

A grayscale topographic map of the Yellowstone region, showing the intricate terrain of the park and its surroundings. The map is the background of the entire page, with a large white letter 'L' in the top right corner.

Geochemical Data for Selected Rivers, Lake Waters, Hydrothermal Vents, and Subaerial Geysers in Yellowstone National Park, Wyoming and Vicinity, 1996–2004

By Pamela A. Gemery-Hill, Wayne C. Shanks, III, Laurie S. Balistrieri, and
Gregory K. Lee

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Contents

Abstract.....	367
Introduction.....	367
Study Area.....	368
Methods.....	368
Field Methods.....	368
Laboratory Methods.....	371
Results.....	373
Summary.....	377
Acknowledgments.....	379
References Cited.....	379

Figures

1. Map showing Yellowstone National Park with sampling areas.....	369
2. Detailed map of Yellowstone Lake with sample locations.....	370
3–6. Maps showing sample locations in:	
3. Norris Geyser Basin.....	375
4. Heart Lake Geyser Basin.....	376
5. Gibbon and Monument Geyser Basins area.....	377
6. Turbid Lake area.....	378

Table

1. Analytical methods.....	372
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Appendixes

1. Creeks and water-column profiles.....	382
2. Hydrothermal vents in Yellowstone Lake.....	398
3. 1999 mixing experiments.....	409
4. Subaerial hydrothermal features.....	419

Geochemical Data for Selected Rivers, Lake Waters, Hydrothermal Vents, and Subaerial Geysers in Yellowstone National Park, Wyoming and Vicinity, 1996–2004

By Pamela A. Gemery-Hill,¹ Wayne C. Shanks, III,¹ Laurie S. Balistrieri,² and Gregory K. Lee¹

Abstract

Analyses of more than 400 water samples collected from creeks and rivers draining into Yellowstone Lake, hydrothermal vents and water-column profiles within Yellowstone Lake, and subaerial hot springs and geysers throughout Yellowstone National Park (the Park) are reported. The samples were collected from 1996 to 2004. All of the water samples were collected and analyzed as part of the USGS Mineral Resources Program Project, Integrated Geoscience Studies of the Greater Yellowstone Area. Goals of this study are to provide state-of-the-art chemical determinations of more than 45 elements and species to help understand the influences of hydrothermal processes within Yellowstone National Park.

Hydrothermal vents within Yellowstone Lake were sampled during 1996–2004. Sampling of creeks contributing to Yellowstone Lake began in 1997 and continued through 1999. Four water-column profiles were collected within Yellowstone Lake in both 1997 and 1998. Water samples were collected from subaerial geysers and hot springs throughout Yellowstone National Park during 1998–2002.

In 1999, mixing experiments were conducted using water samples collected from four subaerial hot springs: three in Norris Geyser Basin and one at West Thumb Geyser Basin. These thermal-water samples were mixed with Yellowstone Lake water to simulate processes at sublacustrine vents and to evaluate conservative–nonconservative behavior of elements during mixing. The results of these experiments are discussed in Balistrieri and others (this volume), and the full data sets are presented here.

The data reported in this paper clearly show the influence of hydrothermal processes on waters within Yellowstone National Park. Yellowstone Lake hydrothermal-indicator elements (As, B, Cl, Cs, Cu, Ge, Hg, Li, Mo, Sb, and W) as defined by Balistrieri and others (this volume) delineate areas of hydrothermal influx. The differences in the levels of these elements between the creek data and water-column profiles indicate an influx of hydrothermal water within Yellowstone Lake. The water-column samples have higher values of the hydrothermal-indicator elements than the creeks flowing into the lake; therefore significant input of hydrothermal-indicator elements from the hydrothermal vents within the lake is indicated.

There are large variations in the values of the indicator elements among vents in Yellowstone Lake. The values of the hydrothermal-indicator elements are elevated for all of the vent samples, but a group of the West Thumb vents contain the highest values. This could indicate more active vents and (or) less mixing with lake water during sampling or during ascent to the lake floor. The subaerial features in the Park also show considerable variations in the values of the indicator elements. Some thermal features in the Park, such as Porkchop and Green Dragon Geysers in Norris Geyser Basin, have highly elevated hydrothermal-indicator-element values, while other features have values similar to Yellowstone Lake water, which is 99 percent meteoric water. These differences must reflect varying amounts of hydrothermal activity and input in these areas.

Introduction

Yellowstone National Park (the Park) was first designated as a National Park in 1872 for its scenic beauty and spectacular hydrothermal activity. Ten thousand thermal features and 300 geysers in the more than 2-million-acre park represent over half of the Earth's known hydrothermal

¹U.S. Geological Survey, Box 25046, MS 973, Denver Federal Center, Denver, CO 80225.

²U.S. Geological Survey, University of Washington, School of Oceanography, Box 357940, Seattle, WA 98195.

features and provide unique opportunities for research. Gooch and Whitfield (1888) were the first to carry out chemical analyses of thermal and surficial waters, and Allen and Day (1935) did the first extensive work. Beginning in the 1960s, the intensity of aqueous geochemical studies in Yellowstone has steadily increased (Ball, Nordstrom, Cunningham, and others, 1998; Ball, Nordstrom, Jenne, and Vivit, 1998; Ball and others, 2001, 2002; Balistrieri and others, this volume; Fournier, 1989; Kharaka and others, 1991, 2000; Thompson and others, 1975; Thompson and Yadav, 1979; Thompson and DeMonge, 1996; White and others, 1970, 1971, 1988). However, the development and widespread use of inductively coupled plasma (ICP) spectrographic methods in the late 1980s and early 1990s has led to a renaissance in trace-element geochemistry, with many more elements determined than by previous methods. For example, Balistrieri and others (this volume) have clearly shown that Mo and W are important geothermal elements, whereas most previous studies did not analyze for these elements. Balistrieri and others (this volume) conclude that As, B, Cl, Cs, Cu, Ge, Hg, Li, Mo, Sb, and W are important geothermal elements based on enrichments in Yellowstone Lake waters and in sublacustrine vent fluids. Shanks and others (this volume) would also include Tl, which is enriched in siliceous sinter deposits related to sublacustrine vents.

In the present study, water samples were collected from various sources throughout Yellowstone National Park and were analyzed for a suite of chemical components and stable-isotopic compositions to provide a basic understanding of the influences of hydrothermal processes on the water, sediments, and biota of Yellowstone Lake and surrounding areas. This report summarizes data on the geochemistry of water samples collected from creeks and rivers draining into and out of Yellowstone Lake, hydrothermal vents and water-column profiles within Yellowstone Lake, and subaerial geysers and hot springs throughout the Park. These different sources of water all contribute valuable information to the water chemistry in Yellowstone Lake and the Park as a whole. Sample locations, methods for collecting and analyzing the water samples, and analytical results are reported.

Study Area

All of the samples reported here were collected in Yellowstone National Park, which is situated in the northwest corner of Wyoming. The samples were collected throughout the Park concentrating around Yellowstone Lake and major hydrothermal areas, but with some lesser known hydrothermal areas also included (fig. 1).

Methods

Field Methods

Because very few water-quality data or discharge measurements were available for surface water flow into Yellowstone Lake, samples were collected during July 1997, August–September 1998, and July 1999 from the major streams that enter the lake (fig. 2). Locations were obtained by global positioning satellite (GPS), and the temperature and pH of the water were determined at each site. Point-source or integrated water samples were collected in 500-mL polyethylene bottles and brought to a field-based laboratory for processing. The bottles had been acid-washed and well rinsed with distilled, deionized water before use.

Estimates of stream discharge were made by timing floats and determining the cross-sectional area of the stream (in 1998) or by measuring the flow rate at 1 to 20 locations in a cross section of the stream using a velocity meter (in 1999). The accuracy of the flow estimates varied between years and sampling sites because different individuals used different methods at different times and because some streams could not be waded. Balistrieri and others (this volume) utilized these flow measurements to calculate a chemical mass balance for Yellowstone Lake and assess chemical fluxes. Because the U.S. Geological Survey (USGS) gages the Yellowstone River at its outlet from the lake (station 06186500), continuous discharge measurements from this site are available (<http://waterdata.usgs.gov>, accessed 5/18/04). Outflows from the lake during our sampling periods were 52 ± 3 and 156 ± 9 m³/s in 1998 and 1999, respectively. Balistrieri and others (this volume), by comparing total fluxes into the lake from as many as 44 streams, changes in lake level, and flux out of the lake at Fishing Bridge, were able to calculate a total error for all the stream-flow measurements of ± 22 percent relative to the measured flow at the gaging station.

Hydrothermal vent samples for this study were collected in the West Thumb, Mary Bay, and Stevenson Island areas (fig. 2). The West Thumb vent samples were from two shallow (≤ 5 m deep) vents and several vent fields at depths of 29–53 m. Shallow vent fluids from Mary Bay were collected near the shore off Steamboat Point and near Pelican Creek at depths of 7–10 m. Hydrothermal fluids were also collected from a deep hole in Mary Bay at depths of 48–54 m. Samples collected near Stevenson Island were from the deepest vents (95–110 m) in Yellowstone Lake.

