30	1.07
Ferrous iron (Fe(II))	1.30	0.897	1.08	1.17	7.34	0.860
Manganese (Mn)	0.044	0.032	0.045	0.139	0.082	0.033
Copper (Cu)	<0.0005	<0.0005	<0.0005	0.0020	<0.0005	<0.0005
Zinc (Zn)	0.017	0.009	0.016	0.057	0.033	0.002
Cadmium (Cd)	0.0005	0.0005	0.0003	0.0004	0.0004	0.0004
Chromium (Cr)	0.0019	0.0012	<0.0005	0.0006	<0.0005	<0.0005
Cobalt (Co)	<0.0007	<0.0007	0.0009	0.0012	0.0008	<0.0007
Mercury total (Hg(T)), ng/L	28	22	21	84	140	119
Methylmercury (CH_3Hg), ng/L	0.037	---	---	0.013	---	---
Nickel (Ni)	0.0040	0.0040	0.0012	0.0031	0.0025	0.0011
Lead (Pb)	0.0028	0.0025	0.0029	0.0025	0.0037	0.0036
Beryllium (Be)	0.002	0.002	0.002	0.004	0.002	0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.126	0.160	---	---	---	---
Antimony total (Sb(T))	---	0.145	0.0359	0.0126	0.126	0.0802
Antimonite (Sb(III))	---	---	0.002	0.002	0.085	0.030
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.52	1.50	1.69	0.433	2.11	3.27
Arsenite (As(III))	0.154	0.208	0.270	0.020	1.64	3.20
Dissolved organic carbon (DOC)	---	0.5	---	0.7	0.8	0.4
δD, per mil	-135.73	-135.42	-134.50	-126.10	-136.60	-136.60
$\delta^{18}O$, per mil	-13.47	-13.25	-13.21	-10.87	-13.70	-13.76
sum cations, meq/L	17.2	16.7	17.3	16.3	14.8	20.2
sum anions, meq/L	17.3	17.0	18.9	16.3	16.2	20.4
Charge imbalance, percent	-0.3	-2.3	-8.8	-0.1	-8.9	-1.0

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 8. Results of water analyses for West Nymph Creek thermal area, 2003—2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Blue-green 15 by 25 m hot spring	Yellow-green surging hot spring downslope of 04WA105	Turbid 10 by 75 m spring containing yellow spherules	Turbid 15-m-diameter hot spring adjacent to stream channel	Steep-sided gently surging blue-green hot spring
Sample ID	04WA105	04WA106	04WA107	04WA108	04WA109
Collection Date / Time	9/2/04 14:45	9/2/04 16:00	9/2/04 16:50	9/2/04 18:00	9/3/04 12:15
Temperature, °C	47.9[2]	36.9	78.5	66.2[2]	65.7
pH (field / laboratory)	5.68 / 4.42	4.63 / 5.39	2.52 / 2.42	2.25 / 2.17	6.52 / 8.26
Specific conductance (field / laboratory), µS/cm	375 / 363	297 / 292	1225 / 2230	2350 / 393	1265 / 1249
Eh, V	0.014	0.107	0.114	0.413	-0.026
Density, g/mL at 20°C	0.9985	0.9985	0.9989	0.9995	0.9993
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	5.49	6.51	10.7	2.90	6.43
Magnesium (Mg)	0.374	0.826	3.10	0.750	0.102
Sodium (Na)	59.6	36.7	33.9	18.5	242
Potassium (K)	4.09	4.51	22.4	26.1	10.4
Strontium (Sr)	0.011	0.014	0.028	0.011	0.017
Barium (Ba)	0.013	0.016	0.089	0.007	0.017
Lithium (Li)	0.283	0.161	0.056	0.029	0.501
Sulfate (SO_4)	43.4	93.6	450	1010	70.3
Thiosulfate (S_2O_3)	26.7	1.0	0.8	1.5	24.5
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.13	0.37	0.52	0.007	0.16
Alkalinity (HCO_3)	85.6	5.76	---	---	116
Acidity (free / total), mM	--- / ---	--- / ---	4.77 / 6.89	9.46 / 19.0	--- / ---
Fluoride (F)	7.54	5.18	0.795	0.248	12.1
Chloride (Cl)	8.39	5.10	2.22	2.69	249
Bromide (Br)	<0.03	<0.03	<0.03	<0.03	0.710
Nitrate (NO_3)	0.007	0.009	0.018	0.009	0.078
Nitrite (NO_2)	0.003	0.001	<0.0004	<0.0004	0.006
Ammonium (NH_4)	0.30	1.00	14.2	28.7	1.50
Silica (SiO_2)	101	87.9	278	366	276
Boron (B)	0.24	0.18	0.53	1.04	3.53
Aluminum (Al)	0.240	0.951	4.61	60.3	0.126
Iron total (Fe(T))	0.013	0.168	1.34	10.8	0.006
Ferrous iron (Fe(II))	0.011	0.166	1.35	10.7	0.006
Manganese (Mn)	0.134	0.124	0.621	0.276	0.094
Copper (Cu)	<0.0005	<0.0005	<0.0005	0.0018	<0.0005
Zinc (Zn)	<0.0005	0.004	0.049	0.096	<0.0005
Cadmium (Cd)	<0.0001	<0.0001	0.0002	0.0004	0.0002
Chromium (Cr)	<0.0005	<0.0005	<0.0005	0.0039	<0.0005
Cobalt (Co)	<0.0007	0.0009	0.0018	0.0016	0.0011
Mercury total (Hg(T)), ng/L	120	89	650	1900	430
Methylmercury (CH_3Hg), ng/L	0.019	---	0.100	0.013	0.021
Nickel (Ni)	<0.0005	<0.0005	<0.0005	0.0019	<0.0005
Lead (Pb)	<0.0008	<0.0008	0.0010	0.0058	0.0018
Beryllium (Be)	0.001	0.001	0.004	0.004	0.004
Vanadium (V)	<0.005	<0.005	<0.005	0.012	<0.005
Molybdenum (Mo)	---	---	---	---	---
Antimony total (Sb(T))	<0.0005	<0.0005	<0.0005	<0.0005	0.0043
Antimonite (Sb(III))	---	---	<0.0005	<0.0005	0.004
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	0.002	0.001	0.002	0.010	0.627
Arsenite (As(III))	0.001	0.001	0.002	0.009	0.627
Dissolved organic carbon (DOC)	1.3	3.5	2.9	21	1.0
δD, per mil	-138.80	-134.40	-110.10	-105.60	-129.60
$\delta^{18}O$, per mil	-17.09	-16.04	-6.85	-5.07	-11.05
sum cations, meq/L	3.0	2.2	7.0	12.8	11.2
sum anions, meq/L	2.9	2.3	7.2	12.9	11.0
Charge imbalance, percent	5.2	-5.6	-2.8	-1.5	2.3

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 8. Results of water analyses for West Nymph Creek thermal area, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Quiescent hot spring with reddish algal mat	Quiescent hot spring with reddish algal mat, edge of pool	Quiescent hot spring at pool exit	Quiescent hot spring 13.7 m from pool exit	Surface-water drainage, south end of area
Sample ID	04WA110	04WA110B	04WA110C	04WA110D	04WA111
Collection Date / Time	9/3/04 13:30	9/3/2004	9/3/2004	9/3/2004	9/3/04 14:50
Temperature, °C	54.6	---	---	---	42.1
pH (field / laboratory)	7.40 / 8.13	--- / ---	--- / ---	--- / ---	6.06 / 6.46
Specific conductance (field / laboratory), µS/cm	1725 / 1793	--- / ---	--- / ---	--- / ---	531 / 534
Eh, V	0.196	---	---	---	0.243
Density, g/mL at 20°C	0.9991	---	---	---	0.9986
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	9.97	---	---	---	5.63
Magnesium (Mg)	0.087	---	---	---	0.784
Sodium (Na)	344	---	---	---	94.2
Potassium (K)	7.76	---	---	---	4.95
Strontium (Sr)	0.017	---	---	---	0.011
Barium (Ba)	0.012	---	---	---	0.006
Lithium (Li)	0.430	---	---	---	0.210
Sulfate (SO_4)	42.8	---	---	---	105
Thiosulfate (S_2O_3)	1.2	---	---	---	0.5
Polythionate (S_nO_6), mg/L / n	<0.5	---	---	---	<0.5
Hydrogen sulfide (H_2S)	0.004	---	---	---	0.004
Alkalinity (HCO_3)	97.2	---	---	---	12.6
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	22.4	---	---	---	7.04
Chloride (Cl)	434	---	---	---	69.3
Bromide (Br)	1.16	---	---	---	0.146
Nitrate (NO_3)	0.008	---	---	---	0.506
Nitrite (NO_2)	0.007	---	---	---	0.032
Ammonium (NH_4)	0.20	---	---	---	0.20
Silica (SiO_2)	251	---	---	---	100
Boron (B)	6.12	---	---	---	1.13
Aluminum (Al)	0.133	---	---	---	1.01
Iron total (Fe(T))	0.003	<0.002	<0.002	<0.002	0.074
Ferrous iron (Fe(II))	<0.002	---	---	---	0.057
Manganese (Mn)	0.068	---	---	---	0.043
Copper (Cu)	<0.0005	---	---	---	<0.0005
Zinc (Zn)	0.001	---	---	---	0.002
Cadmium (Cd)	0.0001	---	---	---	<0.0001
Chromium (Cr)	<0.0005	---	---	---	<0.0005
Cobalt (Co)	<0.0007	---	---	---	<0.0007
Mercury total (Hg(T)), ng/L	15	---	---	---	30
Methylmercury (CH_3Hg), ng/L	0.045	---	---	---	0.354
Nickel (Ni)	<0.0005	---	---	---	<0.0005
Lead (Pb)	0.0024	---	---	---	0.0008
Beryllium (Be)	0.003	---	---	---	0.001
Vanadium (V)	<0.005	---	---	---	<0.005
Molybdenum (Mo)	---	---	---	---	---
Antimony total (Sb(T))	0.0354	0.0348	0.0328	0.0348	0.0072
Antimonite (Sb(III))	0.003	0.002	0.003	0.0010	<0.0005
Selenium (Se)	<0.001	---	---	---	<0.001
Arsenic total (As(T))	1.50	1.49	1.50	1.56	0.232
Arsenite (As(III))	1.06	1.03	0.980	0.340	0.046
Dissolved organic carbon (DOC)	1.0	---	---	---	1.7
δD, per mil	-139.20	---	---	---	-135.90
$\delta^{18}O$, per mil	-14.61	---	---	---	-15.97
sum cations, meq/L	15.7	---	---	---	4.6
sum anions, meq/L	15.9	---	---	---	4.6
Charge imbalance, percent	-1.2	---	---	---	-0.1

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 8. Results of water analyses for West Nymph Creek thermal area, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Pale blue-green violently surging hot spring	Vigorous spouter on steep slope adjacent to loud fumarole	Brown turbid 5 by 8 m sunken pool
Sample ID	04WA112	04WA113	04WA114
Collection Date / Time	9/3/04 15:40	9/3/04 16:50	9/3/04 18:00
Temperature, °C	85.5	70.6[2]	81.3
pH (field / laboratory)	7.08 / 8.16	6.67 / 7.66	2.40 / 2.32
Specific conductance (field / laboratory), µS/cm	1810 / 1904	995 / 1006	1480 / 2860
Eh, V	-0.097	-0.076	0.132
Density, g/mL at 20°C	0.9992	0.9990	0.9991
Dissolved oxygen (DO), mg/L	---	---	---
Constituent, mg/L[1]			
Calcium (Ca)	5.10	3.40	4.90
Magnesium (Mg)	<0.001	0.097	1.09
Sodium (Na)	362	175	42.0
Potassium (K)	5.19	11.1	24.2
Strontium (Sr)	0.009	0.006	0.005
Barium (Ba)	0.003	0.002	<0.0008
Lithium (Li)	0.480	0.486	0.052
Sulfate (SO_4)	56.5	339	625
Thiosulfate (S_2O_3)	1.7	12.8	0.5
Polythionate (S_nO_6), mg/L / n	2.0 / 4	8.9 / 4	<0.5
Hydrogen sulfide (H_2S)	0.060	0.041	0.13
Alkalinity (HCO_3)	111	45.6	---
Acidity (free / total), mM	--- / ---	--- / ---	6.48 / 9.51
Fluoride (F)	28.1	10.4	1.25
Chloride (Cl)	456	16.4	3.08
Bromide (Br)	1.68	<0.03	<0.03
Nitrate (NO_3)	0.015	0.022	0.037
Nitrite (NO_2)	0.033	0.006	<0.0004
Ammonium (NH_4)	0.30	1.40	14.3
Silica (SiO_2)	293	176	352
Boron (B)	6.77	1.91	0.45
Aluminum (Al)	0.174	2.29	14.5
Iron total (Fe(T))	<0.002	0.019	6.59
Ferrous iron (Fe(II))	<0.002	0.019	6.62
Manganese (Mn)	0.039	0.219	0.248
Copper (Cu)	<0.0005	<0.0005	<0.0005
Zinc (Zn)	0.020	0.014	0.043
Cadmium (Cd)	0.0004	0.0002	0.0002
Chromium (Cr)	<0.0005	<0.0005	<0.0005
Cobalt (Co)	0.0010	<0.0007	0.0016
Mercury total (Hg(T)), ng/L	14	49	63
Methylmercury (CH_3Hg), ng/L	0.112	---	---
Nickel (Ni)	<0.0005	<0.0005	0.0019
Lead (Pb)	0.0034	0.0014	<0.0008
Beryllium (Be)	<0.001	0.004	0.006
Vanadium (V)	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	---	---
Antimony total (Sb(T))	0.0590	<0.0005	<0.0005
Antimonite (Sb(III))	0.002	<0.0005	<0.0005
Selenium (Se)	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.85	0.001	0.004
Arsenite (As(III))	1.38	<0.001	0.003
Dissolved organic carbon (DOC)	0.8	1.5	2.8
δD, per mil	-139.20	-119.60	-112.70
$\delta^{18}O$, per mil	-14.68	-13.16	-8.00
sum cations, meq/L	16.2	8.1	8.8
sum anions, meq/L	17.3	8.6	9.2
Charge imbalance, percent	-6.9	-6.6	-4.7

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 9. Results of water analyses for Nymph Lake area, 2003—2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Frying Pan Spring near pool entrance, South side of highway	Frying Pan Spring near pool exit, South side of highway	Hazle Lake, South side	Hazle Lake, North side	Nymph Creek Springs, new vent
Sample ID	05WA136	05WA135	03WA136	03WA137	04WA134
Collection Date / Time	6/8/05 10:15	6/8/05 9:35	6/7/03 11:15	6/7/03 12:20	9/7/04 15:30
Temperature, °C	---	60.7	16.3	29.9	60.6
pH (field / laboratory)	--- / ---	2.42 / 2.38	3.13 / 3.21	5.32 / 7.32	2.86 / 2.80
Specific conductance (field / laboratory), µS/cm	--- / ---	1480 / 2130	905 / 894	560 / 549	995 / 1363
Eh, V	---	0.228	0.312	0.066	0.132
Density, g/mL at 20°C	---	0.9988	0.9989	0.9987	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	---	2.51	9.34	7.95	6.50
Magnesium (Mg)	---	0.539	1.51	1.38	2.20
Sodium (Na)	---	44.4	84.9	76.2	67.1
Potassium (K)	---	10.4	21.7	24.8	38.1
Strontium (Sr)	---	0.018	0.099	0.065	0.016
Barium (Ba)	---	0.054	0.046	0.057	0.030
Lithium (Li)	---	0.323	0.577	0.487	0.140
Sulfate (SO_4)	---	422	191	129	276
Thiosulfate (S_2O_3)	---	<0.1	---	---	<0.1
Polythionate (S_nO_6), mg/L / n	---	<0.5	---	---	<0.5
Hydrogen sulfide (H_2S)	---	<0.002	0.59	0.30	0.22
Alkalinity (HCO_3)	---	---	---	34.4	---
Acidity (free / total), mM	--- / ---	5.34 / 7.35	--- / ---	--- / ---	2.11 / 2.54
Fluoride (F)	---	1.90	1.00	1.00	1.03
Chloride (Cl)	---	7.90	88.0	49.0	53.0
Bromide (Br)	---	0.100	0.375	0.254	0.183
Nitrate (NO_3)	---	0.020	<0.1	<0.1	0.165
Nitrite (NO_2)	---	0.001	0.001	0.007	---
Ammonium (NH_4)	---	0.81	1.25	1.93	1.60
Silica (SiO_2)	---	178	111	144	223
Boron (B)	---	0.44	1.71	1.02	0.77
Aluminum (Al)	---	12.3	7.89	0.589	2.22
Iron total (Fe(T))	---	1.12	6.35	2.99	3.27
Ferrous iron (Fe(II))	---	1.02	6.34	2.97	3.28
Manganese (Mn)	---	0.035	0.153	0.130	0.114
Copper (Cu)	---	0.0005	0.0008	<0.0005	<0.0005
Zinc (Zn)	---	0.007	0.011	<0.004	0.023
Cadmium (Cd)	---	0.0001	0.0002	0.0002	0.0002
Chromium (Cr)	---	0.0015	0.0039	0.0028	<0.0005
Cobalt (Co)	---	<0.0007	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	64	57	35	23	17
Methylmercury (CH_3Hg), ng/L	---	---	1.45	0.752	---
Nickel (Ni)	---	0.0014	0.0040	<0.002	0.0022
Lead (Pb)	---	<0.0008	0.0010	<0.0008	<0.0008
Beryllium (Be)	---	<0.001	0.002	0.001	0.003
Vanadium (V)	---	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	<0.007	<0.007	<0.007	---
Antimony total (Sb(T))	---	0.0127	0.0040	0.0020	0.0021
Antimonite (Sb(III))	---	0.009	---	---	0.002
Selenium (Se)	---	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	---	0.150	0.125	0.026	0.145
Arsenite (As(III))	---	0.142	0.082	0.026	0.129
Dissolved organic carbon (DOC)	---	2.3	2.4	2.6	0.7
δD, per mil	---	-126.20	-117.18	-129.44	-141.50
$\delta^{18}O$, per mil	---	-13.04	-13.13	-15.60	-17.76
sum cations, meq/L	---	7.3	6.4	4.7	6.1
sum anions, meq/L	---	6.9	6.0	4.5	6.5
Charge imbalance, percent	---	6.2	7.6	2.9	-6.6

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

Table 9. Results of water analyses for Nymph Lake area, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Nymphy Creek upstream from Nymph Lake	Flood Creek (Nymph Lake discharge channel)	Unnamed pool 50 m from road near Hazle Lake	Unnamed pool 50 m from road near Hazle Lake - side of pool
Sample ID	04WA132	04WA133	04WA131	04WA131B
Collection Date / Time	9/7/04 12:30	9/7/04 14:05	9/7/04 11:05	9/7/04 11:05
Temperature, °C	18.1	14.8	65.7	---
pH (field / laboratory)	6.87 / 8.43	6.31 / 7.83	5.79 / 8.12	--- / ---
Specific conductance (field / laboratory), µS/cm	732 / 717	776 / 763	926 / 945	--- / ---
Eh, V	0.261	0.266	0.157	---
Density, g/mL at 20°C	0.9987	0.9987	0.9987	---
Dissolved oxygen (DO), mg/L	7.7	6.5	---	---
Constituent, mg/L[1]				
Calcium (Ca)	11.3	10.9	3.64	---
Magnesium (Mg)	1.53	1.69	<0.001	---
Sodium (Na)	130	130	176	---
Potassium (K)	13.0	16.2	11.6	---
Strontium (Sr)	0.029	0.033	0.023	---
Barium (Ba)	0.011	0.021	0.005	---
Lithium (Li)	0.602	0.556	0.448	---
Sulfate (SO_4)	73.8	141	110	---
Thiosulfate (S_2O_3)	<0.1	<0.1	0.8	---
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	---
Hydrogen sulfide (H_2S)	---	0.006	0.003	0.027
Alkalinity (HCO_3)	174	49.5	47.7	---
Acidity (free / total), mM	--- / ---	0.621 / 0.707	--- / ---	--- / ---
Fluoride (F)	5.70	5.05	6.80	---
Chloride (Cl)	81.0	94.0	184	---
Bromide (Br)	0.286	0.296	0.604	---
Nitrate (NO_3)	0.001	0.117	0.007	---
Nitrite (NO_2)	0.052	0.006	0.003	---
Ammonium (NH_4)	<0.05	0.60	0.50	---
Silica (SiO_2)	104	122	213	---
Boron (B)	1.27	1.33	3.32	---
Aluminum (Al)	0.260	0.678	0.043	---
Iron total (Fe(T))	0.033	0.059	0.020	0.020
Ferrous iron (Fe(II))	0.032	0.059	0.020	0.019
Manganese (Mn)	0.004	0.110	0.010	---
Copper (Cu)	<0.0005	<0.0005	<0.0005	---
Zinc (Zn)	0.004	0.009	0.001	---
Cadmium (Cd)	0.0002	0.0002	0.0003	---
Chromium (Cr)	<0.0005	<0.0005	<0.0005	---
Cobalt (Co)	<0.0007	<0.0007	0.0007	---
Mercury total (Hg(T)), ng/L	22	45	29	---
Methylmercury (CH_3Hg), ng/L	0.114	0.016	0.282	---
Nickel (Ni)	0.0008	0.0007	0.0011	---
Lead (Pb)	<0.0008	0.0008	0.0012	---
Beryllium (Be)	<0.001	0.002	<0.001	---
Vanadium (V)	<0.005	<0.005	<0.005	---
Molybdenum (Mo)	---	---	---	---
Antimony total (Sb(T))	0.0056	0.0066	0.0294	0.0261
Antimonite (Sb(III))	0.002	0.0011	0.009	0.009
Selenium (Se)	<0.001	<0.001	0.001	---
Arsenic total (As(T))	0.232	0.122	0.863	0.831
Arsenite (As(III))	0.002	0.009	0.863	0.831
Dissolved organic carbon (DOC)	4.2	4.7	0.7	---
δD, per mil	-132.10	-125.40	-138.80	---
$\delta^{18}O$, per mil	-15.92	-14.20	-14.95	---
sum cations, meq/L	6.7	6.8	8.2	---
sum anions, meq/L	6.9	6.5	8.6	---
Charge imbalance, percent	-2.8	4.2	-4.7	---

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

Table 10. Results of water analyses for Lower Geyser Basin, 2003—2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Azure Spring	Mound Geyser, on bluff West of Firehole River	Mound Spring	Mound Spring overflow channel 0.9 m downstream	Mound Spring overflow channel 6.4 m downstream	Mound Spring overflow channel 12.5 m downstream
Sample ID	04WA139	04WA141	03WA133	03WA133-T1	03WA133-T2	03WA133-T3
Collection Date / Time	9/9/04 15:05	9/9/04 16:45	6/6/03 11:00	6/6/2003	6/6/2003	6/6/2003
Temperature, °C	75.5	93.5	94.7	90.0	84.0	75.9
pH (field / laboratory)	8.89 / 9.20	8.50 / 8.84	8.94 / 8.65	8.87 / ---	8.91 / ---	8.96 / ---
Specific conductance (field / laboratory), µS/cm	1496 / 1526	1430 / 1525	1350 / 1421	1350 / ---	1391 / ---	1415 / ---
Eh, V	-0.090	-0.178	-0.168	-0.193	-0.151	-0.128
Density, g/mL at 20°C	0.9990	0.9991	0.9993	---	---	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	0.980	0.772	0.046	<0.04	0.063	<0.04
Magnesium (Mg)	<0.001	<0.001	0.045	<0.001	0.009	<0.001
Sodium (Na)	295	319	289	303	305	316
Potassium (K)	10.8	10.0	9.83	9.72	9.96	9.80
Strontium (Sr)	0.008	0.010	<0.0007	<0.0007	<0.0007	<0.0007
Barium (Ba)	<0.0008	<0.0008	<0.0008	0.002	0.002	0.0009
Lithium (Li)	2.50	1.71	1.62	1.59	1.60	1.58
Sulfate (SO_4)	38.7	23.8	16.3	15.3	15.3	15.7
Thiosulfate (S_2O_3)	5.0	0.5	0.3	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.055	0.50	0.50	0.37	0.33	0.23
Alkalinity (HCO_3)	192	221	295	301	307	310
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	33.9	31.1	36.4	25.9	26.0	26.7
Chloride (Cl)	301	305	254	259	266	266
Bromide (Br)	1.02	1.03	0.837	0.864	0.861	0.877
Nitrate (NO_3)	0.037	0.061	0.270	<0.1	<0.1	<0.1
Nitrite (NO_2)	0.106	0.040	0.239	0.001	0.002	0.001
Ammonium (NH_4)	<0.05	0.20	0.63	0.42	0.36	0.40
Silica (SiO_2)	239	253	354	290	276	304
Boron (B)	4.06	3.90	3.34	3.39	3.48	3.48
Aluminum (Al)	0.215	0.264	0.440	0.334	0.367	0.340
Iron total (Fe(T))	0.006	0.003	0.006	<0.002	0.006	0.006
Ferrous iron (Fe(II))	0.006	0.003	0.004	<0.002	0.005	0.005
Manganese (Mn)	<0.001	<0.001	0.004	<0.001	0.002	<0.001
Copper (Cu)	<0.0005	<0.0005	0.0020	<0.003	<0.003	<0.003
Zinc (Zn)	0.003	0.002	<0.004	<0.004	<0.004	<0.004
Cadmium (Cd)	0.0003	0.0003	0.0002	<0.001	<0.001	<0.001
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.002	<0.002	<0.002
Cobalt (Co)	<0.0007	<0.0007	0.0007	<0.004	<0.004	<0.004
Mercury total (Hg(T)), ng/L	51	58	230	---	---	---
Methylmercury (CH_3Hg), ng/L	0.017	0.003	---	---	---	---
Nickel (Ni)	<0.0005	0.0047	0.0030	0.0030	0.0030	0.0020
Lead (Pb)	0.0018	0.0018	0.0019	<0.008	<0.008	<0.008
Beryllium (Be)	<0.001	0.001	<0.001	0.001	0.002	0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	---	0.025	0.014	0.016	0.019
Antimony total (Sb(T))	0.0790	0.0122	0.0470	---	---	---
Antimonite (Sb(III))	0.006	0.008	---	---	---	---
Selenium (Se)	<0.001	<0.001	<0.001	<0.04	<0.04	<0.04
Arsenic total (As(T))	1.41	1.25	0.924	1.10	1.06	1.08
Arsenite (As(III))	1.41	1.22	0.924	0.937	1.06	1.08
Dissolved organic carbon (DOC)	---	0.6	0.4	---	---	---
δD, per mil	-140.70	-140.70	-144.37	---	---	---
$\delta^{18}O$, per mil	-15.91	-16.38	-17.31	---	---	---
sum cations, meq/L	13.4	14.3	12.9	13.4	13.4	14.0
sum anions, meq/L	14.1	14.3	14.1	13.7	14.0	14.1
Charge imbalance, percent	-5.4	0.1	-9.2	-2.3	-3.7	-0.9

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 10. Results of water analyses for Lower Geyser Basin, 2003—2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Mound Spring overflow channel 17.1 m downstream	Mound Spring overflow channel 21.3 m downstream	Mound Spring overflow channel 26.2 m downstream	Mound Spring overflow channel 28.7 m downstream	Mound Spring	Mound Spring
Sample ID	03WA133-T4	03WA133-T5	03WA133-T6	03WA133-T7	04WA137	05WA111
Collection Date / Time	6/6/2003	6/6/2003	6/6/2003	6/6/2003	9/9/04 12:30	6/4/05 11:10
Temperature, °C	67.6	62.0	57.6	54.0	94.5	94.0
pH (field / laboratory)	9.05 / ---	9.09 / ---	9.14 / ---	9.19 / ---	8.99 / 9.49	8.98 / 9.68
Specific conductance (field / laboratory), µS/cm	1431 / ---	1447 / ---	1481 / ---	1481 / ---	1314 / 1392	1330 / 1400
Eh, V	-0.102	-0.070	-0.043	-0.024	-0.214	-0.066
Density, g/mL at 20°C	---	---	---	---	0.9991	0.9991
Dissolved oxygen (DO), mg/L	---	---	---	---	---	<0.1
Constituent, mg/L[1]						
Calcium (Ca)	<0.04	<0.04	<0.04	<0.04	<0.04	0.328
Magnesium (Mg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium (Na)	319	324	327	322	292	280
Potassium (K)	10.0	10.2	10.1	10.5	8.84	9.83
Strontium (Sr)	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	0.0008
Barium (Ba)	<0.0008	0.0009	<0.0008	<0.0008	<0.0008	<0.0008
Lithium (Li)	1.61	1.62	1.68	1.70	1.43	1.66
Sulfate (SO_4)	16.2	16.3	16.5	16.6	15.7	13.4
Thiosulfate (S_2O_3)	0.1	0.2	0.2	0.2	0.4	0.3
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.19	0.14	0.11	0.081	0.40	0.80
Alkalinity (HCO_3)	313	315	319	318	294	294
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	28.0	28.2	28.7	28.6	32.0	28.3
Chloride (Cl)	262	256	266	263	247	241
Bromide (Br)	0.893	0.875	0.910	0.905	0.786	0.800
Nitrate (NO_3)	<0.1	<0.1	<0.1	<0.1	0.095	0.341
Nitrite (NO_2)	0.001	0.001	0.001	0.001	0.211	0.195
Ammonium (NH_4)	0.58	0.36	0.35	0.47	0.20	<0.05
Silica (SiO_2)	249	244	294	308	322	331
Boron (B)	3.58	3.59	3.57	3.64	3.37	3.14
Aluminum (Al)	0.344	0.343	0.345	0.344	0.351	0.376
Iron total (Fe(T))	0.004	0.004	0.004	0.005	0.006	<0.002
Ferrous iron (Fe(II))	0.004	0.003	0.003	0.003	0.006	<0.002
Manganese (Mn)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	<0.003	<0.003	<0.003	<0.003	<0.0005	<0.0005
Zinc (Zn)	<0.004	0.009	<0.004	<0.004	0.005	<0.0005
Cadmium (Cd)	<0.001	<0.001	<0.001	<0.001	0.0004	0.0001
Chromium (Cr)	<0.002	<0.002	<0.002	<0.002	<0.0005	<0.0005
Cobalt (Co)	<0.004	<0.004	<0.004	<0.004	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	---	---	---	---	57	35
Methylmercury (CH_3Hg), ng/L	---	---	---	---	0.001	---
Nickel (Ni)	0.0030	0.0030	0.0020	0.0020	0.0009	<0.0005
Lead (Pb)	<0.008	<0.008	<0.008	<0.008	0.0017	<0.0008
Beryllium (Be)	0.001	0.001	0.001	0.001	0.001	0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.025	0.028	0.029	0.028	---	0.030
Antimony total (Sb(T))	---	---	---	---	0.0159	0.0097
Antimonite (Sb(III))	---	---	---	---	0.016	0.003
Selenium (Se)	<0.04	<0.04	<0.04	<0.04	<0.001	<0.001
Arsenic total (As(T))	1.14	1.14	1.16	1.16	1.02	0.793
Arsenite (As(III))	1.14	1.14	1.16	1.16	0.910	0.786
Dissolved organic carbon (DOC)	---	---	---	---	---	7.0
δD, per mil	---	---	---	---	-143.70	-144.90
$\delta^{18}O$, per mil	---	---	---	---	-17.26	-17.33
sum cations, meq/L	14.1	14.3	14.5	14.3	12.9	12.5
sum anions, meq/L	14.1	14.0	14.4	14.3	13.6	13.2
Charge imbalance, percent	0.0	2.5	0.8	0.1	-5.4	-5.9