All vent samples were collected with a submersible remotely operated vehicle (ROV) designed and piloted by Dave Lovalvo of Eastern Oceanics, Inc. Klump and others (1992) described an early version of that vehicle. Although the exact configuration of the vehicle varied from year to year, it always collected vent-fluid samples using piston-operated plastic syringes that were connected by

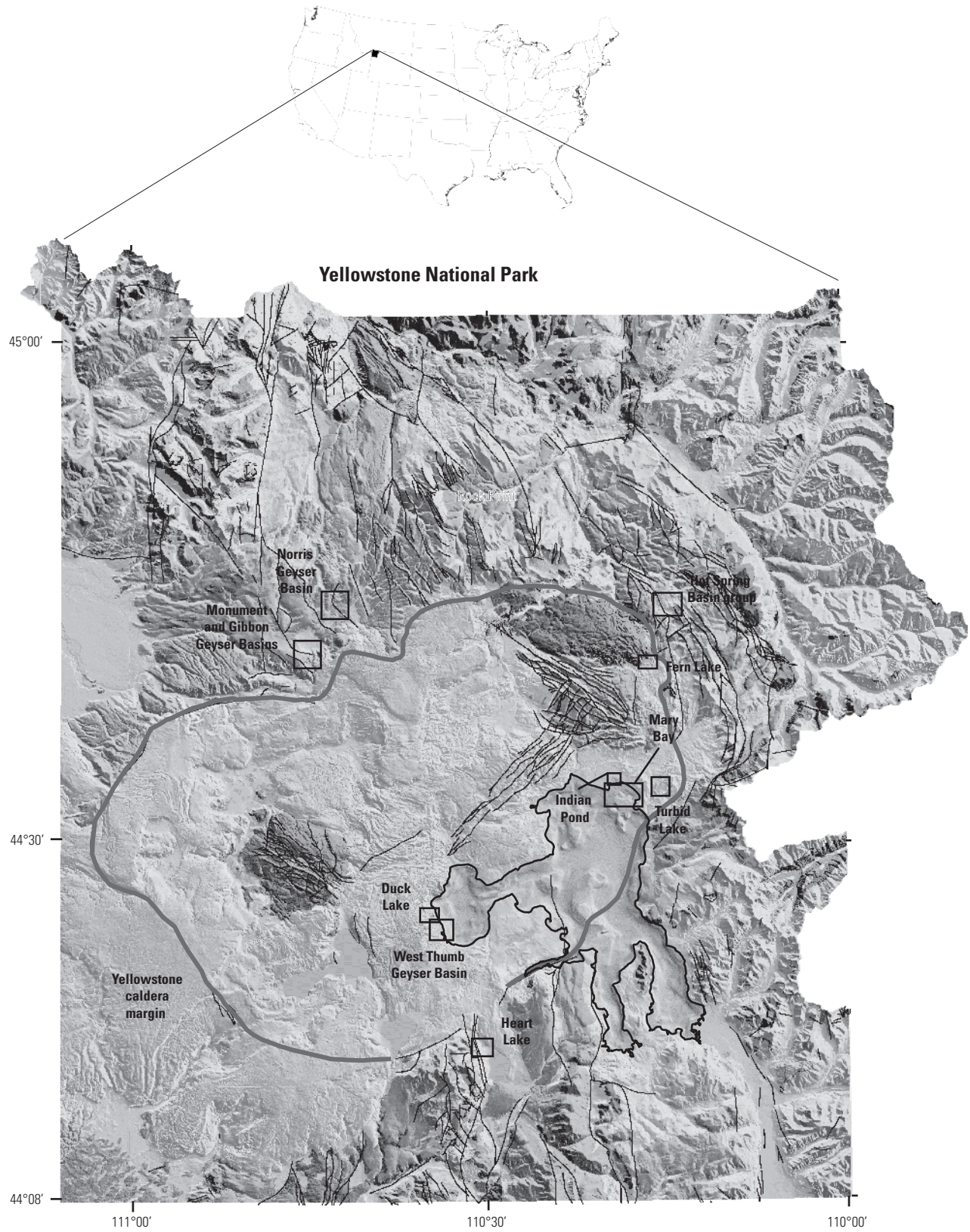


Figure 1. Map of Yellowstone National Park showing topography, faults (narrow black lines), and the caldera margin. Areas where multiple samples were collected are outlined with black rectangles and labeled accordingly.

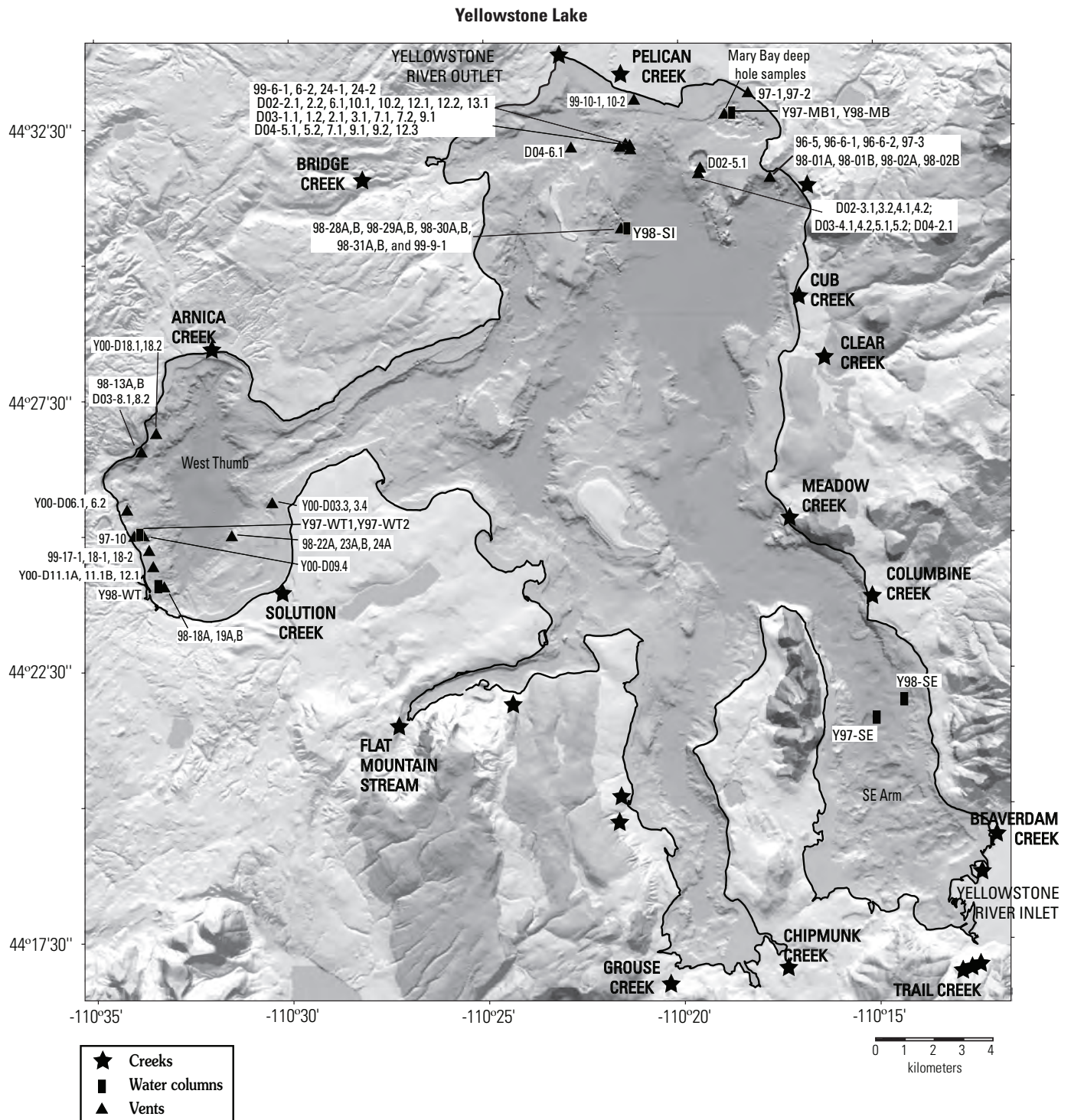


Figure 2. Detailed map of Yellowstone Lake with new bathymetry (see Morgan and others, this volume) showing locations of creeks and samples of water-column profiles and vents. Sampled from 1996–2004.

polypropylene tubing to an articulated and extendible probe. The temperature of each vent was continuously monitored during sample collection, and the probe was maintained in position by remotely maneuvering the submersible while making video observations in the control room of the support boat. After retrieval of the ROV, samples were transferred through 3-way valves from the syringes on the vehicle into other syringes for biological and chemical measurements. The vent samples were returned to the field-based laboratory for processing.

Samples from different depths in the water column of Yellowstone Lake were collected in Southeast Arm, West Thumb, and Mary Bay in July 1997 and 1998 and near Stevenson Island in July 1998 (fig. 2) using a trace-metal-clean hydrobottle (no internal cords) attached either to a Kevlar line, a Hydrolab cable, or the hydrowire on the research boat. All wire types produced consistent results with no evidence of contamination for the elements of interest. The water-column samples in Mary Bay were collected directly above the vents in the deep hole in Mary Bay. The water-column samples near Stevenson Island and from West Thumb were collected close to, but not directly above, known hydrothermal vents. Water-column samples from Southeast Arm were collected at least 10 km from any known hydrothermal vents. Water-column samples were placed in 500-mL acid-cleaned and well-rinsed polyethylene bottles on board the boat and returned to the field-based laboratory. In-place measurements of temperature, pH, conductivity, redox potential, and dissolved oxygen concentrations in the water column were made as a function of depth, using a Hydrolab, prior to collection of water samples. Those profiles were used to determine the depths for collection of water samples and to confirm that the entire water column was oxygenated at every site.

A large-volume (20 L) sample from the Yellowstone River at its outlet from Yellowstone Lake (near Fishing Bridge) (fig. 2) was collected in a low-density polyethylene container in July 1999. The sample was collected using Teflon tubing, an in-line 0.45- μm nylon-filter capsule, and a peristaltic pump. The sample was returned to the field-based laboratory for processing and for use in the mixing experiments described below.

Water samples from two subaerial geysers were collected from West Thumb Geyser Basin (Black Pool and Vandalized Pool) in September 1998. They were immediately filtered on-site using a 0.45- μm nylon filter. During July 1999, water samples were collected from three subaerial geysers in Norris Geyser Basin (Green Dragon, Echinus, and Porkchop Geysers) and from Black Pool at West Thumb Geyser Basin using a peristaltic pump with Teflon tubing and an in-line 0.45- μm nylon-filter capsule. These particular geysers were chosen because they are indicative of the spectrum of hydrothermal fluids observed in the Park. Water samples from Porkchop, Black Pool, and Vandalized Pool are neutral to alkaline and Cl-rich. The hydrothermal fluids from Green Dragon and Echinus

are acidic and enriched in SO_4 and Cl. Geyser waters collected in 1999 were immediately mixed with filtered water collected from the Yellowstone Lake outlet at Fishing Bridge in 500-mL polyethylene bottles in proportions ranging from 10- (samples G1–W1) to 100-percent (samples G10–W10) geyser water. The temperatures of the mixtures were maintained by insulating the bottles. The samples were processed at the field-based laboratory less than 2 hours after mixing.

Water samples from many subaerial geysers throughout Yellowstone National Park were collected from 1998 through 2002. The samples generally were collected from the center or most active upwelling area of the geyser pools using an extendable, rigid sampling device. Temperature and pH were measured on site. Samples YNP-00-528.1 and 528.5 are duplicate water samples from an acidic Monument Geyser Basin hot spring. These duplicate samples were used to test for contamination related to an extendible aluminum sampling tool, which we use to place our polyethylene sampling bottles in the hottest portion of the spring. Sample 528.1 was collected using the sampling tool, whereas sample 528.5 was collected from the same spot using a polyethylene bottle on nylon line. Comparison of the data from these 2 samples (see appendix 4) indicates that the sampler is noncontaminating.

Laboratory Methods

Values of pH of vent fluids, water-column samples, and mixed solutions were determined at the field-based laboratory after standardizing a pH meter and electrode using six buffer solutions ranging from pH 1.68 to 10. Subsamples of all water samples were taken for analysis of dissolved elements, Hg, anions, oxygen-isotope values ($\delta^{18}\text{O}$), hydrogen isotope values (δD), and either alkalinity or dissolved inorganic carbon. Subsamples of water for sulfur isotopes of sulfide and sulfate ($\delta^{34}\text{S}_{\text{H}_2\text{S}}$, $\delta^{34}\text{S}_{\text{SO}_4}$) were collected where sufficient water was available. Samples for anion and dissolved-element determinations were obtained by filtering the water through 0.45- μm disposable nylon filters into new polyethylene bottles for anions; into acid-washed, well-rinsed polyethylene bottles for dissolved elements; and into acid-washed glass bottles with Teflon caps for Hg. Samples for dissolved Hg analyses were preserved with Ultrex concentrated HNO_3 , saturated with sodium dichromate, to prevent volatilization of Hg. Anion samples were kept cool prior to analysis, whereas samples to be analyzed for dissolved elements were preserved by adding one drop of redistilled concentrated nitric acid per 10 mL of sample solution. Anion analyses of vent and water-column samples from 1996–1999 were by ion chromatography at the field-based laboratory. Anion analyses of all other water samples were by ion chromatography in the USGS laboratories in Denver, Colo. (Theodorakos, 2002). Dissolved elements were determined at the USGS laboratories in Denver, using inductively coupled plasma–atomic

Table 1. Analytical methods.

Descriptor	Method	Species determined (reported)	Equipment used	References or comments
ICP-MS	Inductively coupled plasma–mass spectrometry	Ag, Al, As, Au, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Ho, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pr, Rb, Re, Sb, Sc, Se, SiO ₂ , Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr	Perkin Elmer Elan 6000 inductively coupled plasma–mass spectrometer	Lamothe and others (2002)
ICP-AES	Inductively coupled plasma–atomic emission spectrometry	B, Ca, K, Mg, Na	Perkin Elmer Optima 3000 simultaneous inductively coupled plasma–atomic emission spectrometer	Briggs (2002)
IC-Aq	Ion chromatography	F ⁻ , Cl ⁻ , NO ₃ ⁻ , SO ₄ ²⁻	Dionex Model 2021 or equivalent, guard column AG4A or equivalent, separator column AS4A or equivalent, Dionex anion fiber suppressor (AFS-1) or Dionex micromembrane suppressor (AMMS-1)	Theodorakos (2002)
Hg-CVAFS	Mercury by cold vapor atomic fluorescence spectroscopy	Hg	Lachat QuikChem mercury analyzer with fluorescence detector	Hageman (2002)
ISO1	Oxygen isotopes	δ ¹⁸ O	MultiPrep coupled to a Micromass Optima isotope ratio mass spectrometer	Online method adapted from offline method in Epstein and Mayeda (1953)
ISO2	Hydrogen isotopes	δD	Finnigan MAT 252 isotope ratio mass spectrometer	Kendall and Coplen (1985)
ISO3	Sulfur isotopes on sulfide materials	δ ³⁴ S _{H₂S}	Carlo Erba NC2500 elemental analyzer coupled to a Micromass Optima isotope ratio mass spectrometer	Giesemann and others (1994)
ISO4	Sulfur isotopes on sulfate materials	δ ³⁴ S _{SO₄}	Carlo Erba NC2500 elemental analyzer coupled to a Micromass Optima isotope ratio mass spectrometer	Giesemann and others (1994)
ISO5	Carbon isotopes of dissolved total carbonate	δ ¹³ C _{CO₃}	A Matt Emmons acid injection multiprep device coupled to a Micromass Optima isotope ratio mass spectrometer	McCrea (1950). There is no reference for the Matt Emmons acid injection device. It consists of a heating block held at 90°C and an autosampler with a double needle that evacuates, injects acid, and then samples the evolved gas.

emission spectrometry (ICP–AES) for major ions and B (Briggs, 2002), inductively coupled plasma–mass spectrometry (ICP–MS) for minor elements (Lamothe and others, 2002), and cold vapor-atomic fluorescence spectroscopy (CVAFS) for Hg (Hageman, 2002).

Water samples for oxygen and hydrogen isotope analyses were placed in 20-mL glass scintillation vials, tightly capped, and analyzed at the USGS laboratories in Denver by isotope ratio mass spectrometry. Water samples were prepared for hydrogen-isotopic analyses using the Zn-reduction technique (Kendall and Coplen, 1985) and for oxygen-isotope analyses using an automated CO₂ equilibration technique (adapted from Epstein and Mayeda, 1953). Values of $\delta^{18}\text{O}$ and δD are relative to Vienna Standard Mean Ocean Water (VSMOW); they have reproducibility of approximately 0.2 and 1.0 per mil, respectively. Water samples for sulfur isotope analyses were initially collected in 40-mL glass vials with septa caps, but the 40-mL vials were replaced by 250-mL bottles with septa caps in 2003. The 250-mL bottles also allowed the determination of carbon isotope values of dissolved total carbonate ($\delta^{13}\text{C}_{\text{CO}_3}$). All water samples for sulfur and carbon isotopes were analyzed at the USGS laboratories in Denver by isotope ratio mass spectrometry following precipitation of Ag₂S from H₂S, BaSO₄ from dissolved total SO₄, and BaCO₃ from dissolved total CO₃. Sulfur-isotope analyses were performed by combustion using continuous flow techniques described by Giesemann and others (1994). Carbon-isotope analyses were performed by using an on-line acid-digestion method similar to the off-line method described by McCrea (1950). Values of $\delta^{34}\text{S}_{\text{H}_2\text{S}}$ and $\delta^{34}\text{S}_{\text{SO}_4}$ are relative to the standard Canyon Diablo troilite (CDT) with reproducibility of 0.2 per mil. Values of $\delta^{13}\text{C}_{\text{CO}_3}$ are relative to Vienna Pee Dee belemnite (VPDB); they have reproducibility of 0.1 per mil or better.

Alkalinity was determined using either a Chemetrics test kit (hot spring and stream samples) or by Gran titration (Stumm and Morgan, 1996) at the field-based laboratory (water-column and mixing-experiment samples). Dissolved total inorganic carbon content of vent fluids and water-column samples was determined by flow-injection analyses at the field-based laboratory. Table 1 provides a summary of the analytical methods.

Blank samples using distilled, deionized water were included with each batch of 20 samples. The blank samples had element concentrations below detection limits. Standard reference solutions, either from the USGS or from the National Institute of Standards and Technology, were included in each batch of samples. The standards, as well as duplicates of samples, were used to determine accuracy and precision of the analyses.

Results

Appendixes 1–4 tabulate the geochemical data discussed here and in Balistrieri and others (this volume). Each table contains detailed site data and water analyses. The data in this chapter are reported in mass/volume units, which provide a convenient conversion for the data in Balistrieri and others (this volume) that are reported in mol/volume units. Abbreviations for the methods (column 3) correspond to those listed in table 1. Blanks in the data fields exist because not all samples were analyzed by each method, and there were variations in the elements detected by ICP-MS. Samples within each table are sorted by location and then by sample collection date. Longitude and latitude in these tables and in figures 1–6 are referenced to the Clarke 1866 spheroid and North American 1927 datum.

Appendix 1 contains data for the water-column profiles and the creeks flowing into Yellowstone Lake. The pH values range from 2.5 to 8.5, with the majority of samples being in the neutral range (6.5–7.5). Approximately neutral pH values are expected for samples of fresh water, whereas low values generally reflect hydrothermal influences related to oxidation of H₂S to produce H₂SO₄.