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 10. Results of water analyses for Lower Geyser Basin, 2003—2005--Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Mound Spring overflow channel 0.6 m downstream	Mound Spring overflow channel 5.8 m downstream	Mound Spring overflow channel 12.2 m downstream	Mound Spring overflow channel 20.7 m downstream	Mound Spring overflow channel 26.8 m downstream	Mound Spring overflow channel 55 m downstream
Sample ID	05WA112	05WA113	05WA114	05WA115	05WA116	05WA117
Collection Date / Time	6/4/05 12:00	6/4/05 12:15	6/4/05 12:45	6/4/05 13:35	6/4/05 13:55	6/4/05 14:15
Temperature, °C	93.2	87.0	79.0	70.3	63.3	24.5
pH (field / laboratory)	9.01 / 9.68	9.06 / 9.68	9.06 / 9.70	9.08 / 9.69	9.17 / 9.71	9.50 / 9.80
Specific conductance (field / laboratory), µS/cm	1332 / 1400	1370 / 1410	1410 / 1430	1420 / 1445	1445 / 1465	1585 / 1560
Eh, V	-0.049	0.014	0.046	0.066	0.113	0.235
Density, g/mL at 20°C	0.9992	0.9992	0.9992	0.9992	0.9992	0.9992
Dissolved oxygen (DO), mg/L	<0.1	<0.1	0.7	1.5	2.8	5.9
Constituent, mg/L[1]						
Calcium (Ca)	0.330	0.331	0.328	0.336	0.356	0.306
Magnesium (Mg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium (Na)	294	310	286	306	308	323
Potassium (K)	10.1	10.1	10.5	10.3	10.2	10.9
Strontium (Sr)	0.0007	<0.0007	<0.0007	<0.0007	<0.0007	0.0007
Barium (Ba)	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008
Lithium (Li)	1.66	1.67	1.74	1.74	1.81	1.89
Sulfate (SO_4)	13.2	14.1	13.3	13.5	16.4	18.5
Thiosulfate (S_2O_3)	0.4	0.4	0.4	0.5	0.6	0.3
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.79	0.72	0.45	0.20	0.12	0.005
Alkalinity (HCO_3)	296	300	304	307	312	326
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	28.5	29.0	29.5	29.7	30.0	32.0
Chloride (Cl)	243	246	248	252	256	274
Bromide (Br)	0.900	0.900	0.900	0.900	0.900	1.10
Nitrate (NO_3)	0.050	0.046	0.056	0.008	0.011	0.070
Nitrite (NO_2)	0.083	0.045	0.110	0.053	0.015	0.006
Ammonium (NH_4)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (SiO_2)	368	354	341	356	352	325
Boron (B)	3.22	3.35	3.22	3.36	3.42	3.51
Aluminum (Al)	0.385	0.368	0.368	0.375	0.404	0.331
Iron total (Fe(T))	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Ferrous iron (Fe(II))	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Manganese (Mn)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	0.005	<0.0005	0.001	<0.0005	0.002	0.001
Cadmium (Cd)	0.0001	0.0001	0.0002	<0.0001	0.0001	0.0001
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt (Co)	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	31	29	26	28	28	20
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---	---
Nickel (Ni)	<0.0005	<0.0005	<0.0005	<0.0005	0.0007	0.0006
Lead (Pb)	0.0014	<0.0008	<0.0008	<0.0008	<0.0008	0.0010
Beryllium (Be)	0.001	0.001	0.001	0.001	0.001	<0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.029	0.028	0.028	0.028	0.030	0.032
Antimony total (Sb(T))	0.0073	0.0097	0.0213	0.0258	0.0366	0.0418
Antimonite (Sb(III))	0.002	0.003	0.006	0.009	0.011	0.004
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	0.768	0.823	0.992	1.04	1.10	1.16
Arsenite (As(III))	0.706	0.803	0.906	0.959	1.07	0.213
Dissolved organic carbon (DOC)	0.9	3.6	5.8	0.5	1.8	1.4
δD, per mil	-144.50	-144.70	-143.00	-143.30	-142.90	-138.50
$\delta^{18}O$, per mil	-17.34	-17.18	-16.89	-16.81	-16.57	-15.33
sum cations, meq/L	13.1	13.8	12.8	13.7	13.8	14.5
sum anions, meq/L	13.3	13.5	13.7	13.8	14.1	15.1
Charge imbalance, percent	-1.7	2.0	-6.6	-1.3	-2.5	-3.8

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 10. Results of water analyses for Lower Geyser Basin, 2003—2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Ojo Caliente Spring	Ojo Caliente Spring	Ojo Caliente Spring at pool exit, 12.2 m from source	Ojo Caliente Spring overflow channel 16.5 m from source	Ojo Caliente Spring overflow channel 19.5 m from source	Ojo Caliente Spring overflow channel 23.3 m from source
Sample ID	04WA138	05WA101	05WA102	05WA103	05WA104	05WA105
Collection Date / Time	9/9/04 14:00	6/3/05 11:30	6/3/05 13:20	6/3/05 13:40	6/3/05 13:50	6/3/05 14:10
Temperature, °C	93.5	94.1	91.5	88.3	86.5	83.8
pH (field / laboratory)	7.53 / 8.57	7.63 / 7.82	7.60 / 7.94	7.73 / 8.10	7.74 / 8.11	7.80 / 8.21
Specific conductance (field / laboratory), µS/cm	1475 / 1515	1470 / 1560	1485 / 1580	1500 / 1585	1505 / 1580	1515 / 1590
Eh, V	-0.150	-0.027	-0.036	-0.039	-0.030	-0.017
Density, g/mL at 20°C	0.9990	0.9992	0.9992	0.9992	0.9992	0.9993
Dissolved oxygen (DO), mg/L	---	<0.1	<0.1	<0.1	<0.1	<0.1
Constituent, mg/L[1]						
Calcium (Ca)	0.704	0.876	0.871	0.848	0.830	0.883
Magnesium (Mg)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium (Na)	301	310	327	349	335	340
Potassium (K)	7.86	9.11	8.75	9.03	9.04	9.27
Strontium (Sr)	0.006	0.006	0.006	0.006	0.006	0.006
Barium (Ba)	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008
Lithium (Li)	3.55	4.03	3.71	4.07	4.13	4.12
Sulfate (SO_4)	22.0	23.0	22.6	22.5	23.6	22.6
Thiosulfate (S_2O_3)	0.3	0.4	0.4	0.4	0.4	0.4
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.38	0.96	0.50	0.42	0.32	0.31
Alkalinity (HCO_3)	217	235	235	238	237	239
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	35.1	31.1	31.0	31.4	32.0	31.7
Chloride (Cl)	311	312	306	307	313	315
Bromide (Br)	1.10	1.20	0.900	1.10	1.10	1.20
Nitrate (NO_3)	0.017	0.018	0.038	0.031	0.032	0.016
Nitrite (NO_2)	0.021	0.042	0.041	0.034	0.026	0.016
Ammonium (NH_4)	0.20	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (SiO_2)	234	291	250	264	246	258
Boron (B)	4.16	4.07	4.29	4.71	4.56	4.77
Aluminum (Al)	0.298	0.275	0.272	0.273	0.266	0.274
Iron total (Fe(T))	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Ferrous iron (Fe(II))	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Manganese (Mn)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	<0.0005	0.0030	0.0034	<0.0005	<0.0005	<0.0005
Zinc (Zn)	0.002	0.001	0.002	<0.0005	0.001	<0.0005
Cadmium (Cd)	0.0004	<0.0001	<0.0001	<0.0001	0.0001	0.0001
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt (Co)	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	87	205	72	45	42	36
Methylmercury (CH_3Hg), ng/L	0.012	---	---	---	---	---
Nickel (Ni)	<0.0005	0.0013	0.0024	0.0006	<0.0005	<0.0005
Lead (Pb)	0.0020	<0.0008	0.0029	<0.0008	<0.0008	<0.0008
Beryllium (Be)	<0.001	0.001	0.001	0.001	0.001	<0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	0.042	0.036	0.017	0.037	0.040
Antimony total (Sb(T))	0.0094	0.0095	0.0077	0.0095	0.0096	0.0140
Antimonite (Sb(III))	0.009	0.004	0.003	0.003	0.003	0.004
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.29	1.07	1.16	1.27	1.26	1.31
Arsenite (As(III))	1.27	1.03	1.13	1.26	1.19	1.28
Dissolved organic carbon (DOC)	0.6	0.9	3.2	3.1	0.7	0.5
δD, per mil	-141.40	-142.80	-140.40	-142.10	-140.30	-140.00
$\delta^{18}O$, per mil	-16.49	-16.46	-16.51	-16.34	-16.32	-16.33
sum cations, meq/L	13.8	14.3	15.0	16.0	15.4	15.6
sum anions, meq/L	14.6	14.8	14.6	14.6	14.9	14.9
Charge imbalance, percent	-5.7	-3.1	2.9	8.7	3.5	4.6

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 10. Results of water analyses for Lower Geyser Basin, 2003—2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Ojo Caliente Spring overflow channel 26.7 m from source	Ojo Caliente Spring overflow channel 30.0 m from source	Ojo Caliente Spring overflow channel 34.3m from source	Ojo Caliente Spring overflow channel 38.0 m from source	Ojo Caliente Spring overflow channel 41.9 m from source	Red Terrrace Spring/Queen's Laundry
Sample ID	05WA106	05WA107	05WA108	05WA109	05WA110	03WA134
Collection Date / Time	6/3/05 14:20	6/3/05 14:45	6/3/05 15:00	6/3/05 15:15	6/3/05 15:30	6/6/03 15:45
Temperature, °C	80.5	76.4	71.8	66.6	63.2	80.9[2]
pH (field / laboratory)	7.93 / 8.30	7.95 / 8.38	8.14 / 8.53	8.21 / 8.60	8.25 / 8.67	7.74 / 8.64
Specific conductance (field / laboratory), µS/cm	1535 / 1600	1560 / 1605	1580 / 1600	1600 / 1465	1610 / 1630	1440 / 1467
Eh, V	0.029	0.046	0.094	0.127	0.156	-0.076
Density, g/mL at 20°C	0.9992	0.9991	0.9991	0.9991	0.9992	0.9994
Dissolved oxygen (DO), mg/L	<0.1	1.1	0.9	2.1	2.3	---
Constituent, mg/L[1]						
Calcium (Ca)	0.948	0.923	0.871	0.879	0.860	0.488
Magnesium (Mg)	<0.001	<0.001	<0.001	<0.001	<0.001	0.009
Sodium (Na)	335	338	341	335	330	298
Potassium (K)	9.04	9.81	9.98	10.1	9.99	12.4
Strontium (Sr)	0.007	0.006	0.006	0.006	0.006	<0.0007
Barium (Ba)	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008
Lithium (Li)	3.97	4.33	4.27	4.40	4.32	2.18
Sulfate (SO_4)	22.4	23.2	23.4	21.3	25.0	19.5
Thiosulfate (S_2O_3)	0.6	0.5	0.5	0.5	0.6	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.19	0.104	0.043	0.036	0.022	0.027
Alkalinity (HCO_3)	240	240	241	219	242	377
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	31.9	32.1	32.3	31.2	33.3	33.1
Chloride (Cl)	318	320	318	290	322	235
Bromide (Br)	1.10	1.20	1.20	1.20	1.10	0.780
Nitrate (NO_3)	0.015	0.005	0.017	0.034	0.031	<0.1
Nitrite (NO_2)	0.014	0.014	0.004	0.016	0.015	0.047
Ammonium (NH_4)	<0.05	<0.05	<0.05	<0.05	<0.05	0.06
Silica (SiO_2)	244	259	258	256	254	313
Boron (B)	4.41	4.49	4.67	4.56	4.44	3.12
Aluminum (Al)	0.321	0.287	0.280	0.272	0.265	0.316
Iron total (Fe(T))	<0.002	<0.002	<0.002	<0.002	0.004	0.006
Ferrous iron (Fe(II))	<0.002	<0.002	<0.002	<0.002	0.002	0.004
Manganese (Mn)	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Copper (Cu)	0.0038	<0.0005	0.0011	0.0039	<0.0005	<0.0005
Zinc (Zn)	<0.0005	0.002	0.001	0.001	0.002	<0.004
Cadmium (Cd)	<0.0001	<0.0001	0.0001	0.0001	0.0001	<0.0001
Chromium (Cr)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt (Co)	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	35	28	26	21	21	69
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---	0.183
Nickel (Ni)	0.0028	<0.0005	0.0017	0.0012	<0.0005	0.0030
Lead (Pb)	0.0025	<0.0008	<0.0008	<0.0008	0.0089	0.0013
Beryllium (Be)	0.001	0.001	0.001	<0.001	<0.001	0.003
Vanadium (V)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.043	0.042	0.043	0.040	0.040	0.033
Antimony total (Sb(T))	0.0182	0.0443	0.0643	0.0657	0.0689	0.0400
Antimonite (Sb(III))	0.005	0.029	0.043	0.047	0.048	---
Selenium (Se)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.32	1.35	1.40	1.40	1.38	1.04
Arsenite (As(III))	1.30	1.30	1.20	0.876	0.779	0.476
Dissolved organic carbon (DOC)	---	4.0	0.6	---	2.1	---
δD, per mil	-140.70	-140.10	-139.60	-139.50	-139.40	-143.66
$\delta^{18}O$, per mil	-16.21	-16.13	-16.05	-15.93	-15.96	-16.83
sum cations, meq/L	15.4	15.6	15.7	14.9	15.2	13.5
sum anions, meq/L	15.0	15.1	15.1	13.8	15.3	14.9
Charge imbalance, percent	2.3	3.1	4.0	7.7	-0.5	-9.6

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 10. Results of water analyses for Lower Geyser Basin, 2003—2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Steep Cone	Steep Cone	Steep Cone overflow channel	Unnamed pool on bluff West of Firehole River	Unnamed pool on bluff West of Firehole River	Unnamed green pool West of Firehole River
Sample ID	03WA135	04WA136	04WA136B	03WA138	04WA140	04WA142
Collection Date / Time	6/6/03 17:00	9/9/04 11:10	9/9/04 11:10	6/7/03 15:00	9/9/04 16:05	9/9/04 17:35
Temperature, °C	93.5	94.5	---	82.5	93.6	53.1
pH (field / laboratory)	7.71 / 8.62	7.79 / 8.62	--- / ---	7.42 / 8.38	7.10 / 8.33	7.39 / 8.51
Specific conductance (field / laboratory), µS/cm	1340 / 1422	1330 / 1400	--- / ---	1440 / 1526	1405 / 1576	1665 / 1649
Eh, V	-0.099	-0.183	---	-0.150	-0.134	0.154
Density, g/mL at 20°C	0.9993	0.9991	---	0.9991	0.9991	0.9992
Dissolved oxygen (DO), mg/L	---	---	---	---	---	---
Constituent, mg/L[1]						
Calcium (Ca)	<0.04	<0.04	---	0.959	0.840	0.767
Magnesium (Mg)	<0.001	<0.001	---	0.003	<0.001	<0.001
Sodium (Na)	277	296	---	296	311	340
Potassium (K)	10.5	9.50	---	9.67	9.48	8.82
Strontium (Sr)	<0.0007	<0.0007	---	0.005	0.005	0.004
Barium (Ba)	<0.0008	<0.0008	---	<0.0008	<0.0008	<0.0008
Lithium (Li)	1.72	1.56	---	2.01	1.67	3.69
Sulfate (SO_4)	14.9	14.9	---	32.3	31.7	57.0
Thiosulfate (S_2O_3)	<0.1	0.3	---	<0.1	0.7	3.7
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	---	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.16	0.20	---	0.40	0.31	0.015
Alkalinity (HCO_3)	293	276	---	213	106	208
Acidity (free / total), mM	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---	--- / ---
Fluoride (F)	36.2	32.3	---	32.3	30.8	36.7
Chloride (Cl)	254	259	---	307	363	327
Bromide (Br)	0.858	0.903	---	1.04	1.64	1.66
Nitrate (NO_3)	<0.1	0.075	---	0.115	0.030	0.051
Nitrite (NO_2)	0.024	0.051	---	0.063	0.024	0.006
Ammonium (NH_4)	0.12	0.10	---	0.51	0.20	<0.05
Silica (SiO_2)	362	355	---	274	277	208
Boron (B)	3.36	3.37	---	4.05	3.84	4.19
Aluminum (Al)	0.253	0.305	---	0.106	0.127	0.147
Iron total (Fe(T))	0.008	0.002	<0.002	<0.002	<0.002	0.003
Ferrous iron (Fe(II))	0.008	<0.002	<0.002	<0.002	<0.002	0.002
Manganese (Mn)	<0.001	<0.001	---	0.001	<0.001	0.002
Copper (Cu)	<0.0005	<0.0005	---	<0.0005	<0.0005	<0.0005
Zinc (Zn)	<0.004	0.007	---	<0.004	0.003	0.002
Cadmium (Cd)	0.0002	0.0004	---	0.0003	0.0003	0.0003
Chromium (Cr)	<0.0005	<0.0005	---	<0.0005	<0.0005	<0.0005
Cobalt (Co)	<0.0007	<0.0007	---	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	290	100	---	160	200	14
Methylmercury (CH_3Hg), ng/L	---	0.012	---	---	---	0.017
Nickel (Ni)	0.0030	<0.0005	---	<0.002	<0.0005	0.0005
Lead (Pb)	0.0012	0.0019	---	0.0012	0.0019	0.0018
Beryllium (Be)	0.001	<0.001	---	0.001	0.001	0.001
Vanadium (V)	<0.005	<0.005	---	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.023	---	---	0.046	---	---
Antimony total (Sb(T))	0.0480	0.0234	0.0263	0.0960	0.0159	0.0653
Antimonite (Sb(III))	---	0.017	0.005	---	0.016	0.004
Selenium (Se)	<0.001	<0.001	---	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.11	1.09	1.18	1.34	1.45	1.50
Arsenite (As(III))	1.11	1.09	0.360	1.34	1.45	1.39
Dissolved organic carbon (DOC)	---	---	---	0.7	0.6	1.3
δD, per mil	-141.93	-143.30	---	-139.57	-138.30	-135.20
$\delta^{18}O$, per mil	-17.26	-17.26	---	-15.83	-15.63	-14.10
sum cations, meq/L	12.5	13.3	---	13.4	14.0	15.5
sum anions, meq/L	14.2	13.8	---	14.5	14.3	15.7
Charge imbalance, percent	-12.2	-3.8	---	-7.6	-1.6	-1.2