The values for boron and the major cations (Ca, K, Mg, Na) are highly variable. Boron values in the creeks range from <10 to 960 $\mu\text{g/L}$, with the majority of the values being <10 $\mu\text{g/L}$. Pelican Creek and Sedge Creek are the sources of the highest values for B (960 $\mu\text{g/L}$ and 650 $\mu\text{g/L}$, respectively). The range in B values for the water-column data is <10 to 130 $\mu\text{g/L}$, with the bulk of the values between 50 and 100 $\mu\text{g/L}$. Boron is a hydrothermal-indicator element (Balistrieri and others, this volume). Therefore, B concentrations in Pelican Creek, Sedge Creek, and the water-column profiles indicate hydrothermal input.

Calcium values in both the creek data and water-column profiles are generally less than 10 mg/L. Potassium is low in both the creek and water-column samples. The highest K value for the creek data is 11 mg/L; in the water-column data, the highest value is 4.3 mg/L (MB-1). Magnesium values range from 1 to 50 mg/L in the creeks; most of the samples have values under 10 mg/L. The majority of the water-column data show a Mg range of 1.9 to 2.5 mg/L. Sodium values in the creek data are generally less than 10 mg/L, and the highest value is 41 mg/L (Pelican Creek). The majority of the water-column data have Na values between 6 and 10 mg/L.

In general, the values of the hydrothermal-indicator elements B, As, Cl, Cs, Cu, Ge, Li, Mo, Sb, and W show an increase from the creek data to the water-column-profile data, indicating that these elements are added within the lake from hydrothermal vents on the lake bottom (Balistrieri and others, this volume). This pattern is evident in appendix 1 when comparing these elements between the creek and water-column data. For As, Cl, Cs, Mo, Sb, and W, the majority of the creek data have values very close to the

lower limit of determination, whereas the water-column data have higher values. The values of these hydrothermal-indicator elements in the water-column data are not excessive, only generally higher than the creek data, indicating an addition of these elements from within the lake. A few of the creek samples, such as Pelican Creek and Sedge Creek, have values more consistent with or higher than the water-column data. There are higher values of Li in both the creek and water-column data than the other indicator elements. In the creek data, the Li values range from <0.1 to 190 $\mu\text{g/L}$, but the majority of the values are less than 20 $\mu\text{g/L}$. Some of the creek data have values in the 30–60 $\mu\text{g/L}$ range, which is the same range as the water-column data.

The data from hydrothermal vents within Yellowstone Lake are presented in appendix 2. The range in pH values is 4.9 to 8.6. Boron is elevated in some of the vent samples, ranging from 35 to 730 $\mu\text{g/L}$. The highest value is from a West Thumb vent (sample 98-19a). Values for Ca range from 3.2 to 23 mg/L. The range in values of K and Mg is fairly narrow, <1 to 3.9 mg/L. Sodium values range from 6.0 to 160 mg/L, but the highest value is an anomaly. The majority of Na values are 7–10 mg/L.

West Thumb samples have higher values of most or all of the hydrothermal-indicator elements than other sublacustrine vent areas. Samples 96-2-6a, 97-10, 98-19a, YNP-99-17-1, Y00-D06.1, Y00-D06.2, and Y00-D09.4 have the highest hydrothermal-indicator-element values. Most vent samples have As values between 3.7 and 54 $\mu\text{g/L}$, but the West Thumb group listed above has values from 72 to 210 $\mu\text{g/L}$. Chlorine values in the majority of the vent samples range from 3 to 8 mg/L. Chlorine values greater than 23 mg/L are found only in West Thumb samples. The values of Cs for the bulk of the vent samples are less than 10 $\mu\text{g/L}$. All Cs values above 16 $\mu\text{g/L}$ are West Thumb samples. Li values are quite high in some of the West Thumb samples, ranging from 110 to 1,200 $\mu\text{g/L}$. The majority of the rest of the vent samples have Li values between 34 and 77 $\mu\text{g/L}$. Two samples from Elliot's Crater rim (D02-3.2, D02-4.2) have Li values greater than 100 $\mu\text{g/L}$. Values for Mo are low in most vent samples, with a range of 0.04 to 7.5 $\mu\text{g/L}$. The highest Mo values (12–36 $\mu\text{g/L}$) are seen in a few of the West Thumb samples. The range in Sb values for the majority of the vent samples is <0.02–2.6 $\mu\text{g/L}$. The West Thumb samples listed above have Sb values from 4.2 to 400 $\mu\text{g/L}$. The values of W in the bulk of the vent samples are low, ranging from 1.0 to 6.4 $\mu\text{g/L}$. Any values of W greater than 6.4 $\mu\text{g/L}$ correspond to West Thumb samples.

Appendix 3 presents data from the 1999 mixing experiments. The locations of the three geysers sampled from Norris Geysers Basin (Echinus, Green Dragon, and Porkchop) are shown in figure 3. The four geysers used in the mixing experiments were chosen because they represent the spectrum of hydrothermal fluids found in Yellowstone Park. Green Dragon and Echinus Geysers were chosen as the

acidic, SO_4 - and Cl-rich end member and have pH values of 2.6 and 3.2, respectively. Porkchop Geysers and Black Pool (West Thumb Geysers Basin) represent the neutral to alkaline, Cl-rich end member. Porkchop and Black Pool have pH values of 6.6 and 7.9, respectively.

The geyser waters were mixed with Yellowstone Lake water in varying amounts, so in appendix 3, samples G1, E1, P1, and W1 represent 10-percent geyser water and 90-percent lake water, and G10, E10, P10, and W10 are pure geyser water. Therefore the data in each of the series, progressing from 1 to 10, reflects the increase in geyser water, in 10-percent increments.

Boron is highly enriched in all four of the geyser waters (78–9,360 $\mu\text{g/L}$); therefore an increase in the value of B is seen in the progression from sample 1 through 10 for each mixing experiment. Calcium, with values from 0 to 5 mg/L, either decreases as geyser water increases or just fluctuates (Porkchop). Magnesium values also decrease through the mixing experiments. The values of K and Na increase with increasing amounts of geyser water. Sodium is quite enriched in the geyser waters, ranging from 159 to 406 mg/L.

Most of the hydrothermal-indicator elements are elevated in the geyser waters as is expected for hydrothermal features. Therefore enrichment in the values of the indicator elements increases as the amount of geyser water increases. The Echinus mixing experiment is the exception for the elements Mo, Sb, and W. The values of these three elements either fluctuate or decrease slightly through the Echinus mixing experiment, indicating similarities in the values of these elements between the lake outflow water and Echinus Geysers.

The As values range from 300 to 2,900 $\mu\text{g/L}$, Cl from 150 to 660 mg/L, and Cs from 81 to 500 $\mu\text{g/L}$. Values of Li are the highest of the hydrothermal-indicator-element values, varying from 1,000 to 7,000 $\mu\text{g/L}$. Molybdenum, Sb, and W are less elevated with ranges of 6.1–240 $\mu\text{g/L}$, 0.64–130 $\mu\text{g/L}$, and 5.8–350 $\mu\text{g/L}$, respectively. Of the four geysers sampled, Echinus Geysers has the lowest values for all hydrothermal-indicator elements. Porkchop Geysers has the highest values for As, Cl, Cs, Li, Mo, and Sb. The highest values for W are from Black Pool.

Data from subaerial features in Yellowstone National Park are summarized in appendix 4. The pH values range from 1.1 to 9.9. Boron values are high for many of the subaerial samples, which is consistent with B being a hydrothermal-indicator element. The range in B values is <10 to 9,360 $\mu\text{g/L}$. Values for Ca and K range from 1 to 60 mg/L. Magnesium values show the narrowest range, varying from <0.1 to 18 mg/L. Sodium values range from <0.1 to 430 mg/L.

The ranges in the values of the hydrothermal-indicator elements for the subaerial samples are fairly wide and highly variable between samples, even within the same area. The values of As range from 0.4 to 3,100 $\mu\text{g/L}$. The values of Cl and Cs vary from <0.08 to 660 mg/L and from 0.01 to 580 $\mu\text{g/L}$, respectively. Lithium values show the larg-

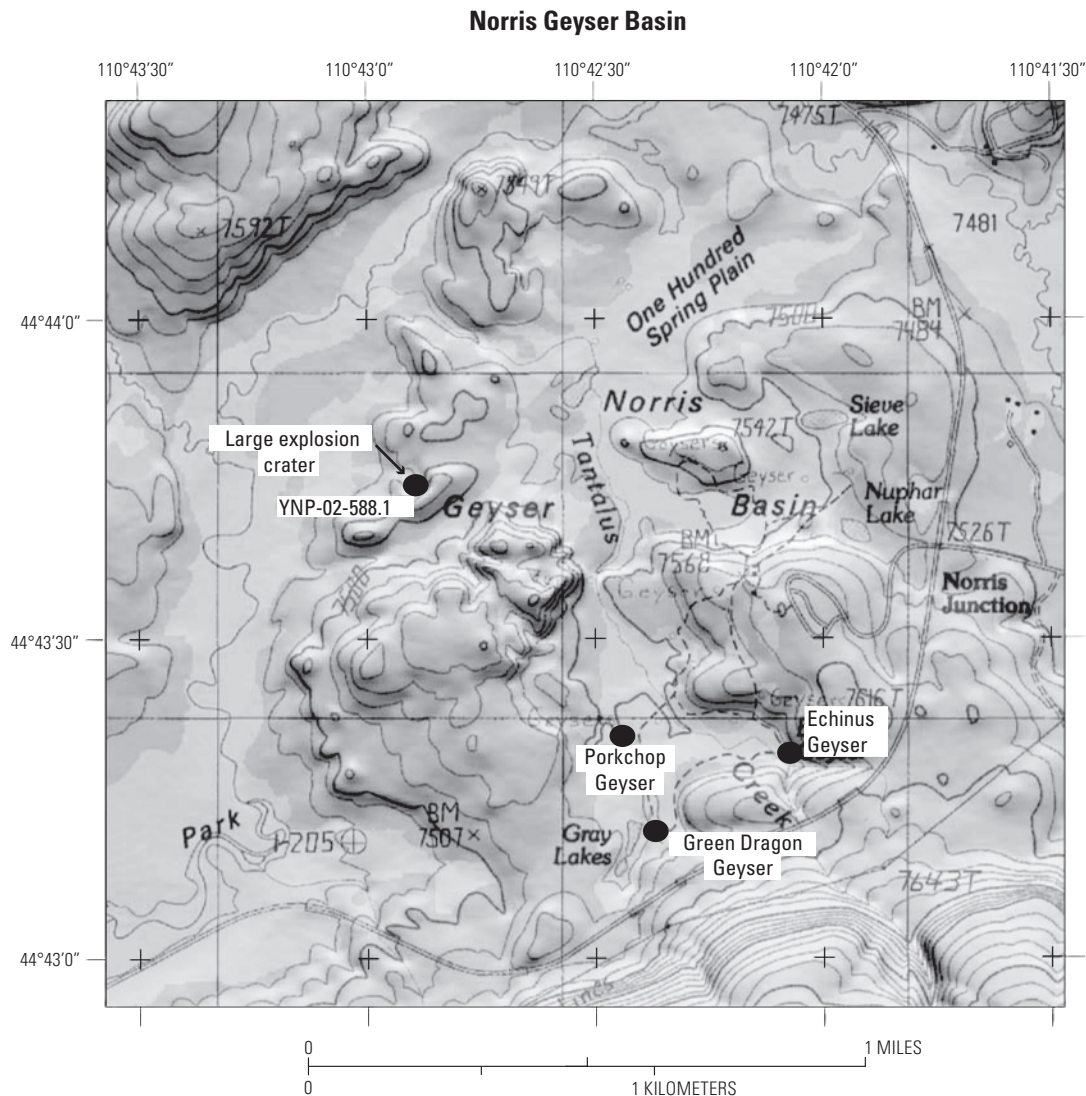


Figure 3. Map of the Norris Geyser Basin area showing sample locations of geysers and explosion crater. Echinus, Green Dragon, and Porkchop Geysers were sampled multiple years including 1999 for the mixing experiments.

est range, with a variation from 0.9 to 10,000 $\mu\text{g/L}$. The ranges in values for Mo, Sb, and W are smaller than the other indicator elements. Molybdenum values vary from <0.02 to 290 $\mu\text{g/L}$, whereas the range in Sb values is from <0.02 to 160 $\mu\text{g/L}$. Values of W vary from 0.2 to 390 $\mu\text{g/L}$. The variability in the data from the subaerial samples is related to the amount of hydrothermal influence in the samples. The four geysers used in the mixing experiments are also included in appendix 4 because they were sampled at other times unrelated to the mixing experiments. Porkchop Geyser has the highest values for As, B, Cl, Cs, Cu, Ge, Hg, Li, Mo, and Sb, and values of W are highest in Black Pool. The Heart Lake area has some samples with high levels of hydrothermal-indicator elements. Other areas sampled have lower levels of the indicator elements suggesting weaker hydrothermal activity. The differences in the hydrothermal-indicator elements could also

be related to water sources and perhaps can help in source-water studies.

The geysers of Norris Geyser Basin reflect the spectrum of hydrothermal fluids found in Yellowstone National Park. Four geysers were sampled in Norris Geyser Basin (fig. 3)—three along the southern boardwalk of Back Basin and one in a large explosion crater to the west of Porcelain Basin. Both acidic and neutral to alkaline fluids are found in the geysers in Norris Geyser Basin. Porkchop Geyser has a neutral pH and very high values of the hydrothermal-indicator elements. Echinus Geyser is acidic and has much lower hydrothermal-indicator-element values than Porkchop.

Heart Lake Geyser Basin is shown in figure 4. Two geysers were sampled in both the Rustic Geyser area and a central geyser area. One geyser from the upper basin was

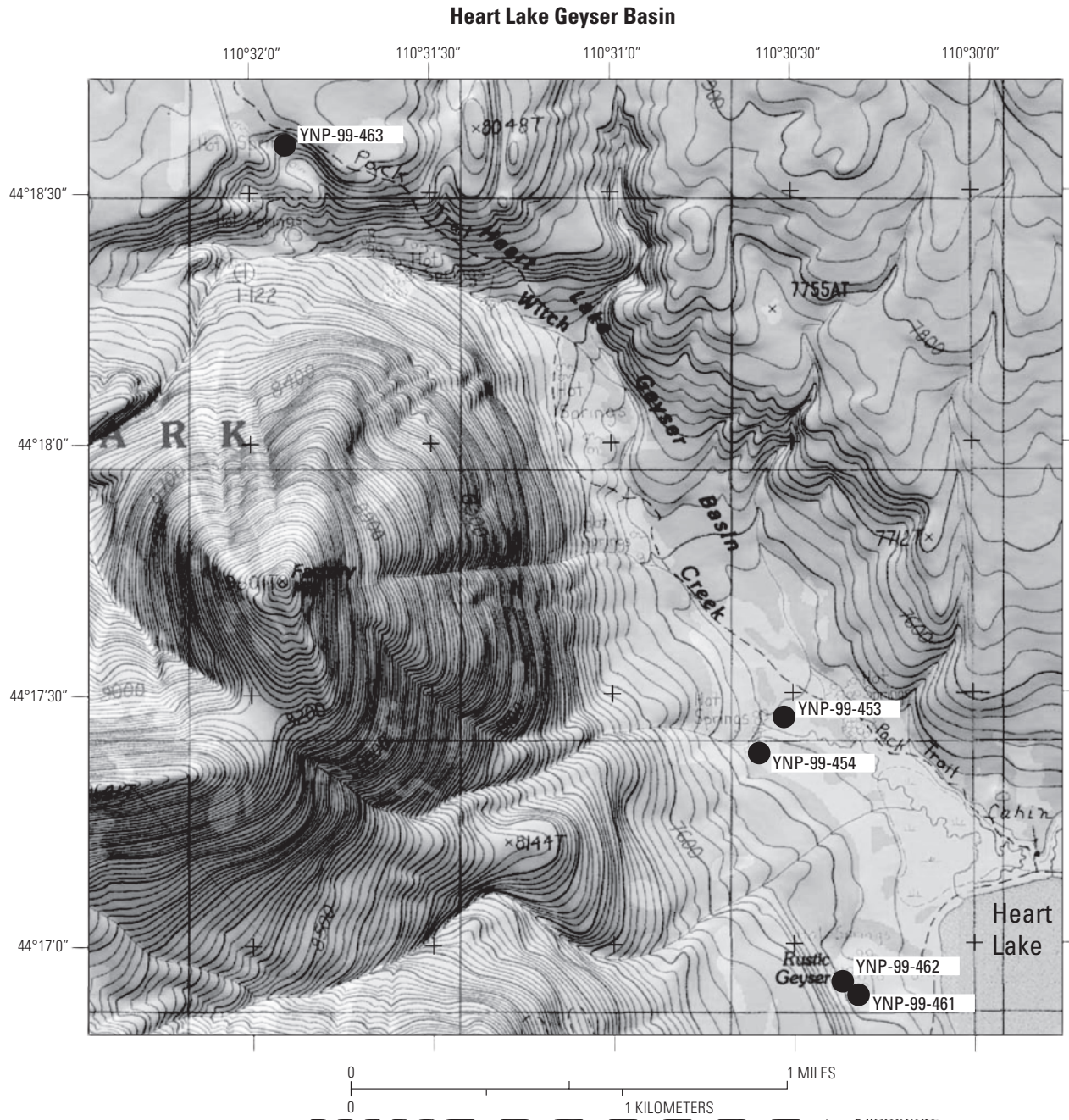


Figure 4. Map of Heart Lake Geyser Basin in northwest corner of Heart Lake. Locations of the five geysers sampled in 1999 are shown.

sampled. Representing the range of hydrothermal fluids found in the Park, two of the geysers are acidic and three are neutral to alkaline. The geyser from the upper basin is the most acidic, with a pH of 2.1, and has the lowest hydrothermal-indicator-element values. Three geysers have very similar high hydrothermal-indicator-element values: the alkaline geyser from the central geyser area (YNP-99-454) and the alkaline and acidic geysers from the Rustic Geyser area (YNP-99-461 and YNP-99-462).

Figure 5 shows both Gibbon and Monument Geyser Basins. Of the geysers sampled, thirteen were in Monument

Geyser Basin, six were near the Gibbon River, one was at Artists Paintpots, and two samples were from Gibbon Geyser Basin. The geysers sampled in Monument Geyser Basin are all acidic (pH=1.1 to 2.5). The majority of the geysers near the Gibbon River are neutral to alkaline (pH=6.1 to 7.2), as is the geyser at Artists Paintpots (pH=7.3). In Gibbon Geyser Basin, one sample is near neutral (pH=6.1) and the other is acidic (pH=3.7).