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 11. Results of water analyses for Washburn Hot Springs, 2003—2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Inkpot #1	Largest spring	Inkpot #3	Neutral mudpot
Sample ID	03WA127	03WA128	03WA129	03WA130
Collection Date / Time	6/3/03 11:00	6/3/03 14:00	6/3/03 15:15	6/3/03 15:50
Temperature, °C	82.9	84.5	69.0	---
pH (field / laboratory)	6.45 / 8.09	6.61 / 8.01	3.04 / 2.74	--- / 8.24
Specific conductance (field / laboratory), µS/cm	2135 / 2260	2050 / 2100	4460 / 5170	--- / 2350
Eh, V	-0.178	-0.168	0.083	---
Density, g/mL at 20°C	0.9994	0.9995	1.0005	0.9993
Dissolved oxygen (DO), mg/L	---	---	---	---
Constituent, mg/L[1]				
Calcium (Ca)	22.2	22.6	38.4	15.5
Magnesium (Mg)	9.76	10.1	18.9	5.52
Sodium (Na)	34.7	35.0	29.8	20.8
Potassium (K)	11.1	11.3	14.2	7.76
Strontium (Sr)	0.142	0.144	0.201	0.111
Barium (Ba)	0.064	0.062	0.031	0.016
Lithium (Li)	0.019	0.018	0.040	0.005
Sulfate (SO_4)	830	783	2050	809
Thiosulfate (S_2O_3)	0.8	1.2	<0.1	---
Polythionate (S_nO_6), mg/L / n	0.9 / 4	<0.5	<0.5	---
Hydrogen sulfide (H_2S)	2.3	1.0	4.6	---
Alkalinity (HCO_3)	168	145	---	140
Acidity (free / total), mM	--- / ---	--- / ---	3.06 / 4.92	--- / ---
Fluoride (F)	0.500	0.500	0.400	0.300
Chloride (Cl)	0.856	0.821	5.81	0.722
Bromide (Br)	0.102	0.102	0.102	0.102
Nitrate (NO_3)	<0.1	0.147	<0.1	<0.1
Nitrite (NO_2)	0.122	0.020	0.001	0.002
Ammonium (NH_4)	281	263	571	329
Silica (SiO_2)	178	152	233	89.3
Boron (B)	5.67	4.27	6.52	1.18
Aluminum (Al)	0.076	0.092	16.8	0.003
Iron total (Fe(T))	<0.002	0.012	14.9	0.020
Ferrous iron (Fe(II))	<0.002	0.010	14.9	---
Manganese (Mn)	0.124	0.141	0.712	0.091
Copper (Cu)	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	<0.004	<0.004	0.081	<0.004
Cadmium (Cd)	<0.0001	0.0016	0.0002	0.0002
Chromium (Cr)	0.0037	0.0043	0.030	<0.0005
Cobalt (Co)	<0.0007	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	2100	510	83	---
Methylmercury (CH_3Hg), ng/L	0.194	---	---	---
Nickel (Ni)	<0.002	<0.002	0.0050	<0.002
Lead (Pb)	<0.0008	<0.0008	<0.0008	<0.0008
Beryllium (Be)	<0.001	<0.001	0.005	<0.001
Vanadium (V)	<0.005	0.011	0.033	0.008
Molybdenum (Mo)	<0.007	<0.007	<0.007	<0.007
Antimony total (Sb(T))	0.0020	<0.001	<0.001	<0.001
Antimonite (Sb(III))	---	---	---	---
Selenium (Se)	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	0.003	0.003	0.0004	<0.04
Arsenite (As(III))	0.003	0.003	<0.001	---
Dissolved organic carbon (DOC)	17	21	---	10
δD, per mil	-112.95	-116.52	-107.75	---
$\delta^{18}O$, per mil	-4.21	-5.57	-4.12	---
sum cations, meq/L	17.2	16.2	34.6	18.2
sum anions, meq/L	18.5	17.2	35.3	17.9
Charge imbalance, percent	-7.1	-5.5	-2.0	1.6

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 12. Results of water analyses for Potts Hot Spring Basin, 2003–2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Explosion Pool	Jade Pool	Pince Nez Spring	Unnamed pool near Explosion Pool
Sample ID	03WA154	03WA156	03WA153	03WA155
Collection Date / Time	9/5/03 15:00	9/5/03 18:00	9/5/03 13:40	9/5/03 16:00
Temperature, °C	51.9	25.0	91.6	77.0
pH (field / laboratory)	8.18 / 8.50	3.24 / 3.29	8.65 / 8.99	6.98 / 8.72
Specific conductance (field / laboratory), µS/cm	1955 / 1983	590 / 592	1894 / 2000	1827 / 1892
Eh, V	0.153	0.709	-0.137	0.122
Density, g/mL at 20°C	0.9998	0.9987	0.9995	0.9996
Dissolved oxygen (DO), mg/L	---	---	---	---
Constituent, mg/L[1]				
Calcium (Ca)	0.819	2.51	0.313	0.470
Magnesium (Mg)	0.018	0.698	<0.001	0.202
Sodium (Na)	428	53.3	415	408
Potassium (K)	20.4	4.70	22.6	18.1
Strontium (Sr)	0.002	0.018	0.003	0.001
Barium (Ba)	0.001	0.042	0.001	<0.0008
Lithium (Li)	3.90	0.516	4.54	3.78
Sulfate (SO_4)	43.5	98.4	32.4	41.8
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	<0.002	0.003	0.30	<0.002
Alkalinity (HCO_3)	603	---	572	567
Acidity (free / total), mM	--- / ---	0.669 / 1.17	--- / ---	--- / ---
Fluoride (F)	29.8	3.00	37.5	30.6
Chloride (Cl)	266	56.1	258	285
Bromide (Br)	0.874	0.173	0.901	0.833
Nitrate (NO_3)	<0.1	<0.1	<0.1	<0.1
Nitrite (NO_2)	0.098	0.003	1.55	0.160
Ammonium (NH_4)	<0.05	<0.05	<0.05	<0.05
Silica (SiO_2)	279	183	486	366
Boron (B)	3.66	0.83	3.73	3.48
Aluminum (Al)	0.132	2.72	0.139	0.125
Iron total (Fe(T))	<0.002	3.87	<0.002	0.002
Ferrous iron (Fe(II))	<0.002	0.934	<0.002	<0.002
Manganese (Mn)	0.009	0.073	<0.001	0.007
Copper (Cu)	<0.0005	<0.0005	0.0007	<0.0005
Zinc (Zn)	<0.004	0.013	<0.004	<0.004
Cadmium (Cd)	0.0004	0.0004	0.0004	0.0007
Chromium (Cr)	<0.0005	0.0031	<0.0005	<0.0005
Cobalt (Co)	0.0012	0.0015	0.0023	0.0009
Mercury total (Hg(T)), ng/L	37	14	108	69
Methylmercury (CH_3Hg), ng/L	---	---	---	---
Nickel (Ni)	<0.002	0.0070	0.0030	0.0030
Lead (Pb)	0.0016	0.0019	0.0015	0.0021
Beryllium (Be)	0.002	0.002	0.002	0.001
Vanadium (V)	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	0.069	<0.007	0.072	0.069
Antimony total (Sb(T))	0.0960	0.0070	0.103	0.0880
Antimonite (Sb(III))	---	---	---	---
Selenium (Se)	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	1.75	0.016	2.00	1.75
Arsenite (As(III))	0.047	0.021	1.87	0.043
Dissolved organic carbon (DOC)	0.9	1.5	0.9	1.0
δD, per mil	-131.87	-84.41	-140.60	-134.19
$\delta^{18}O$, per mil	-13.01	-4.14	-15.36	-13.77
sum cations, meq/L	19.6	3.6	18.7	18.7
sum anions, meq/L	19.8	3.5	18.7	19.8
Charge imbalance, percent	-0.9	0.6	-0.4	-5.5

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 13. Results of water analyses for Sulphur Caldron area, 2003–2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Mud Geyser	Sulphur Caldron	Sulphur Caldron	Unnamed hot spring at lake shore
Sample ID	03WA132	03WA131	05WA139	04WA135
Collection Date / Time	6/5/03 13:50	6/5/03 10:00	6/8/05 13:45	9/8/04 12:45
Temperature, °C	34.7[2]	74.3	74.8	58.1
pH (field / laboratory)	1.93 / 1.87	1.68 / 1.52	1.85 / 1.76	4.81 / 3.69
Specific conductance (field / laboratory), µS/cm	5350 / 6040	6800 / 13000	4480 / 8760	1090 / 1210
Eh, V	0.421	0.476	0.240	0.274
Density, g/mL at 20°C	1.0000	1.0017	1.0006	0.9990
Dissolved oxygen (DO), mg/L	---	---	---	---
Constituent, mg/L[1]				
Calcium (Ca)	45.2	61.8	43.2	16.2
Magnesium (Mg)	21.9	14.0	8.73	4.71
Sodium (Na)	73.1	20.3	20.8	159
Potassium (K)	26.4	22.9	22.7	37.0
Strontium (Sr)	0.352	0.211	0.192	0.143
Barium (Ba)	0.044	0.073	0.088	0.092
Lithium (Li)	0.040	0.037	0.018	0.719
Sulfate (SO_4)	1330	3170	2310	290
Thiosulfate (S_2O_3)	---	---	<0.1	0.5
Polythionate (S_nO_6), mg/L / n	---	---	<0.5	2.9 / 4
Hydrogen sulfide (H_2S)	0.002	<0.002	<0.002	0.003
Alkalinity (HCO_3)	---	---	---	<1
Acidity (free / total), mM	16.2 / 24.6	42.9 / 58.8	28.4 / 39.7	--- / ---
Fluoride (F)	0.400	1.00	1.70	5.39
Chloride (Cl)	100	2.72	3.80	134
Bromide (Br)	0.370	0.102	<0.03	0.370
Nitrate (NO_3)	<0.1	0.279	0.103	0.038
Nitrite (NO_2)	<0.0004	<0.0004	0.001	<0.0004
Ammonium (NH_4)	4.51	0.89	46.9	<0.05
Silica (SiO_2)	247	456	356	289
Boron (B)	2.10	3.58	3.63	2.47
Aluminum (Al)	40.3	122	94.2	0.218
Iron total (Fe(T))	21.1	24.8	14.8	0.134
Ferrous iron (Fe(II))	15.0	24.6	14.4	0.134
Manganese (Mn)	1.50	0.869	0.718	0.429
Copper (Cu)	0.0022	0.0023	0.0090	<0.0005
Zinc (Zn)	0.058	0.247	0.122	0.004
Cadmium (Cd)	0.0002	0.0006	0.0004	0.0003
Chromium (Cr)	0.054	0.058	0.048	<0.0005
Cobalt (Co)	0.0052	0.0068	0.0050	<0.0007
Mercury total (Hg(T)), ng/L	22	120	600	120
Methylmercury (CH_3Hg), ng/L	---	6.69	---	0.030
Nickel (Ni)	0.033	0.049	0.015	0.0013
Lead (Pb)	0.0016	0.022	0.012	0.0014
Beryllium (Be)	0.001	0.010	0.008	0.001
Vanadium (V)	0.034	0.055	0.036	<0.005
Molybdenum (Mo)	<0.007	<0.007	<0.007	---
Antimony total (Sb(T))	0.0020	0.0020	0.0007	<0.0005
Antimonite (Sb(III))	---	---	<0.0005	<0.0005
Selenium (Se)	0.002	0.005	<0.001	<0.001
Arsenic total (As(T))	0.017	0.003	0.003	0.042
Arsenite (As(III))	0.012	0.003	0.003	0.034
Dissolved organic carbon (DOC)	4.3	8.1	6.9	---
δD, per mil	-111.24	-107.78	-108.00	-127.30
$\delta^{18}O$, per mil	-10.49	-7.94	-8.73	-13.90
sum cations, meq/L	23.0	36.0	27.5	8.8
sum anions, meq/L	21.0	35.9	27.5	9.7
Charge imbalance, percent	9.1	0.2	-0.2	-9.4

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 14. Results of water analyses for Lemonade Creek area, 2003—2005

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Uppermost thermal spring in drainage	Middle thermal spring in drainage	Lowermost thermal spring in drainage	Lemonade Creek 2 m downstream from confluence with overflow channel	Lemonade Creek 27 m downstream from confluence with overflow channel
Sample ID	03WA148	03WA158	03WA159	03WA160	03WA161
Collection Date / Time	9/3/03 13:30	9/7/03 16:00	9/7/03 17:30	9/7/03 17:30	9/7/03 17:30
Temperature, °C	76.6	76.7	77.9	56.2	49.6
pH (field / laboratory)	2.54 / 2.32	2.30 / 2.23	2.32 / ---	2.26 / ---	2.22 / ---
Specific conductance (field / laboratory), µS/cm	1636 / 2710	1850 / 3230	1816 / ---	2260 / ---	2460 / ---
Eh, V	0.132	0.142	---	---	---
Density, g/mL at 20°C	0.9992	0.9992	---	---	---
Dissolved oxygen (DO), mg/L	---	---	---	---	---
Constituent, mg/L[1]					
Calcium (Ca)	12.7	7.60	---	---	---
Magnesium (Mg)	2.59	2.41	---	---	---
Sodium (Na)	84.5	46.6	---	---	---
Potassium (K)	29.4	24.1	---	---	---
Strontium (Sr)	0.045	0.022	---	---	---
Barium (Ba)	0.034	0.018	---	---	---
Lithium (Li)	0.491	0.067	---	---	---
Sulfate (SO_4)	448	675	---	---	---
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.34	1.8	2.1	---	---
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	6.15 / 7.15	8.86 / 10.4	--- / ---	--- / ---	--- / ---
Fluoride (F)	0.700	0.800	---	---	---
Chloride (Cl)	91.0	13.0	---	---	---
Bromide (Br)	0.427	0.276	---	---	---
Nitrate (NO_3)	<0.1	<0.1	---	---	---
Nitrite (NO_2)	0.001	0.003	---	---	---
Ammonium (NH_4)	2.95	3.36	---	---	---
Silica (SiO_2)	318	513	---	---	---
Boron (B)	2.51	0.62	---	---	---
Aluminum (Al)	8.14	13.2	---	---	---
Iron total (Fe(T))	2.69	3.58	---	3.46	3.56
Ferrous iron (Fe(II))	2.69	3.53	---	2.30	1.61
Manganese (Mn)	0.158	0.134	---	---	---
Copper (Cu)	<0.0005	0.0009	---	---	---
Zinc (Zn)	0.009	0.031	---	---	---
Cadmium (Cd)	0.0001	0.0004	---	---	---
Chromium (Cr)	0.0030	0.0030	---	---	---
Cobalt (Co)	0.0009	<0.0007	---	---	---
Mercury total (Hg(T)), ng/L	47	57	---	21	15
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---
Nickel (Ni)	0.0040	0.0050	---	---	---
Lead (Pb)	0.0028	0.0024	---	---	---
Beryllium (Be)	0.002	0.002	---	---	---
Vanadium (V)	<0.005	<0.005	---	---	---
Molybdenum (Mo)	<0.007	<0.007	---	---	---
Antimony total (Sb(T))	0.0120	<0.001	---	---	---
Antimonite (Sb(III))	---	---	---	---	---
Selenium (Se)	<0.001	<0.001	---	---	---
Arsenic total (As(T))	0.262	0.043	---	0.098	0.094
Arsenite (As(III))	0.233	0.043	---	0.051	0.045
Dissolved organic carbon (DOC)	0.8	0.8	---	---	---
δD, per mil	-142.19	-141.29	---	---	---
$\delta^{18}O$, per mil	-16.67	-16.85	---	---	---
sum cations, meq/L	9.0	9.6	---	---	---
sum anions, meq/L	9.5	10.0	---	---	---
Charge imbalance, percent	-5.4	-4.2	---	---	---

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 14. Results of water analyses for Lemonade Creek area, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Lemonade Creek 140 m downstream from confluence with overflow channel	Thermal vent	Thermal vent overflow channel 1 m downstream from source	Thermal vent overflow channel 1 m upstream from Lemonade Creek	Lemonade Creek upstream from confluence with thermal vent overflow channel
Sample ID	03WA162	05WA118	05WA119	05WA120	05WA121
Collection Date / Time	9/7/03 17:30	6/5/05 13:30	6/5/05 13:55	6/5/05 14:10	6/5/05 16:15
Temperature, °C	40.2	75.7	69.2	62.3	42.5
pH (field / laboratory)	2.18 / ---	2.27 / 2.17	2.23 / 2.16	2.20 / 2.14	2.22 / 2.25
Specific conductance (field / laboratory), µS/cm	2740 / ---	1922 / 3430	2075 / 3500	2300 / 3520	2380 / 2890
Eh, V	---	0.141	0.206	0.266	0.239
Density, g/mL at 20°C	---	0.9992	0.9992	0.9991	0.9989
Dissolved oxygen (DO), mg/L	---	<0.1	0.2	1.1	4.3
Constituent, mg/L[1]					
Calcium (Ca)	---	7.52	7.83	7.45	8.44
Magnesium (Mg)	---	2.27	2.39	2.32	2.07
Sodium (Na)	---	49.5	47.9	39.5	35.1
Potassium (K)	---	25.5	26.3	26.9	20.3
Strontium (Sr)	---	0.022	0.023	0.022	0.030
Barium (Ba)	---	0.018	0.018	0.017	0.029
Lithium (Li)	---	0.058	0.058	0.059	0.166
Sulfate (SO_4)	---	694	698	705	572
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	---	1.67	0.20	0.052	0.054
Alkalinity (HCO_3)	---	---	---	---	---
Acidity (free / total), mM	--- / ---	8.46 / 10.8	8.55 / 10.6	8.59 / 10.4	6.76 / 8.94
Fluoride (F)	---	1.10	1.00	1.00	1.60
Chloride (Cl)	---	8.20	8.30	8.40	19.0
Bromide (Br)	---	<0.03	<0.03	<0.03	0.120
Nitrate (NO_3)	---	0.010	0.020	0.021	0.014
Nitrite (NO_2)	---	0.013	0.001	0.001	0.001
Ammonium (NH_4)	---	3.16	3.36	3.24	2.09
Silica (SiO_2)	---	301	310	317	232
Boron (B)	---	0.43	0.47	0.44	0.62
Aluminum (Al)	---	15.9	16.3	16.5	17.6
Iron total (Fe(T))	3.71	3.52	3.51	3.58	2.86
Ferrous iron (Fe(II))	0.572	3.50	3.47	3.35	1.63
Manganese (Mn)	---	0.134	0.143	0.136	0.135
Copper (Cu)	---	<0.0005	<0.0005	<0.0005	<0.0005
Zinc (Zn)	---	0.030	0.033	0.032	0.018
Cadmium (Cd)	---	0.0002	0.0002	0.0002	<0.0001
Chromium (Cr)	---	0.0010	0.0008	0.0009	0.0019
Cobalt (Co)	---	0.0008	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	12	52	33	25	33
Methylmercury (CH_3Hg), ng/L	---	---	---	---	---
Nickel (Ni)	---	0.0028	0.0027	0.0029	0.0023
Lead (Pb)	---	<0.0008	<0.0008	<0.0008	<0.0008
Beryllium (Be)	---	0.002	0.002	0.002	0.001
Vanadium (V)	---	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	---	<0.007	<0.007	<0.007	<0.007
Antimony total (Sb(T))	---	0.0005	0.0010	0.0013	0.0025
Antimonite (Sb(III))	---	0.0005	0.0010	0.0011	0.0007
Selenium (Se)	---	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	0.092	0.039	0.041	0.041	0.075
Arsenite (As(III))	0.018	0.038	0.041	0.041	0.039
Dissolved organic carbon (DOC)	---	0.8	0.7	0.8	1.8
δD, per mil	---	-142.40	-141.40	-140.40	-138.20
$\delta^{18}O$, per mil	---	-16.91	-16.72	-16.57	-16.43
sum cations, meq/L	---	10.3	10.9	11.0	10.3
sum anions, meq/L	---	10.1	10.2	10.4	9.3
Charge imbalance, percent	---	2.1	6.2	4.9	10.4

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Table 14. Results of water analyses for Lemonade Creek area, 2003–2005—Continued

[δD and $\delta^{18}O$, isotopic composition of hydrogen and oxygen relative to VSMOW; g/mL, grams per milliliter; m, meters; meq/L, milliequivalents per liter; mg/L, milligrams per liter; mM, millimolar; µS/cm, microsiemens per centimeter; n, number; ng/L nanograms per liter; V, volts; ---, not measured; °C, degrees Celsius; <, less than]

Location	Lemonade Creek 15 m downstream from confluence with overflow channel	Lemonade Creek 27 m downstream from confluence with overflow channel	Lemonade Creek 60 m downstream from confluence with overflow channel	Lemonade Creek 140 m downstream from confluence with overflow channel
Sample ID	05WA122	05WA123	05WA124	05WA125
Collection Date / Time	6/5/05 16:50	6/5/05 17:20	6/5/05 17:40	6/5/05 18:30
Temperature, °C	41.5	40.9	39.4	35.2
pH (field / laboratory)	2.20 / 2.22	2.20 / 2.20	2.20 / 2.20	2.24 / 2.20
Specific conductance (field / laboratory), µS/cm	2570 / 3090	2630 / 3150	2675 / 3130	2760 / 3110
Eh, V	0.386	0.436	0.376	0.365
Density, g/mL at 20°C	0.9991	0.9990	0.9991	0.9990
Dissolved oxygen (DO), mg/L	4.2	4.5	4.8	5.3
Constituent, mg/L[1]				
Calcium (Ca)	7.99	8.06	8.35	8.29
Magnesium (Mg)	2.17	2.15	2.13	2.19
Sodium (Na)	37.9	36.1	35.9	43.4
Potassium (K)	23.3	23.4	23.7	22.8
Strontium (Sr)	0.027	0.027	0.028	0.028
Barium (Ba)	0.025	0.025	0.026	0.026
Lithium (Li)	0.125	0.129	0.130	0.126
Sulfate (SO_4)	611	626	622	627
Thiosulfate (S_2O_3)	<0.1	<0.1	<0.1	<0.1
Polythionate (S_nO_6), mg/L / n	<0.5	<0.5	<0.5	<0.5
Hydrogen sulfide (H_2S)	0.072	0.029	0.016	---
Alkalinity (HCO_3)	---	---	---	---
Acidity (free / total), mM	7.23 / 9.76	7.41 / 10.1	7.39 / 9.92	7.36 / 10.2
Fluoride (F)	1.00	1.00	1.00	1.00
Chloride (Cl)	16.0	15.2	14.8	14.9
Bromide (Br)	<0.03	<0.03	0.100	<0.03
Nitrate (NO_3)	0.015	0.014	0.019	0.014
Nitrite (NO_2)	0.001	<0.0004	0.001	0.001
Ammonium (NH_4)	2.52	2.77	2.50	1.77
Silica (SiO_2)	263	262	269	259
Boron (B)	0.55	0.55	0.59	0.55
Aluminum (Al)	17.4	17.4	17.0	17.2
Iron total (Fe(T))	3.17	3.14	3.14	3.11
Ferrous iron (Fe(II))	1.72	1.45	1.14	0.573
Manganese (Mn)	0.137	0.134	0.141	0.135
Copper (Cu)	0.0027	<0.0005	<0.0005	<0.0005
Zinc (Zn)	0.028	0.024	0.025	0.024
Cadmium (Cd)	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (Cr)	0.0015	0.0014	0.0015	0.0015
Cobalt (Co)	0.0008	<0.0007	<0.0007	<0.0007
Mercury total (Hg(T)), ng/L	25	20	17	10
Methylmercury (CH_3Hg), ng/L	---	---	---	---
Nickel (Ni)	0.0051	0.0015	0.0032	0.0032
Lead (Pb)	0.0025	<0.0008	<0.0008	0.0010
Beryllium (Be)	0.002	0.002	0.002	0.002
Vanadium (V)	<0.005	<0.005	<0.005	<0.005
Molybdenum (Mo)	<0.007	<0.007	<0.007	<0.007
Antimony total (Sb(T))	0.0020	0.0020	0.0015	0.0019
Antimonite (Sb(III))	<0.0005	<0.0005	0.0006	<0.0005
Selenium (Se)	<0.001	<0.001	<0.001	<0.001
Arsenic total (As(T))	0.057	0.055	0.053	0.050
Arsenite (As(III))	0.033	0.035	0.027	0.014
Dissolved organic carbon (DOC)	1.4	3.9	1.6	1.7
δD, per mil	-137.90	-139.00	-138.80	-138.00
$\delta^{18}O$, per mil	-16.23	-16.33	-16.40	-16.25
sum cations, meq/L	10.8	10.8	10.8	10.4
sum anions, meq/L	9.9	10.1	10.1	10.4
Charge imbalance, percent	9.1	6.4	6.6	-0.3

[1] Except for acidity (mM), mercury (ng/L), methylmercury (ng/L), and δD and δ18O (per mil)

[2] Flow-cell measurement

Quality Assurance and Quality Control

Several techniques were used to assure the quality of the analytical data. These techniques included calculation of charge balance to determine the C.I., analysis of USGS standard reference water samples (SRWS), replicate determinations in the laboratory, spike recovery determinations, and determination by alternative analytical methods.

The charge-balance calculation is one of the first and simplest of quality-assurance/quality-control procedures to check the accuracy of a water analysis. It is based on the principle that an aqueous solution containing electrolytes, or charged ions, must be electrically neutral overall. The equivalent concentration of cations must equal that of anions:

$$\sum_i c_i = 0 = \sum_i c_i^+ - \sum_i c_i^- \tag{20}$$

where c_i = the equivalent concentration (usually in milliequivalents per liter) for the *i*th ion, c_i^+ = the equivalent concentration for the *i*th cation, and c_i^- = the equivalent concentration for the *i*th anion. Two important problems arise for waters of low pH. One problem has to do with including the hydrogen-ion concentration and the other has to do with speciation.

Charge balances are routinely calculated by analytical laboratories using the major ions: Na, K, Ca, Mg, Cl, SO_4, HCO_3, ($\pm NO_3$, F). Once the pH drops below 3, the hydrogen ion becomes a major cation (about a milliequivalent), and Fe and Al can become major cations. If the hydrogen-ion concentration is absent from the charge-balance calculation, the C.I. will become progressively worse as the pH decreases. An example of C.I. calculated for acid-sulfate water samples without the inclusion of the hydrogen ion is shown in figure 37A.

The second problem arises because aqueous complexes become dominant relative to free ions in acid-sulfate waters or in any water of higher total dissolved solids (Nordstrom and Alpers, 1999). Charge balances are calculated assuming that the analytical determinations of major ions represent the aqueous free ions in solution, for example, that the analytically determined dissolved Al is all present as Al^{3+}. Sulfate is the dominant anion in acid-sulfate waters and forms complexes, or ion pairs, with cations; the higher the oxidation state on the cation, the stronger the complex (Stumm and Morgan, 1981). Hence, for pH<3 most of the dissolved Al is complexed with SO_4. Such reactions as:

$$Al^{3+} + SO_4^{2-} \leftrightarrow AlSO_4^{+} \tag{21}$$

have the consequence of lowering the charge on the dissolved Al from 3+ to 1+, and incorporating a certain amount of SO_4 into the cation sum, effectively removing it from the anion pool. Although they do not change the charge balance, the overall effect of these speciation reactions is to reduce the total charge of dissolved ions in solution. The amount of the reduction increases with increasing concentration of dissolved ions, especially if the major dissolved ions are polyvalent.

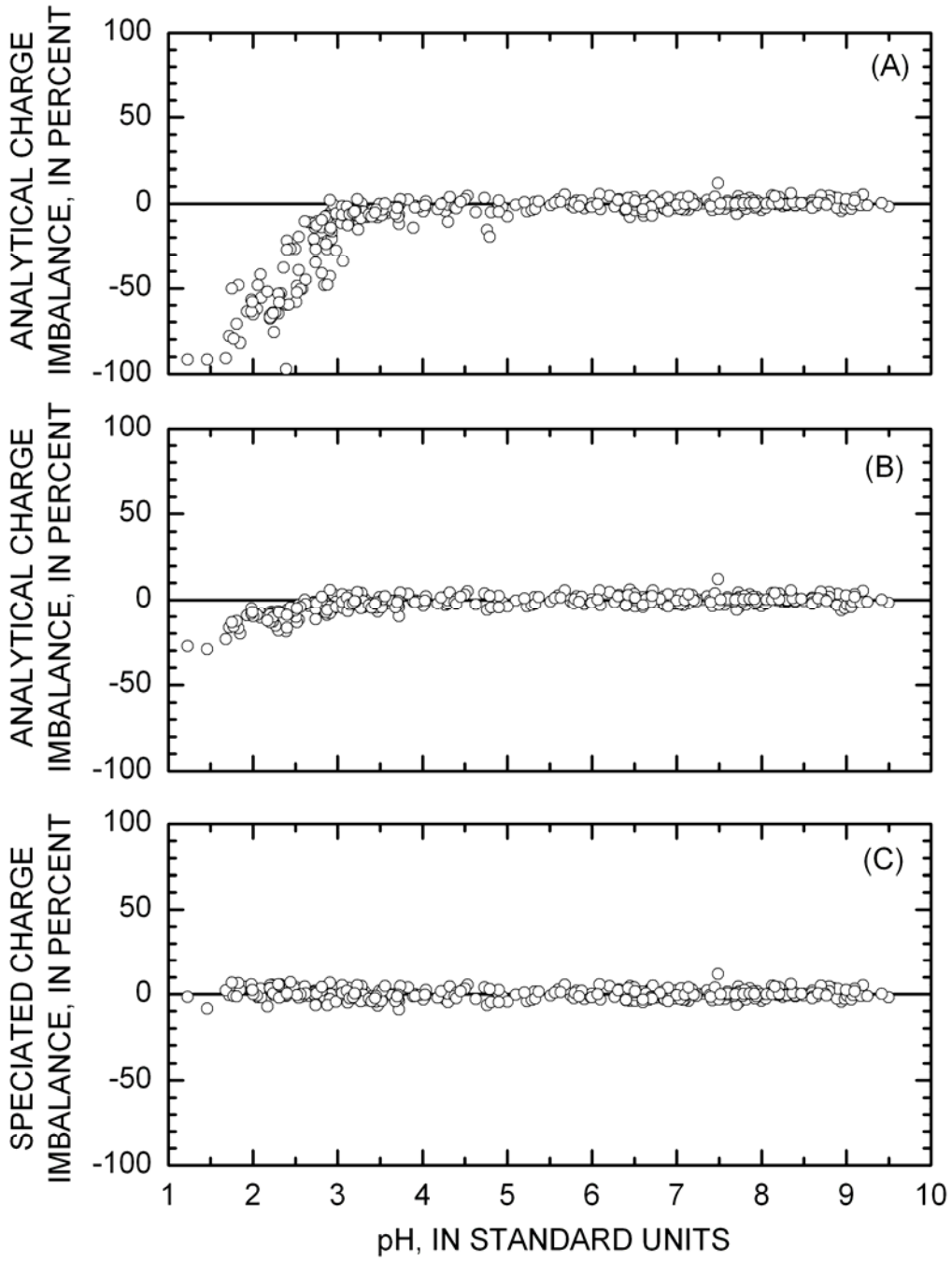


Figure 37. Charge imbalance calculated (A) without including H^+ concentration and without speciation; (B) with H^+ concentration included but without speciation; and (C) including both H^+ concentration and speciation.

Hydrogen ions represent a unique and important instance of the effect of complexing on the charge balance. Consider the reaction:

$$H^+ + SO_4^{2-} \leftrightarrow HSO_4^- \tag{22}$$

in which the cation, H^+, is incorporated into the anionic species, HSO_4^-. The pK_1 for this reaction is 1.98, which means that as the pH approaches 2, increasing amounts of dissolved SO_4^{2-} become HSO_4^-. Below pH 2, free SO_4^{2-} ion is no longer dominant, HSO_4^- is. More importantly, the hydrogen in HSO_4^- is not part of the hydrogen measured by the pH electrode, which measures only the activity of free H^+. This hydrogen must be added to produce HSO_4^- ion in the speciation calculation.

The occurrence in solution of an unmeasured source of H^+ means that, for acid waters, equivalent hydrogen-ion concentrations must be calculated based on the pH measurement and the water must be speciated before an accurate charge balance can be calculated. Hence, charge balance must be based on a model of speciation using thermodynamic data. At least two codes are programmed to do this, the PHREEQE series (Parkhurst and Appelo, 1999) and WATEQ4F (Ball and Nordstrom, 1991). Figure 37 shows the divergence of analytical C.I. (fig. 37B) from speciated C.I. (fig. 37C) for acid samples, relative to pH. Note that the divergence becomes significant (a difference of greater than 10 percent) when the pH is less than 3, but that the greatest improvement occurs when H^+ is added to the C.I. calculation.

One other problem is noteworthy here. Measurements of pH as defined by the National Institute of Standards and Technology (NIST, formerly NBS, National Bureau of Standards) are only valid for measurements to about pH 1. Below that pH the conventions for defining pH no longer apply. Fortunately, another option is available based on the Pitzer method of calculating activity coefficients (Pitzer, 1991). This approach has been used to define and measure pH values down to -3.6 for acid waters in the Richmond mine of Iron Mountain, California (Nordstrom and Alpers, 1999; Nordstrom and others, 2000). Geochemical codes are available to calculate speciation in concentrated solutions using the Pitzer model, but unlike most codes that use the ion-association model, not all of the necessary parameters for acid-sulfate waters are available. This issue is the subject of current research.

One hundred forty-three samples were analyzed for major cations and anions and the data were checked for C.I. using the geochemical code WATEQ4F (Ball and Nordstrom, 1991). WATEQ4F uses equation 24 to calculate C.I.:

$$\text{C.I.(percent)} = \frac{100 \times (\text{sum cations} - \text{sum anions})}{(\text{sum cations} + \text{sum anions}) \div 2} \tag{23}$$

where sum cations and sum anions are in meq/L.