Eight samples were collected around Turbid Lake, and their locations are shown in figure 6. Two samples each were collected at Sedge Creek inlet, Bear Creek inlet, and

Gibbon and Monument Geyser Basins

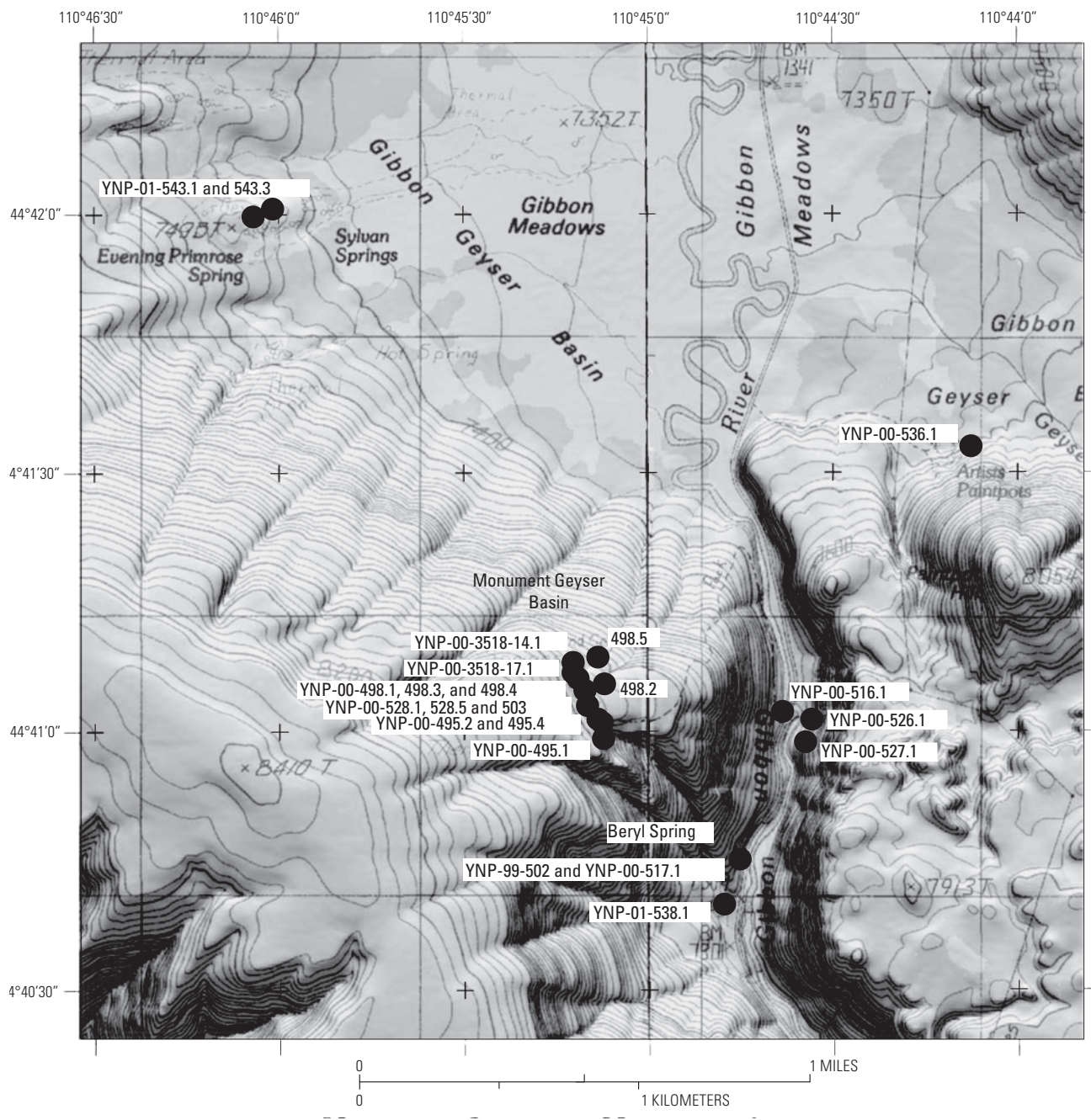


Figure 5. Map of Gibbon and Monument Geyser Basins area. Sample locations are shown in both geyser basins, along the Gibbon River at Beryl Spring, and at Artists Paintpots. Monument Geyser Basin was sampled in multiple years, most extensively in 2000.

the mudpots on the southeast shore. Two samples of lake water were also collected. The samples collected at the inlets to Turbid Lake have the lowest values for the hydrothermal-indicator elements. The mudpots have the highest hydrothermal-indicator-element values, and the lake has intermediate values. Therefore, there must be some input of hydrothermal water within the lake.

Summary

This chapter summarizes data on the geochemistry of more than 400 water samples collected from 1996 to 2004 from creeks and rivers draining into and out of Yellowstone Lake, hydrothermal vents and water-column profiles within Yellowstone Lake, and from subaerial geysers and hot springs

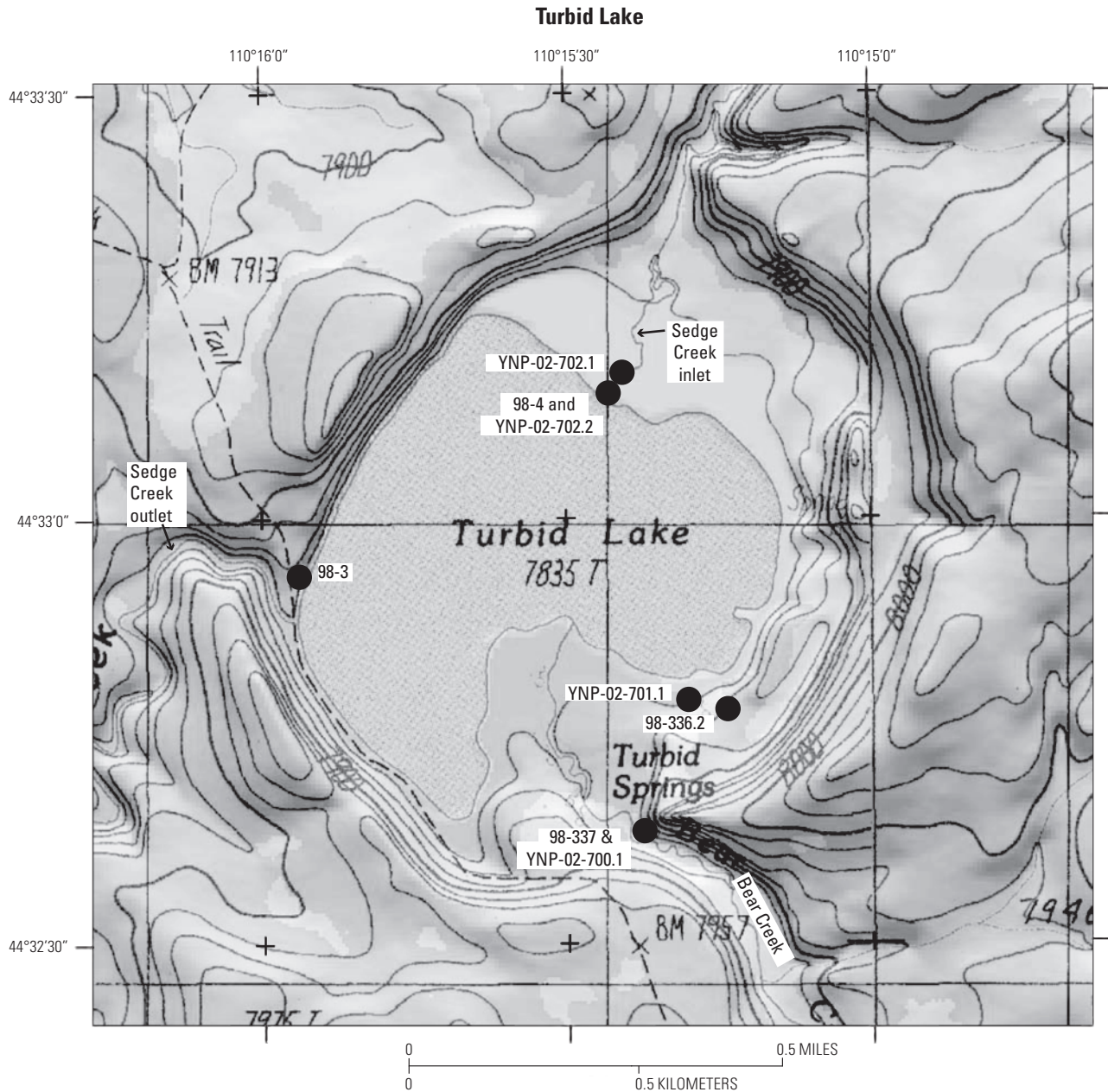


Figure 6. Detailed map of Turbid Lake showing inlets from Sedge and Bear Creeks at the north and south, respectively. The outlet to Sedge Creek is on the west side of the lake. Samples were collected in 1998 and 2002 at approximately the same locations.

throughout the Park. These different sources of water all contribute valuable information to the water chemistry in Yellowstone Lake and the Park as a whole. Goals of the geochemical fluid studies were to provide state-of-the-art chemical determinations of over 45 elements and species to help understand the influences of hydrothermal processes within Yellowstone National Park.

The values of the hydrothermal-indicator elements As, B, Cl, Cs, Cu, Ge, Li, Mo, Sb, and W can highlight

hydrothermal activity in the Park (Balistrieri and others, this volume). An increase in the values of these indicator elements from the creek data to the water-column-profile data of Yellowstone Lake indicate that these elements are likely added within the lake from hydrothermal vents on the lake bottom. The increase in concentration of the geothermal-indicator elements in certain areas of the lake (West Thumb) and Park (Heart Lake and Norris Geyser Basins) suggest highly active hydrothermal features.

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Appendixes



Appendix 1. Site and analytical data from creeks and water column profiles.