The C.I., sum cations (meq/L), and sum anions (meq/L) are reported in tables 6-14 for samples having major cation and anion determinations. A frequency plot of C.I. for all samples with complete analyses is shown in figure 38. The Gaussian fit C.I. mean is –1.0 percent with a standard deviation of 5.0 percent. Analyses having a C.I. less than ±10 percent are considered reliable for speciation calculations (Nordstrom and Munoz, 1994). Two sample analyses out of 143 had a C.I. (-12 and +10.4 percent) greater than ±10 percent.

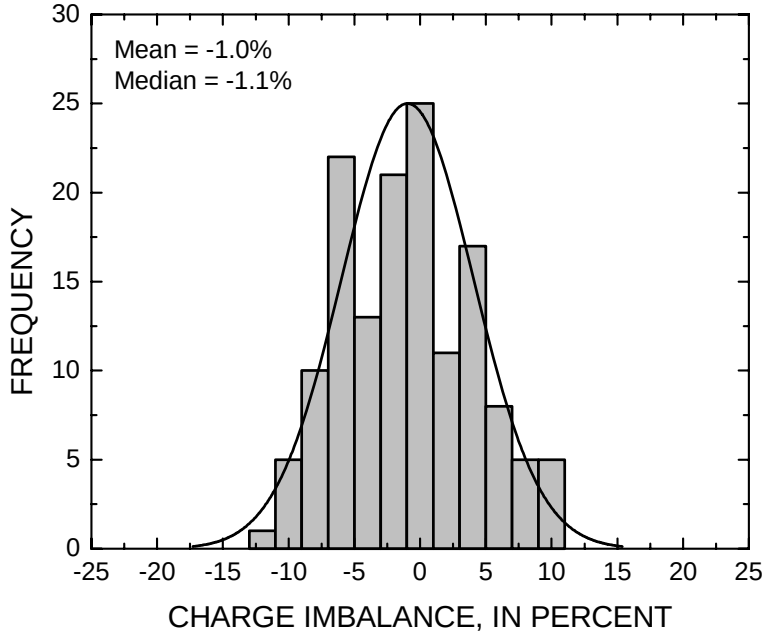


Figure 38. Frequency distribution of charge imbalance for samples having major cation and anion determinations.

U.S. Geological Survey SRWSs were analyzed as unknowns along with the samples to check for accuracy. Standard reference water samples AMW4, M102, M134, M136, M140, M150, M156, M158, M166, M172, SRWS67, SRWS69, T115, T159, T161, T163, T173, T179, T181, Hg7, Hg15, and Hg26 were used to check the analytical methods for major and trace metals, anions, and Hg (Farrar, 2000; Connor and others, 2001). The SRWSs were analyzed several times during each analytical run. For each SRWS constituent, the analytical result, the most probable value (MPV), and the percent difference are presented in table 15. Additional information about the USGS SRWS program can be obtained at URL http://bqs.usgs.gov/srs.

Replicate determinations were performed for all methods and all constituents. Samples were diluted as necessary to bring the analyte concentration within the optimal range of the method, and for each dilution at least two separate aliquots of each sample were analyzed. Replicate determinations minimize errors owing to dilution, contamination, and analytical imprecision. Reported concentrations are the means, excluding outliers, of the replicate determinations.

Spike recoveries for total Sb were performed by spiking samples with an Sb stock solution and then analyzing the spiked and unspiked samples by hydride-generation atomic-absorption spectrometry (HGAAS). The recoveries for samples from Ojo Caliente and Lemonade Creek were 112 and 109 percent, respectively. McCleskey and others (2004) reported spike recoveries ranging from 82 to 105 percent for 17 elements in Yellowstone samples analyzed by ICP–OES.

Concentrations of F, Al, As(T), Fe(T), Cd, Co, Cr, Cu, Ni, Pb, Sb(T), and Se were determined by more than one method. Comparing analytical results from two alternative methods can serve as an accuracy check, although in all cases one method was preferred over the other depending on sample matrix and proximity to the method detection limit. Concentrations of Al, As(T), Fe(T), Cd, Co, Cr, Cu, Ni, Pb, Sb(T), and Se were determined by ICP–OES as well as by the

preferred HGAAS method for As(T) and Sb(T), FerroZine method for Fe(T), and GFAAS for Al, Cd, Co, Cr, Cu, Pb, and Se. Concentrations of Al were measured by GFAAS only for samples that were below the ICP-OES detection limit. Cadmium, Co, Cr, Cu, Pb, and Se concentrations were near or below the ICP-OES detection limit for nearly all samples. Therefore, for these constituents comparison with the preferred method was of little value. The data reported in Tables 6–14 were obtained using the preferred method unless there was insufficient sample volume to perform the determinations.

Comparison of analytical results from alternative methods for F, total dissolved As, and total dissolved Fe are shown in figures 39 A to C. For the 2003 samples, F concentrations were determined by both ion chromatography and ion-selective electrode (fig. 39A). The authors have observed that F concentrations determined by ion chromatography using the AS4 column set are susceptible to errors owing to irresolvable organic-acid peaks and shifts in retention times caused by high concentrations of Cl or SO_4. These samples often could not be diluted because doing so would have diluted F below its quantitation limit. Specific-ion electrode results for F are reported for the 2003 samples. For the 2004 and 2005 samples, F was determined by ion chromatography using the AS14 column set. The AS14 column set resolves the F peak from the water dip and organic-acid peaks and determinations are not as susceptible to the errors that affect the AS4 column set. The analyses for both Fe and As were from two separate sample bottles (concentrations of As by HGAAS and Fe by FerroZine were determined on a subsample preserved with HCl, whereas the ICP–OES determinations were done on a subsample preserved with HNO_3). Arsenic concentrations determined by ICP–OES are frequently higher than HGAAS. The difference in the arsenic measurements most likely is due to the difference in sample preservation. Samples containing high S^{2-} concentrations may form As-S precipitates when preserved with HCl. With only a few exceptions, Fe concentrations determined by FerroZine and by ICP–OES are in good agreement. Results for the sample preserved with HCl are reported because the redox species concentrations were obtained from this split. The largest differences in Fe concentration were for samples from Jade Pool (03WA156), Mound Spring (03WA113), and one of the Washburn inkpots (03WA128). The uncertainty line was calculated based on the method with the higher detection limit. At the method detection limit the uncertainty is ±100 percent and decreases to ±5 percent at 20 times the detection limit (quantitation limit). Considering the uncertainty of the measurements and that the analyses were performed on different splits, analytical results for total dissolved As and total dissolved Fe obtained by the alternative methods are in good agreement.

Table 15. Measurement of concentrations of dissolved constituents in standard reference water samples

[CVAFS, cold–vapor atomic–fluorescence spectrometry; GFAAS, graphite–furnace atomic–absorption spectrometry; HGAAS, hydride–generation atomic–absorption spectrometry; IC, ion chromatography; ICP–OES, inductively coupled plasma–optical emission spectrometry; ISE, ion–selective electrode; mg/L, milligrams per liter; n, number of analyses; ng/L, nanograms per liter; s, standard deviation; SRWS, standard reference water sample; USGS, U.S. Geological Survey; %RSD, percent relative standard deviation; <, less than; ---, no data]

Analyte	Analytical Method	USGS SRWS	n	mg/L	s	%RSD	Most Probable Value, mg/L	Percent Difference
Calcium (Ca)	ICP-OES	AMW-4	9	344	11	3	338	1.7
Calcium (Ca)	ICP-OES	M166	5	30.8	1.6	5	31.3	-1.7
Calcium (Ca)	ICP-OES	T115	1	51.0	---	---	50.9	0.3
Calcium (Ca)	ICP-OES	T163	5	6.02	0.34	6	6.3	-4.4
Calcium (Ca)	ICP-OES	T173	4	35.0	0.9	3	34.8	0.5
Calcium (Ca)	ICP-OES	T179	3	18.3	0.6	3	18.9	-3.2
Calcium (Ca)	ICP-OES	T181	3	13.1	0.6	5	13.4	-2.6
Magnesium (Mg)	ICP-OES	AMW-4	9	127	2	1	125	1.5
Magnesium (Mg)	ICP-OES	M166	5	18.4	1.4	8	18.5	-0.3
Magnesium (Mg)	ICP-OES	T115	1	28.2	---	---	27.6	2.3
Magnesium (Mg)	ICP-OES	T163	5	1.32	0.06	4	1.23	7.3
Magnesium (Mg)	ICP-OES	T173	4	9.53	0.40	4	9.38	1.6
Magnesium (Mg)	ICP-OES	T179	3	4.57	0.04	1	4.59	-0.4
Magnesium (Mg)	ICP-OES	T181	3	3.13	0.07	2	3.05	2.5
Sodium (Na)	ICP-OES	AMW-4	7	23.5	1.2	5	22.7	3.6
Sodium (Na)	ICP-OES	M166	5	25.5	0.5	2	25.1	1.5
Sodium (Na)	ICP-OES	T115	1	137	---	---	140	-2.0
Sodium (Na)	ICP-OES	T163	5	41.8	1.0	2	39.6	5.6
Sodium (Na)	ICP-OES	T173	4	37.2	1.4	4	36.5	2.0
Sodium (Na)	ICP-OES	T179	3	27.2	0.7	3	26.2	3.7
Sodium (Na)	ICP-OES	T181	3	15.4	0.1	0	15.0	2.4
Potassium (K)	ICP-OES	AMW-4	15	3.98	0.45	11	3.58	11
Potassium (K)	ICP-OES	M166	5	4.39	0.25	6	4.37	0.5
Potassium (K)	ICP-OES	T115	1	6.84	---	---	5.41	26
Potassium (K)	ICP-OES	T163	4	1.02	0.04	3	1.02	-0.1
Potassium (K)	ICP-OES	T173	4	4.15	0.14	3	3.85	7.9
Potassium (K)	ICP-OES	T179	3	1.42	0.07	5	1.40	1.2
Potassium (K)	ICP-OES	T181	3	1.40	0.08	5	1.52	-7.6
Strontium (Sr)	ICP-OES	AMW-4	9	1.46	0.08	6	1.47	-1.2
Strontium (Sr)	ICP-OES	M166	5	0.245	0.013	5	0.249	-1.8
Strontium (Sr)	ICP-OES	SRWS67	1	0.388	---	---	0.375	3.4
Strontium (Sr)	ICP-OES	SRWS69	1	0.647	---	---	0.612	5.7
Strontium (Sr)	ICP-OES	T115	1	0.700	---	---	0.672	4.2
Strontium (Sr)	ICP-OES	T173	4	0.279	0.005	2	0.279	0.2
Strontium (Sr)	ICP-OES	T179	3	0.114	0.003	3	0.113	0.5
Strontium (Sr)	ICP-OES	T181	3	0.082	0.001	1	0.0816	0.7
Barium (Ba)	ICP-OES	AMW-4	15	0.008	0.00	9	0.009	-12
Barium (Ba)	ICP-OES	SRWS67	1	0.236	---	---	0.219	7.6
Barium (Ba)	ICP-OES	SRWS69	1	0.036	---	---	0.043	-16
Barium (Ba)	ICP-OES	T115	1	0.252	---	---	0.250	0.8
Barium (Ba)	ICP-OES	T163	4	0.007	0.001	10	0.0074	-3.5
Barium (Ba)	ICP-OES	T173	4	0.042	0.001	3	0.0422	-0.7
Barium (Ba)	ICP-OES	T179	3	0.037	0.001	3	0.036	2.2
Barium (Ba)	ICP-OES	T181	3	0.026	0.001	5	0.0255	3.8

Table 15. Measurement of concentrations of dissolved constituents in standard reference water samples—Continued

Analyte	Analytical Method	USGS SRWS	n	mg/L	s	%RSD	Most Probable Value, mg/L	Percent Difference
Lithium (Li)	ICP-OES	AMW-4	15	0.086	0.012	14	0.068	27
Lithium (Li)	ICP-OES	SRWS67	1	0.645	---	---	0.627	2.8
Lithium (Li)	ICP-OES	SRWS69	1	0.418	---	---	0.397	5.2
Lithium (Li)	ICP-OES	T115	1	0.150	---	---	0.132	14
Lithium (Li)	ICP-OES	T163	3	<0.002	---	---	0.0016	---
Lithium (Li)	ICP-OES	T173	4	0.018	0.002	10	0.0171	2.6
Lithium (Li)	ICP-OES	T179	3	0.0065	0.001	8	0.0065	-0.1
Lithium (Li)	ICP-OES	T181	3	0.0075	0.001	10	0.0084	-10.5
Sulfate (SO_4)	IC	M150	4	5.97	0.80	13	5.5	8.5
Sulfate (SO_4)	IC	M158	8	109	0.19	0.2	105	3.8
Sulfate (SO_4)	IC	M166	19	55.7	1.5	2.6	56.2	-0.9
Sulfate (SO_4)	IC	M172	8	12.4	0.6	4.5	12.3	0.9
Alkalinity (HCO_3)	Titration	M134	4	75.8	1.0	1.3	76.69	-1.2
Alkalinity (HCO_3)	Titration	M156	2	76.0	1.6	2.0	75.35	0.8
Alkalinity (HCO_3)	Titration	M158	1	76.1	---	---	77.55	-1.9
Fluoride (F)	IC	M102	2	1.08	0.03	2.8	1.1	-1.7
Fluoride (F)	IC	M136	2	1.11	0.07	6.2	1.04	6.8
Fluoride (F)	ISE	M136	1	1.29	---	---	1.04	24
Fluoride (F)	IC	M140	4	0.55	0.07	13.0	0.53	3.1
Fluoride (F)	IC	M150	4	1.08	0.16	14.3	1	8.4
Fluoride (F)	ISE	M156	3	0.46	0.10	22.1	.523	-13
Fluoride (F)	IC	M158	8	0.37	0.03	7.5	0.350	6.0
Fluoride (F)	IC	M166	2	0.71	0.01	1.6	0.69	2.6
Fluoride (F)	ISE	M166	1	0.75	---	---	0.69	8.1
Fluoride (F)	IC	M172	6	0.43	0.01	3.1	0.38	13
Chloride (Cl)	IC	M102	2	45.3	0.5	1.1	44.0	2.9
Chloride (Cl)	IC	M140	4	28.1	0.6	2.2	25.8	8.8
Chloride (Cl)	IC	M150	4	19.4	0.1	0.7	17.0	14
Chloride (Cl)	IC	M166	7	36.7	0.3	0.9	36.4	0.7
Chloride (Cl)	IC	M172	8	16.0	0.2	1.3	16.0	-0.3
Nitrate (NO_3)	IC	M136	2	12.5	0.8	6.7	---	---
Nitrate (NO_3)	IC	M140	4	0.24	0.06	23.4	---	---
Nitrate (NO_3)	IC	M150	4	8.25	0.51	6.2	---	---
Nitrate (NO_3)	IC	M158	6	0.61	0.01	2.0	---	---
Nitrate (NO_3)	IC	M172	8	0.09	0.03	35	---	---
Silica (SiO_2)	ICP-OES	AMW-4	9	51.9	3.4	7	52.3	-0.7
Silica (SiO_2)	ICP-OES	M166	5	12.3	0.4	3	11.7	5.1
Silica (SiO_2)	ICP-OES	T115	1	10.2	---	---	9.90	2.9
Silica (SiO_2)	ICP-OES	T163	5	4.66	0.08	2	4.56	2.3
Silica (SiO_2)	ICP-OES	T173	4	11.2	0.3	3	11.1	0.5
Silica (SiO_2)	ICP-OES	T179	3	14.9	0.8	5	14.9	-0.1
Silica (SiO_2)	ICP-OES	T181	3	13.5	0.8	6	13.1	3.2
Boron (B)	ICP-OES	M166	5	0.140	0.015	11	0.15	-6.6
Boron (B)	ICP-OES	T115	1	0.091	---	---	0.099	-8.3
Boron (B)	ICP-OES	T163	2	0.010	0.0001	1	0.0106	-2.9
Boron (B)	ICP-OES	T173	4	0.145	0.018	12	0.158	-8.1
Boron (B)	ICP-OES	T179	3	0.025	0.001	4	0.028	-9.2
Boron (B)	ICP-OES	T181	3	0.019	0.001	5	0.021	-11

Table 15. Measurement of concentrations of dissolved constituents in standard reference water samples—Continued

Analyte	Analytical Method	USGS SRWS	n	mg/L	s	%RSD	Most Probable Value, mg/L	Percent Difference
Aluminum (Al)	ICP-OES	AMW-4	9	29.0	1.2	4	29.2	-0.8
Aluminum (Al)	ICP-OES	SRWS67	1	<0.07	---	---	0.018	---
Aluminum (Al)	ICP-OES	SRWS69	1	0.611	---	---	0.620	-1.5
Aluminum (Al)	ICP-OES	T115	1	<0.07	---	---	0.040	---
Aluminum (Al)	ICP-OES	T163	5	<0.07	---	---	0.0168	---
Aluminum (Al)	ICP-OES	T173	4	<0.07	---	---	0.071	---
Aluminum (Al)	ICP-OES	T179	3	<0.07	---	---	0.0517	---
Aluminum (Al)	GFAAS	T179	1	0.0553	---	---	0.0517	7.0
Aluminum (Al)	ICP-OES	T181	3	<0.07	---	---	0.0162	---
Aluminum (Al)	GFAAS	T181	9	0.0162	0.0001	0	0.0162	0.0
Iron total (Fe(T))	FerroZine	AMW-4	6	189	6.1	3.2	188	0.5
Iron total (Fe(T))	ICP-OES	AMW-4	9	198	8	4	188	5.5
Iron total (Fe(T))	ICP-OES	SRWS67	1	0.748	---	---	0.760	-1.6
Iron total (Fe(T))	ICP-OES	SRWS69	1	0.208	---	---	0.223	-6.9
Iron total (Fe(T))	ICP-OES	T115	1	1.21	---	---	1.175	3.0
Iron total (Fe(T))	FerroZine	T163	2	0.060	0.0003	0.4	0.060	0.8
Iron total (Fe(T))	ICP-OES	T163	3	0.056	0.005	9	0.06	-5.9
Iron total (Fe(T))	FerroZine	T179	1	0.118	---	---	0.125	-5.4
Iron total (Fe(T))	ICP-OES	T179	3	0.107	0.026	24	0.125	-14
Iron total (Fe(T))	ICP-OES	T181	3	0.104	0.025	24	0.119	-13
Manganese (Mn)	ICP-OES	AMW-4	9	114	6	5	106	8.0
Manganese (Mn)	ICP-OES	SRWS67	1	0.594	---	---	0.571	4.1
Manganese (Mn)	ICP-OES	SRWS69	1	0.237	---	---	0.224	5.7
Manganese (Mn)	ICP-OES	T115	1	0.444	---	---	0.455	-2.4
Manganese (Mn)	ICP-OES	T173	4	0.495	0.011	2	0.495	0.0
Manganese (Mn)	ICP-OES	T179	3	0.043	0.003	8	0.0442	-3.4
Manganese (Mn)	ICP-OES	T181	3	0.010	0.004	38	0.0116	-14
Copper (Cu)	ICP-OES	AMW-4	9	5.97	0.26	4	6.12	-2.4
Copper (Cu)	ICP-OES	SRWS67	1	0.024	---	---	0.027	-12
Copper (Cu)	ICP-OES	SRWS69	1	0.312	---	---	0.297	5.0
Copper (Cu)	ICP-OES	T115	1	0.018	---	---	0.017	3.2
Copper (Cu)	ICP-OES	T163	2	0.035	0.004	10	0.0358	-2.9
Copper (Cu)	GFAAS	T163	3	0.0308	0.0038	13	0.0358	-14.0
Copper (Cu)	ICP-OES	T173	3	0.005	0.003	54	0.0075	-35
Copper (Cu)	GFAAS	T173	3	0.0076	0.0015	20	0.0075	1.3
Copper (Cu)	ICP-OES	T179	3	0.004	0.001	20	0.00386	5.1
Copper (Cu)	GFAAS	T179	9	0.0039	0.0002	6	0.00386	0.7
Copper (Cu)	ICP-OES	T181	3	0.008	0.001	13	0.00779	1.3
Copper (Cu)	GFAAS	T181	9	0.0077	0.0002	2	0.00779	-1.5
Zinc (Zn)	ICP-OES	AMW-4	9	63.6	4.3	7	54.0	18
Zinc (Zn)	ICP-OES	T163	2	0.018	0.001	4	0.0185	-0.4
Zinc (Zn)	ICP-OES	T173	3	0.357	0.021	6	0.348	2.5
Zinc (Zn)	ICP-OES	T179	3	0.009	0.001	11	0.0085	1.9
Zinc (Zn)	ICP-OES	T181	3	0.011	0.001	8	0.0105	0.9
Cadmium (Cd)	ICP-OES	AMW-4	9	0.193	0.015	8	0.175	10
Cadmium (Cd)	ICP-OES	SRWS67	1	0.010	---	---	0.010	8.7
Cadmium (Cd)	ICP-OES	T115	1	0.014	---	---	0.014	1.4
Cadmium (Cd)	ICP-OES	T163	3	0.0069	0.0003	5	0.00659	4.7
Cadmium (Cd)	GFAAS	T163	4	0.0066	0.0003	4	0.0066	0.1
Cadmium (Cd)	ICP-OES	T173	3	0.0012	0.0004	31	0.00126	-8.0
Cadmium (Cd)	GFAAS	T173	2	0.0016	0.0002	12	0.0013	27.1
Cadmium (Cd)	ICP-OES	T179	3	0.0047	0.0002	4	0.00442	6.9
Cadmium (Cd)	GFAAS	T179	25	0.0045	0.0002	4	0.00442	1.1
Cadmium (Cd)	ICP-OES	T181	3	0.0017	0.0002	11	0.0016	6.5
Cadmium (Cd)	GFAAS	T181	11	0.0020	0.0001	7	0.0016	25.3

Table 15. Measurement of concentrations of dissolved constituents in standard reference water samples—Continued

Analyte	Analytical Method	USGS SRWS	n	mg/L	s	%RSD	Most Probable Value, mg/L	Percent Difference
Chromium (Cr)	ICP-OES	AMW-4	9	0.185	0.017	9	0.12	54
Chromium (Cr)	ICP-OES	SRWS67	1	0.032	---	---	0.028	15
Chromium (Cr)	ICP-OES	SRWS69	1	0.004	---	---	0.005	-19
Chromium (Cr)	ICP-OES	T115	1	0.036	---	---	0.036	0.8
Chromium (Cr)	ICP-OES	T163	3	0.039	0.003	7	0.0401	-1.7
Chromium (Cr)	GFAAS	T163	5	0.046	0.001	2	0.0401	15.4
Chromium (Cr)	ICP-OES	T173	3	0.004	0.003	62	0.00488	-15
Chromium (Cr)	ICP-OES	T179	3	0.005	0.001	11	0.00422	7.9
Chromium (Cr)	GFAAS	T179	9	0.0046	0.0003	7	0.00422	10.2
Chromium (Cr)	ICP-OES	T181	3	0.006	0.001	16	0.00564	4.7
Chromium (Cr)	GFAAS	T181	9	0.0059	0.0004	6	0.00564	5.0
Cobalt (Co)	ICP-OES	AMW-4	9	0.183	0.015	8	0.165	11
Cobalt (Co)	ICP-OES	SRWS67	1	0.010	---	---	0.012	-15
Cobalt (Co)	ICP-OES	SRWS69	1	0.010	---	---	0.014	-28
Cobalt (Co)	ICP-OES	T115	1	0.016	---	---	0.015	1.2
Cobalt (Co)	GFAAS	T159	6	0.0141	0.0006	4	0.0133	6.0
Cobalt (Co)	ICP-OES	T163	3	0.011	0.003	23	0.012	-7.7
Cobalt (Co)	GFAAS	T163	17	0.0125	0.0011	9	0.012	4.1
Cobalt (Co)	ICP-OES	T173	3	<0.004	---	---	0.00126	---
Cobalt (Co)	GFAAS	T173	2	0.0014	0.0003	22	0.0013	9.8
Cobalt (Co)	ICP-OES	T179	3	<0.004	---	---	0.0011	---
Cobalt (Co)	ICP-OES	T181	3	0.005	0.001	22	0.0055	-4.8
Cobalt (Co)	GFAAS	T181	9	0.0056	0.0005	9	0.0055	2.6
Mercury (Hg)[1]	CVAFS	Hg7	69	239	26	11	220	8.7
Mercury (Hg)[1]	CVAFS	Hg15	51	423	46	11	410	3.1
Mercury (Hg)[1]	CVAFS	Hg26	58	680	53	8	700	-2.9
Nickel (Ni)	ICP-OES	AMW-4	9	0.327	0.034	10	0.269	22
Nickel (Ni)	ICP-OES	SRWS69	1	0.020	---	---	0.018	6.2
Nickel (Ni)	ICP-OES	T115	1	0.014	---	---	0.017	-18
Nickel (Ni)	ICP-OES	T163	3	0.016	0.002	14	0.0154	1.3
Nickel (Ni)	ICP-OES	T173	3	0.004	0.002	52	0.00538	-22
Nickel (Ni)	ICP-OES	T179	3	<0.002	---	---	0.00141	---
Nickel (Ni)	ICP-OES	T181	3	0.005	0.001	27	0.00472	-0.7
Nickel (Ni)	GFAAS	T181	19	0.0050	0.0006	13	0.00472	5.7
Lead (Pb)	ICP-OES	AMW-4	15	0.055	0.007	13	0.034	63
Lead (Pb)	ICP-OES	SRWS67	1	<0.009	---	---	0.005	---
Lead (Pb)	ICP-OES	SRWS69	1	0.016	---	---	0.023	-30
Lead (Pb)	ICP-OES	T115	1	0.007	---	---	0.013	-43
Lead (Pb)	GFAAS	T159	3	0.0171	0.0009	5	0.0166	3.0
Lead (Pb)	ICP-OES	T163	3	0.036	0.002	5	0.032	11
Lead (Pb)	ICP-OES	T173	3	<0.009	---	---	0.00459	---
Lead (Pb)	GFAAS	T173	4	0.0046	0.0002	4	0.0046	-0.2
Lead (Pb)	ICP-OES	T179	3	<0.009	---	---	0.00186	---
Lead (Pb)	GFAAS	T179	8	0.0019	0.0001	4	0.00186	0.0
Lead (Pb)	ICP-OES	T181	3	0.009	0.002	24	0.0094	-9.2
Lead (Pb)	GFAAS	T181	8	0.0094	0.0001	1	0.0094	0.0
Beryllium (Be)	ICP-OES	AMW-4	15	0.039	0.002	5	0.038	2.6
Beryllium (Be)	ICP-OES	SRWS67	1	0.045	---	---	0.044	1.8
Beryllium (Be)	ICP-OES	SRWS69	1	0.031	---	---	0.032	-1.4
Beryllium (Be)	ICP-OES	T115	1	0.051	---	---	0.054	-4.1
Beryllium (Be)	ICP-OES	T163	5	0.022	0.001	3	0.022	0.0
Beryllium (Be)	ICP-OES	T173	4	0.001	0.001	89	0.002	-40
Beryllium (Be)	ICP-OES	T179	3	0.0038	0.00004	1	0.00374	2.7
Beryllium (Be)	ICP-OES	T181	3	0.0047	0.0002	5	0.0046	1.3

Table 15. Measurement of concentrations of dissolved constituents in standard reference water samples—Continued

Analyte	Analytical Method	USGS SRWS	n	mg/L	s	%RSD	Most Probable Value, mg/L	Percent Difference
Vanadium (V)	ICP-OES	AMW-4	15	0.125	0.010	8	0.116	7.8
Vanadium (V)	ICP-OES	M166	3	0.017	0.001	8	0.0172	-3.6
Vanadium (V)	ICP-OES	T115	1	0.017	---	---	0.017	-2.9
Vanadium (V)	ICP-OES	T163	3	0.035	0.001	3	0.035	1.3
Vanadium (V)	ICP-OES	T173	3	0.004	0.001	38	0.00431	-17
Vanadium (V)	ICP-OES	T179	3	<0.002	---	---	0.00284	---
Vanadium (V)	ICP-OES	T181	3	0.003	0.001	49	0.00371	-26
Molybdenum (Mo)	ICP-OES	AMW-4	7	0.181	0.015	8	0.108	67
Molybdenum (Mo)	ICP-OES	SRWS67	1	0.026	---	---	0.026	1.7
Molybdenum (Mo)	ICP-OES	SRWS69	1	0.078	---	---	0.059	33
Molybdenum (Mo)	ICP-OES	T115	1	0.053	---	---	0.046	16
Molybdenum (Mo)	ICP-OES	T163	3	0.010	0.002	23	0.0126	-23
Molybdenum (Mo)	ICP-OES	T173	4	<0.007	---	---	0.00722	---
Molybdenum (Mo)	ICP-OES	T179	3	<0.007	---	---	0.00218	---
Molybdenum (Mo)	ICP-OES	T181	3	<0.007	---	---	0.00449	---
Antimony (Sb)	HGAAS	AMW-4	1	0.0029	---	---	0.0028	4.1
Antimony (Sb)	HGAAS	T163	5	0.031	0.004	13	0.0325	-3.2
Antimony (Sb)	HGAAS	T181	1	0.0034	---	---	0.0034	-0.9
Selenium (Se)	GFAAS	T159	5	0.0051	0.0001	2	0.0055	-6.5
Selenium (Se)	GFAAS	T161	6	0.0089	0.0002	3	0.0096	-7.2
Selenium (Se)	GFAAS	T179	10	0.0014	0.0002	13	0.0013	6.8
Selenium (Se)	GFAAS	T181	4	0.0012	0.0002	16	0.0013	-6.2
Arsenic total (As(T))	HGAAS	AMW-4	32	0.169	0.005	2.67	0.168	0.3
Arsenic total (As(T))	ICP-OES	AMW-4	9	0.207	0.017	8	0.168	23
Arsenic total (As(T))	HGAAS	T163	16	0.0245	0.0012	5.07	0.0253	-3.1
Arsenic total (As(T))	ICP-OES	T163	3	<0.03	---	---	0.0253	---
Arsenic total (As(T))	ICP-OES	T173	3	<0.03	---	---	0.00267	---
Arsenic total (As(T))	HGAAS	T179	2	0.0016	0.0000	1.02	0.0019	-16
Arsenic total (As(T))	ICP-OES	T179	3	<0.03	---	---	0.0019	---
Arsenic total (As(T))	HGAAS	T181	4	0.0055	0.0004	6.60	0.0061	-11
Arsenic total (As(T))	ICP-OES	T181	3	<0.03	---	---	0.0061	---

[1]Mercury concentrations are ng/L

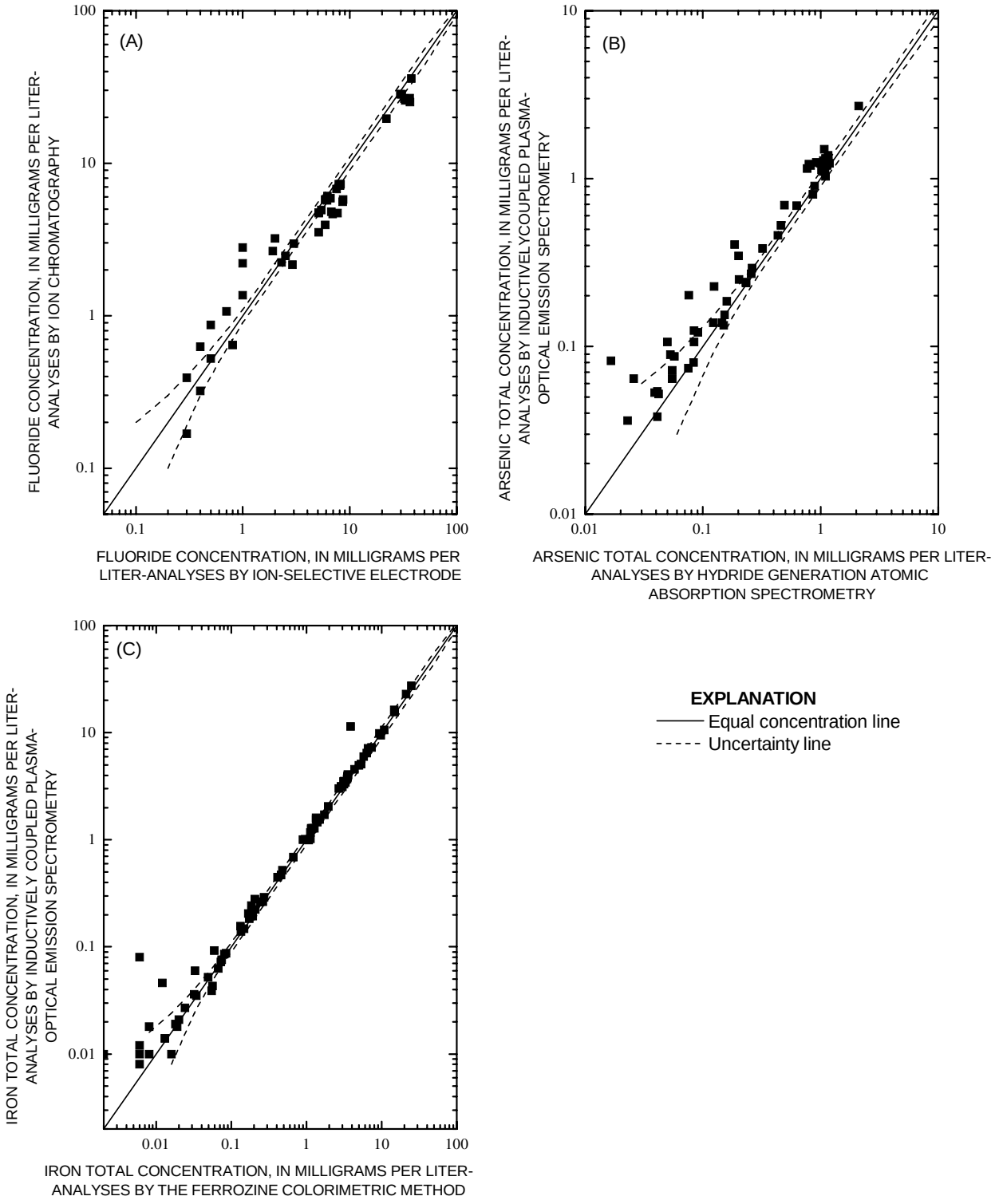


Figure 39. Graphs showing (A) fluoride, (B) total dissolved arsenic, and (C) total dissolved iron concentrations determined by alternative methods.