Field no. Drainage/ description	RS-16-97		RS-32-97		RS-35-97		RS-39-97		RS-40-97		30		37		39		41		40		38		RS-1-98		
	Yellowstone River inlet		Columbine Creek		Clear Creek		Sedge Creek		Pelican Creek		Yellowstone River outlet		Columbine Creek		Clear Creek		Sedge Creek		Pelican Creek		Yellowstone River outlet		Solution Cr		
Latitude	44°18'28"N		44°24'3"N		44°28'35"N		44°31'26"N		44°33'38"N		44°34'3"N		44°24'3"N		44°28'35"N		44°31'26"N		44°33'38"N		44°34'3"N		44°24'22"N		
Longitude	110°10'49"W		110°15'7"W		110°16'8"W		110°16'43"W		110°21'9"W		110°22'48"W		110°15'7"W		110°16'8"W		110°16'43"W		110°21'9"W		110°22'48"W		110°30'1"W		
NPS no.	40		1099		1095		1089		1085		1099		1099		1095		1089		1085		1163				
Date	07/15/97		07/15/97		07/16/97		07/19/97		07/19/97		07/19/97		07/15/97		07/16/97		07/19/97		07/19/97		07/19/97		08/25/98		
Depth	m		-		-		-		-		-		-		-		-		-		-		-		
Treatment/ Sample type	-		Filtered and acidified		Filtered and acidified		Filtered and acidified		Filtered and acidified		Filtered and acidified		Raw and acidified		Raw and acidified		Raw and acidified		Raw and acidified		Raw and acidified		integrated Sanzalone		
Collector	Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		Sanzalone		
pH	7.05		7.07		7.01		3.70		7.03		7.29		-		-		-		-		-		6.25		
Conductivity	uS/cm		-		-		134		213		89		-		-		-		-		-		-		
Temperature	°C		-		-		15.5		16.5		14.2		-		-		-		-		-		12.3		
Flow	CFS		-		-		-		-		-		-		-		-		-		-		6.7		
Alkalinity	Mg/L as CaCO ₃		-		-		-		-		-		-		-		-		-		-		35		
Sum CO ₂	mM		-		0.34		0.58		0.12		1.53		1.04		-		-		-		-		-		
HCO ₃	mM		-		-		-		-		-		-		-		-		-		-		-		
HCO ₃	uM		-		-		-		-		-		-		-		-		-		-		-		
Comments	-		-		-		-		-		-		-		-		-		-		-		difficult flow measure- ment		
Cl	mg/L	IC-Aq	-	-	-	-	3.4	11.4	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	
F	mg/L	IC-Aq	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
NO ₃	mg/L	IC-Aq	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 0.1
SO ₄	mg/L	IC-Aq	1.2	17.4	1.8	37.2	46.8	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6
Ag	ug/L	ICPMS	0.00	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Al	ug/L	ICPMS	16	1200	18	320	320	19	1800	160	470	2500	84	16	1800	160	470	2500	84	16	1800	160	470	2500	84
As	ug/L	ICPMS	0.3	< 0.2	0.3	9.2	14	12	0.3	0.2	12	29	2	0.3	0.2	12	29	13	2	0.3	0.2	12	29	13	2
Au	ug/L	ICPMS	0.01	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
B	ug/L	ICPAES	0	< 10	< 10	280	480	83	< 10	< 10	270	480	82	0	< 10	< 10	270	480	82	0	< 10	< 10	270	480	82
Ba	ug/L	ICPMS	6.8	12	8.4	18	34	8.9	13	10	19	40	9.1	6.8	12	8.4	18	34	8.9	13	10	19	40	9.1	10
Be	ug/L	ICPMS	0.00	< 0.05	< 0.05	< 0.05	0.05	< 0.05	< 0.05	< 0.05	0.05	< 0.05	< 0.05	0.00	< 0.05	< 0.05	0.05	< 0.05	< 0.05	0.00	< 0.05	< 0.05	0.05	< 0.05	< 0.05
Bi	ug/L	ICPMS	0.00	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.00	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.00	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	3.9	5.4	6.7	4.9	12	5.6	5.8	6.9	4.7	13	5.6	3.9	5.4	6.7	4.9	12	5.6	5.8	6.9	4.7	13	5.6	8.2
Cd	ug/L	ICPMS	0.00	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.00	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.00	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ce	ug/L	ICPMS	0.1	2.9	0.2	1.0	0.2	0.05	4.6	0.60	1.4	1.6	0.2	0.1	2.9	0.2	1.0	0.2	0.05	4.6	0.60	1.4	1.6	0.2	0.3
Co	ug/L	ICPMS	0.0	0.2	0.02	0.4	0.2	< 0.02	0.3	0.08	0.4	0.3	0.06	0.0	0.2	0.02	0.4	0.2	< 0.02	0.3	0.08	0.4	0.3	0.06	0.1
Cr	ug/L	ICPMS	0.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Cs	ug/L	ICPMS	0.00	0.01	< 0.01	1.9	3.7	2.6	0.02	0.01	2.0	3.8	0.2	0.00	0.01	< 0.01	1.9	3.7	2.6	0.02	0.01	2.0	3.8	2.6	0.2
Cu	ug/L	ICPMS	0.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.0	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Dy	ug/L	ICPMS	0.01	0.18	0.073	0.12	0.03	< 0.005	0.29	0.12	0.15	0.17	0.008	0.01	0.18	0.073	0.12	0.03	< 0.005	0.29	0.12	0.15	0.17	0.008	0.02
Er	ug/L	ICPMS	0.01	0.12	0.058	0.081	0.01	0.005	0.17	0.075	0.073	0.10	0.007	0.01	0.12	0.058	0.081	0.01	0.005	0.17	0.075	0.073	0.10	0.007	0.02
Eu	ug/L	ICPMS	0.00	0.02	< 0.005	0.01	< 0.005	< 0.005	0.03	0.01	0.02	0.005	< 0.005	0.00	0.02	< 0.005	0.01	< 0.005	< 0.005	0.03	0.01	0.02	0.005	< 0.005	< 0.005
Fe	ug/L	ICPMS	28	170	27	360	110	11	400	110	640	1000	40	28	170	27	360	110	11	400	110	640	1000	40	130
Ga	ug/L	ICPMS	0.00	0.04	< 0.02	< 0.02	< 0.02	< 0.02	0.08	< 0.02	0.03	0.04	< 0.02	0.00	0.04	< 0.02	< 0.02	< 0.02	< 0.02	0.08	< 0.02	0.03	0.04	< 0.02	< 0.02
Gd	ug/L	ICPMS	0.02	0.22	0.094	0.13	0.02	< 0.005	0.35	0.14	0.17	0.19	0.02	0.02	0.22	0.094	0.13	0.02	< 0.005	0.35	0.14	0.17	0.19	0.02	0.02
Ge	ug/L	ICPMS	0.00	< 0.02	< 0.02	0.2	0.4	0.2	< 0.02	< 0.02	0.2	0.4	< 0.02	0.00	< 0.02	< 0.02	0.2	0.4	0.2	< 0.02	< 0.02	0.2	0.4	< 0.02	< 0.02
Hf	ug/L	ICPMS	0.00	< 0.05	14	2.1	10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.00	< 0.05	14	2.1	10	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ho	ug/L	ICPMS	0.00	0.04	0.02	0.03	0.005	< 0.005	0.055	0.02	0.03	0.03	< 0.005	0.00	0.04	0.02	0.03	0.005	< 0.005	0.055	0.02	0.03	0.03	< 0.005	0.006
In	ug/L	ICPMS	0.00	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.00	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
K	mg/L	ICPAES	1.1	1.1	0.56	1.3	6.6	1.7	1.2	0.61	1.4	6.4	1.8	1.1	1.1	0.56	1.3	6.6	1.7	1.2	0.61	1.4	6.4	1.6	1.8
La	ug/L	ICPMS	0.09	1.6	0.2	0.50	0.1	0.04	2.3	0.50	0.66	0.72	0.09	0.09	1.6	0.2	0.50	0.1	0.04	2.3	0.50	0.66	0.72	0.09	0.1
Li	ug/L	ICPMS	0.2	0.9	1.3	25	68	35	0.8	1.1	25	68	35	0.2	0.9	1.3	25	68	35	0.8	1.1	25	68	35	2.5
Mg	mg/L	ICPAES	1.6	2.7	1.5	2.1	7.2	2.4	2.8	1.5	2.1	7.0	2.3	1.6	2.7	1.5	2.1	7.2	2.4	2.8	1.5	2.1	7.0	2.3	2.8
Mn	ug/L	ICPMS	2.5	34	4.3	42	46	0.75	36	9.1	43	52	2.3	2.5	34	4.3	42	46	0.75	36	9.1	43	52	2.3	9.9
Mo	ug/L	ICPMS	0.2	0.2	0.4	0.4	0.50	1.1	0.2	0.5	0.4	0.5	1.1	0.2	0.2	0.4	0.4	0.50	1.1	0.2	0.5	0.4	0.5	1.1	0.59
Na	mg/L	ICPAES	2.4	3.4	2.6	6.2	22	9.0	3.5	2.6	5.8	21	8.6	2.4	3.4	2.6	6.2	22	9.0	3.5	2.6	5			

Appendix 1. Site and analytical data from creeks and water column profiles—Continued.