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APPENDIX
PHOTOGRAPHS

1

Park Geologist Hank Heasler and USGS scientist Kathy Janik at 03WA157, Beryl Spring

2

Sara LoVetere at 04WA146, Beryl Spring

3

Kirk Nordstrom and JoAnn Holloway collecting water samples at 04WA143, Terrace Spring

4

Blaine McCleskey and Kirk Nordstrom at 03WA123, Tantalus Creek at weir

5

Kirk Nordstrom positioning sampling line at 03WA149 - Tantalus Creek at weir

6

JoAnn Holloway, Sara LoVetere, and Kirk Nordstrom at 04WA117, Tantalus Creek at weir

7

Blaine McCleskey measuring temperature at 05WA130, Tantalus Creek at weir

8

05WA147, Tantalus Creek at weir

9

Kirk Nordstrom and Blaine McCleskey collecting water samples at 03WA116, Cinder Pool

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Blaine McCleskey, Kirk Nordstrom, Britta Planer-Friedrich, Beate Böhme, and two unidentified scientists at 03WA150, Cinder Pool

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Blaine McCleskey and Kirk Nordstrom collecting water samples at 04WA115, Cinder Pool

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05WA129, Cinder Pool

13

05WA140, Cinder Pool

14

JoAnn Holloway and Sara LoVetere collecting water samples at 04WA130, "Black Gassy Spring"

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04WA130, "Black Gassy Spring"

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03WA121, Cistern Spring

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Kirk Nordstrom and Virginia Rodriguez collecting water samples at 03WA143, Cistern Spring

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04WA116, Cistern Spring

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05WA134, Cistern Spring

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05WA141, Cistern Spring

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JoAnn Holloway and Blaine McCleskey collecting
water samples at 05WA152, Congress Pool

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Kirk Nordstrom collecting
water samples at 03WA141, Constant Geyser

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03WA120 Echinus Geyser

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03WA144, Echinus Geyser

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05WA151, Pearl Geyser

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04WA129, Perpetual Spouter from across Tantalus Creek

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Kirk Nordstrom measuring specific conductance and temperature at 05WA128, Perpetual Spouter

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Blaine McCleskey at 04WA128, 04WA127 in foreground

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04WA127 with Tantalus Creek in background

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03WA118, Porkchop Geyser

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Hank Haesler, Jim Ball, Kirk Nordstrom, and David Susong discussing science at 03WA145, Porkchop Geyser

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Kirk Nordstrom and Blaine McCleskey collecting water samples at 04WA144, Porkchop Geyser

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Kirk Nordstrom collecting water samples
at 03WA147, "Second Eruptor"

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Sara LoVetere, Kirk Nordstrom, and JoAnn Holloway
collecting water samples at 04WA145

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05WA127, "Second Eruptor"

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Blaine McCleskey and Kirk Nordstrom using the sampling
boom to position the sampling tubing at 05WA142

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03WA119

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David Susong measuring field properties at 03WA146

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05WA126

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03WA142 - Steamboat Geyser

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05WA131, Crystal Spring

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Kirk Nordstrom and Blaine McCleskey using the sampling boom to position the sampling tubing at 03WA122

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Blaine McCleskey, JoAnn Holloway, and Kirk Nordstrom collecting water samples 05WA132

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Specific conductance and temperature being measured at 03WA124

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Kirk Nordstrom measuring specific conductance and temperature at 03WA140

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04WA118

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Visiting scientists Beate Böhme and Britta Planer-Friedrich at 03WA151

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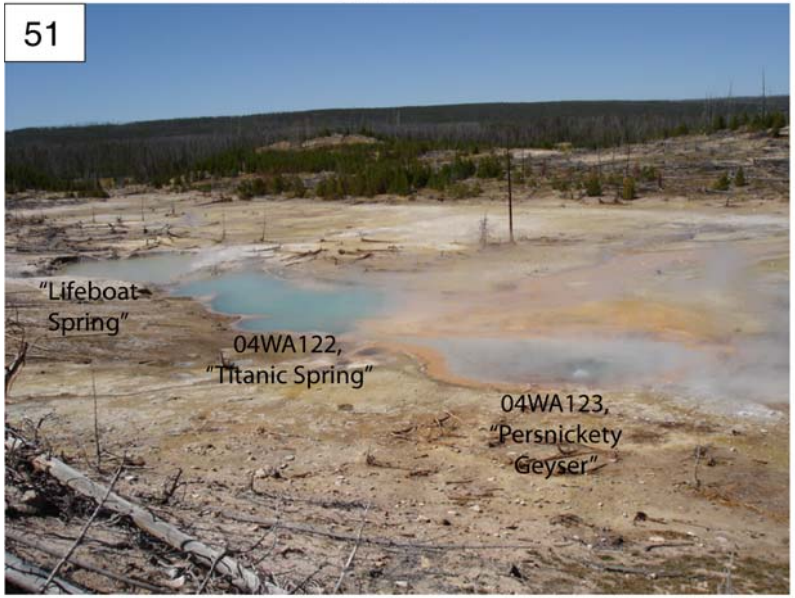
Sara LoVetere and Kirk Nordstrom at 04WA118, JoAnn Holloway at 04WA119

04WA120

Kirk Nordstrom and Blaine McCleskey measuring H_2S at 05WA133



"Lifeboat Spring", 04WA122, and 04WA123

03WA152

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04WA126

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Blaine McCleskey and Kirk Nordstrom collecting water samples at 03WA117, "Titanic Spring"

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03WA139, "Titanic Spring"

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JoAnn Holloway, Sara LoVetere, and Kirk Nordstrom collecting water samples at 04WA122, "Titanic Spring"

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04WA125

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04WA124

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04WA121

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Sara LoVetere, JoAnn Holloway, Blaine McCleskey collecting water samples at 04WA105

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Blaine McCleskey collecting water samples at 04WA106

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Peristaltic pump, battery, and GPS receiver at 04WA107

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Sara LoVetere, Jim Ball, Blaine McCleskey, and JoAnn Holloway collecting water samples at 04WA108

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Jim Ball, Britta Planer-Friedrich, Baas Bremer, and Blaine McCleskey collecting water samples at 04WA109

Close-up showing the bottom of 04WA110

Sara LoVetere, Blaine McCleskey, and JoAnn Holloway collecting water samples at 04WA110

Blaine McCleskey, JoAnn Holloway, and Kirk Nordstrom collecting water samples at 04WA110D

Sampling boom, sampling line, peristaltic pump, and battery at 04WA111

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Sara LoVetere at measuring pH 04WA112

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JoAnn Holloway measuring pH at 04WA113

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Blaine McCleskey, JoAnn Holloway, Sara LoVetere, and Kirk Nordstrom collecting water samples at 04WA114

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Blaine McCleskey using the sampling boom to place the sampling line at 05WA135, Frying Pan Spring

Blaine McCleskey collecting water samples at 05WA135, Frying Pan Spring; 05WA136 in foreground

JoAnn Holloway, Beate Böhme, and Britta Planer-Friedrich collecting water samples at 03WA136, Hazle Lake

03WA137, Hazle Lake

04WA134, close-up of Nymph Creek Springs vent

Sampling boom and sampling line at 04WA132, Nymphy Creek looking upstream

Sampling boom and sampling line at 04WA133, Flood Creek looking downstream

Susan King, Kirk Nordstrom, Sara LoVetere, and JoAnn Holloway collecting water samples at 04WA131

Sampling boom and sampling line at 04WA138, Azure Spring

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Kendra Maas, Blaine McCleskey, Kirk Nordstrom,Nick Rael, and JoAnn Holloway collecting water samples at 03WA133a Mound Spring

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Blaine McCleskey preparing to collect water samples at 04WA137, Mound Spring

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03WA134a Red Terrace Spring/Queen's Laundry

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Sampling boom and sampling line at 04WA138, Ojo Caliente Spring

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05WA111, 112, and 113, Mound Spring

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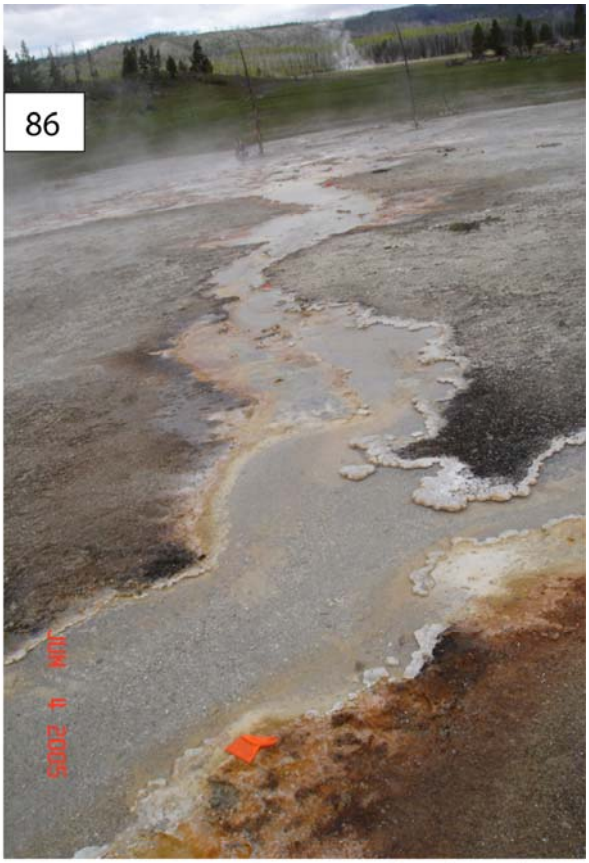

05WA113, Mound Spring overflow channel

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05WA114, 115, and 116, Mound Spring overflow channel

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05WA117, Mound Spring overflow channel

05WA105/106, Ojo Caliente Spring discharge channel

05WA107/108/109, Ojo Caliente Spring discharge channel

05WA108/109/110, Ojo Caliente Spring discharge channel

05WA109/110, Ojo Caliente Spring discharge channel

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JoAnn Holloway and Blaine McCleskey collecting water samples at 05WA101/102, Ojo Caliente Spring

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JoAnn Holloway and Blaine McCleskey sampling at 05WA102/103, Ojo Caliente Spring, Kirk Nordstrom with tourists in background

95

05WA105/106, Ojo Caliente Spring drainage channel

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Kendra Maas and Blaine McCleskey collecting water samples at 03WA135, Steep Cone

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Blaine McCleskey sampling at 04WA136, Steep Cone

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Jim Ball, Britta Planer-Friedrich, Beate Böhme, and Blaine McCleskey sampling at 03WA138

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Kirk Nordstrom and Blaine McCleskey sampling at 04WA140

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JoAnn Holloway and Blaine McCleskey sampling at 04WA141, Mound Geyser

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Sampling boom and sampling line at 04WA142

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03WA127, Washburn inkpot #1

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Blaine McCleskey sampling at 03WA128, Washburn Hot Springs

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03WA129 and 03WA130, Washburn Hot Springs

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03WA130, Washburn Hot Springs

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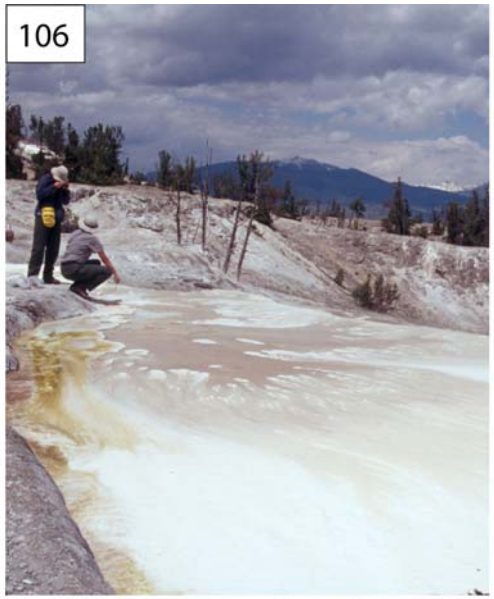

Kendra Maas and Tina Vesbach sampling at 03WA125 Angel Terrace

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Kirk Nordstrom and Nick Rael sampling at 03WA126 Canary Spring

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Nancy Hinman, Ralph Taylor, Kirk Nordstrom, JoAnn Holloway, and Beate Böhme sampling at 03WA154 - Explosion Pool

Kirk Nordstrom, Beate Böhme, and BrittaPlaner-Friedrich collecting water samples at 03WA156, Jade Pool

Beate Böhme, JoAnn Holloway, Kirk Nordstrom, and Britta Planer-Friedrich collecting water samples at 03WA153, Pince Nez Spring

Britta Planer-Friedrich and Kirk Nordstrom collecting water samples at 03WA155, Satellite to Explosion Pool

Nick Rael taking a GPS reading at 03WA132, Mud Geyser

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Nick Rael, Kirk Nordstrom, JoAnn Holloway, and Blaine McCleskey collecting water samples at 03WA131, Sulphur Caldron

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JoAnn Holloway and Blaine McCleskey collecting water samples at 05WA139, Sulphur Caldron

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04WA135

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Kirk Nordstrom measuring pH and specific conductance at 03WA148

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JoAnn Holloway, Beate Böhme, and Kirk Nordstrom collecting water samples at 03WA158

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03WA159

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Beate Böhme, Britta Planer-Friedrich, and Kirk Nordstrom collecting water samples at 03WA158

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05WA118

05WA118, 119, 120, and 121

Kirk Nordstrom positioning sampling equipment at 05WA120; 05WA121 in foreground

05WA122

Kirk Nordstrom positioning sampling equipment at 05WA123; 05WA124 in foreground

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05WA124

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05WA125

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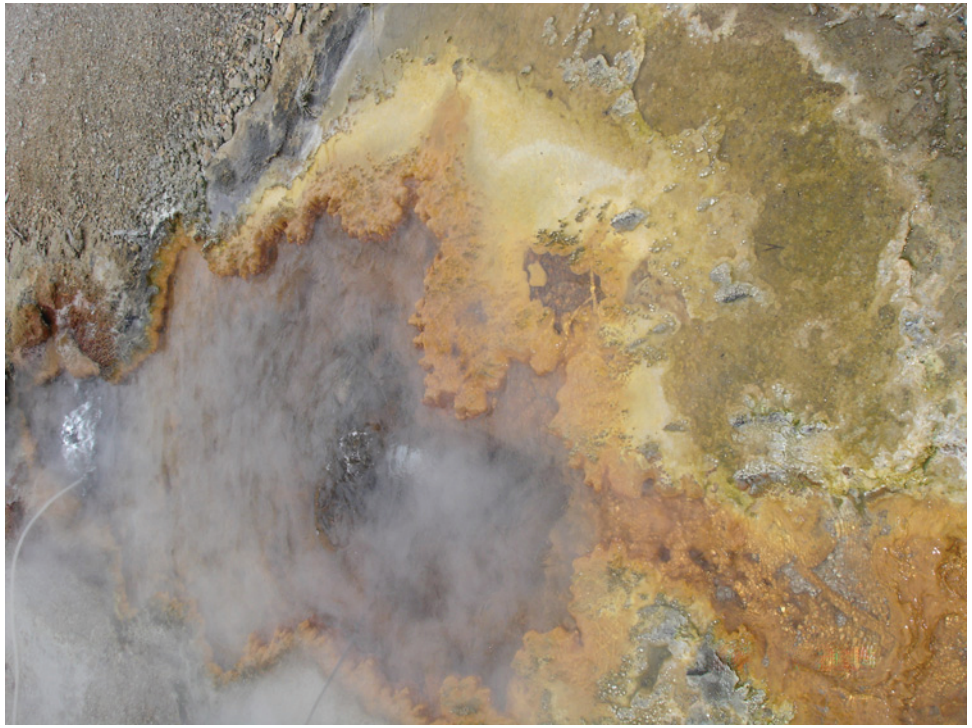
Kirk Nordstrom and JoAnn Holloway collecting water samples at 05WA125