Field no. Drainage/ description	RS-2-98	RS-3-98	RS-4-98	RS-5-98 Flat Mt. Stream	RS-6-98	RS-7-98	RS-8-98 West side S. arm	RS-9-98	RS-10-98	RS-11-98	RS-12-98 Alder Lake Outlet	RS-13-98	RS-14-98
Latitude	44°25'35"N	44°24'33"N	44°24'13"N	44°21'36"N	44°22'6"N	44°22'23"N	44°20'34"N	44°19'57"N	44°18'32"N	44°18'7"N	44°20'17"N	44°22'29"N	44°20'1"N
Longitude	110°27'40"W	110°25'5"W	110°24'27"W	110°27'4"W	110°24'16"W	110°23'11"W	110°21'25"W	110°21'23"W	110°20'59"W	110°20'23"W	110°19'2"W	110°17'48"W	110°16'33"W
NPS no.	1161	1158	1157	1155	1147	1143	1138	1137	no #	1131	1119	1118	1115
Date	08/25/98	08/25/98	08/25/98	08/25/98	08/25/98	08/25/98	08/26/98	08/26/98	08/26/98	08/26/98	08/26/98	08/26/98	08/27/98
Depth m	-	-	-	-	-	-	-	-	-	-	-	-	-
Treatment/ Sample type Collector	point Sanzolone	point Sanzolone	point Sanzolone	integrated Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone
pH	5.75	5.71	6.15	6.45	6.83	6.49	6.92	6.90	4.80	7.74	7.41	7.40	7.74
Conductivity uS/cm	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature °C	8.4	15.6	14.5	14.3	11.4	10.2	5.5	5.4	7.5	12.5	14.7	11.6	10.9
Flow CFS	0.001	0.004	0.009	8.3	3.3	1.3	1.5	5.3	0.3	0.1	0.001	1.3	0.04
Alkalinity Mg/L as CaCO ₃	20	20	50	40	25	22	30	32	45	45	100	70	150
Sum CO ₂ mM	-	-	-	-	-	-	-	-	-	-	-	-	-
HCO ₃ mM	-	-	-	-	-	-	-	-	-	-	-	-	-
HCO ₃ uM	-	-	-	-	-	-	-	-	-	-	-	-	-
Comments	no surface flow to lake	Headwater at Delusion Lake	no surface flow to lake	inlet to Flat Mt. Arm	-	-	-	-	-	-	no surface flow to lake	no surface flow to lake	abundant suspended sed
Cl mg/L	IC-Aq 0.2	1.0	0.5	0.5	0.4	0.4	0.4	0.4	0.2	0.2	1.2	0.6	1.4
F mg/L	IC-Aq 0.2	0.2	0.7	0.6	0.4	0.4	0.8	1.4	0.3	0.2	0.2	0.2	0.3
NO ₃ mg/L	IC-Aq < 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.4	< 0.1	0.2
SO ₄ mg/L	IC-Aq 1.4	< 0.5	1.4	2.5	0.9	0.9	1.2	1.6	1.7	1.2	0.9	1.8	< 0.5
Ag ug/L	ICPMS < 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Al ug/L	ICPMS 37	35	31	21	28	18	11	4.6	31	15	5.2	13	84
As ug/L	ICPMS 0.5	0.6	2	4.9	0.2	< 0.2	0.2	0.3	0.9	0.8	2	0.6	9.2
Au ug/L	ICPMS < 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B ug/L	ICPAES 12	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	11
Ba ug/L	ICPMS 17	11	16	14	9.7	6.8	5.9	2	14	9.5	32	9.4	28
Be ug/L	ICPMS < 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.05	0.1	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Bi ug/L	ICPMS < 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca mg/L	ICPAES 5.3	4.2	9.0	9.6	4.8	4.8	6.2	7.5	8.4	8.6	18	21	25
Cd ug/L	ICPMS < 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ce ug/L	ICPMS 0.76	0.4	0.99	0.2	0.2	0.2	0.1	0.02	0.2	0.1	0.06	0.2	0.83
Co ug/L	ICPMS 0.1	0.1	1.1	0.03	< 0.02	< 0.02	< 0.02	< 0.02	0.02	0.04	0.1	0.2	1.4
Cr ug/L	ICPMS 1	< 1	< 1	< 1	14	< 1	< 1	< 1	< 1	< 1	< 1	1	1
Cs ug/L	ICPMS 0.09	0.06	0.32	0.1	0.01	< 0.01	0.04	0.2	< 0.01	< 0.01	0.02	0.02	0.03
Cu ug/L	ICPMS 0.6	< 0.5	< 0.5	< 0.5	2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.5	1
Dy ug/L	ICPMS 0.089	0.04	0.066	0.02	0.062	0.04	0.02	< 0.005	0.02	0.057	< 0.005	0.01	0.04
Er ug/L	ICPMS 0.059	0.03	0.058	0.02	0.051	0.04	0.01	< 0.005	0.02	0.05	0.005	0.01	0.02
Eu ug/L	ICPMS 0.01	< 0.005	0.007	< 0.005	0.005	< 0.005	< 0.005	< 0.005	0.005	< 0.005	< 0.005	< 0.005	0.01
Fe ug/L	ICPMS 59	140	370	52	29	20	30	17	36	38	170	110	300
Ga ug/L	ICPMS < 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.03
Gd ug/L	ICPMS 0.090	0.05	0.067	0.01	0.057	0.02	0.02	< 0.005	0.02	0.056	0.006	0.01	0.04
Ge ug/L	ICPMS < 0.02	< 0.02	0.04	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Hf ug/L	ICPMS < 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ho ug/L	ICPMS 0.02	0.009	0.02	0.005	0.01	0.01	< 0.005	< 0.005	< 0.005	0.02	< 0.005	< 0.005	0.007
In ug/L	ICPMS < 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
K mg/L	ICPAES 2.3	1.4	2.2	2.1	< 1	< 1	< 1	1.1	1.8	2.1	5.0	1.6	3.4
La ug/L	ICPMS 0.4	0.2	0.3	0.07	0.2	0.2	0.05	0.01	0.09	0.1	0.02	0.1	0.3
Li ug/L	ICPMS 0.1	1.0	5.9	3.9	1.3	0.6	3.2	3.1	0.3	< 0.1	0.3	0.4	0.6
Mg mg/L	ICPAES 1.7	1.4	3.4	1.3	1.1	1.1	1.5	1.7	2.8	2.8	6.9	5.1	15
Mn ug/L	ICPMS 10	30	230	7.3	2.3	0.24	6.4	0.23	2.9	8.4	150	13	500
Mo ug/L	ICPMS 0.3	0.3	0.5	0.3	0.3	0.2	0.53	0.75	0.2	0.1	0.5	0.09	0.4
Na mg/L	ICPAES 2.5	2.0	3.2	3.2	2.6	2.6	2.9	3.1	2.5	2.7	7.1	3.9	12
Nb ug/L	ICPMS < 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Nd ug/L	ICPMS 0.43	0.2	0.36	0.06	0.2	0.2	0.06	< 0.01	0.08	0.1	0.03	0.1	0.30
Ni ug/L	ICPMS 1.0	1.0	3.0	0.6	1.7	1.0	0.3	0.3	0.6	0.7	1.0	1.7	4.6
P ug/L	ICPMS -	-	-	-	-	-	-	-	-	-	-	-	-
Pb ug/L	ICPMS < 0.05	< 0.05	0.2	< 0.05	0.3	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1	< 0.05	0.06
Pr ug/L	ICPMS 0.1	0.05	0.1	0.02	0.04	0.05	0.02	< 0.01	0.03	0.03	< 0.01	0.03	0.09
Rb ug/L	ICPMS 4.4	2.6	6.0	6.1	1.4	1.3	1.9	1.8	1.4	2.2	3.0	1.8	3.2
Re ug/L	ICPMS < 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Sb ug/L	ICPMS 0.05	0.03	0.04	0.2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.05
Sc ug/L	ICPMS 2	0.5	2	2	1	1	1	1	2	2	2	1	1
Se ug/L	ICPMS < 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.2
SiO ₂ mg/L	ICPMS 34	7.7	34	40	18	19	26	30	38	42	29	29	28
Sm ug/L	ICPMS 0.06	0.04	0.06	0.02	0.02	0.03	0.01	< 0.01	0.02	0.04	< 0.01	0.01	0.04
Sn ug/L	ICPMS < 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Sr ug/L	ICPMS 48	35	55	27	32	31	32	28	48	48	89	54	180
Ta ug/L	ICPMS < 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Tb ug/L	ICPMS 0.01	< 0.005	0.01	< 0.005	0.005	0.009	< 0.005	< 0.005	< 0.005	0.008	< 0.005	< 0.005	0.006
Te ug/L	ICPMS < 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Th ug/L	ICPMS 0.02	0.02	0.02	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01
Ti ug/L	ICPMS 0.4	0.2	0.4	< 0.1	0.1	< 0.1	< 0.1	< 0.1	0.2	0.1	< 0.1	0.2	0.8
Tl ug/L	ICPMS < 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Tm ug/L	ICPMS 0.01	< 0.005	0.007	< 0.005	0.007	0.006	< 0.005	< 0.005	< 0.005	0.007	< 0.005	< 0.005	< 0.005
U ug/L	ICPMS 0.02	0.01	0.02	0.06	0.01	0.01	0.03	0.16	0.02	0.04	0.009	0.50	0.66
V ug/L	ICPMS 2	0.2	0.9	0.5	0.1	< 0.1	0.2	0.2	1	2	0.8	3	4
W ug/L	ICPMS 0.03	0.04	0.1	0.05	0.02	< 0.02	< 0.02	0.04					

Appendix 1. Site and analytical data from creeks and water column profiles—Continued.

Field no. Drainage/ description	RS-15-98	RS-16-98 Yellowstone River inlet	RS-17-98 Beaver Dam Cr	RS-17R-98 Beaver Dam Cr	RS-18-98 Trail Cr	RS-19-98	RS-20-98	RS-21-98	RS-22-98	RS-23-98 Grouse Cr	RS-24-98	RS-25-98	RS-26-98 Chipmunk Cr	
Latitude	44°20'46"N	44°18'28"N	44°19'23"N	44°19'23"N	44°17'27"N	44°17'22"N	44°17'21"N	44°17'36"N	44°17'17"N	44°16'53"N	44°16'38"N	44°16'38"N	44°17'18"N	
Longitude	110°13'22"W	110°10'49"W	110°11'6"W	110°11'6"W	110°12'9"W	W	W	W	W	W	W	W	110°17'7"W	
NPS no.	1106	40	1107	1107	1108	1109	1110	1111	1126	1125	1123	1122	1121	
Date	08/27/98	08/28/98	08/28/98	08/28/98	08/29/98	08/30/98	08/30/98	08/30/98	08/30/98	08/30/98	08/30/98	08/30/98	08/30/98	
Depth m	-	-	-	-	-	-	-	-	-	-	-	-	-	
Treatment/ Sample type Collector	point Sanzolone	integrated Sanzolone	integrated Sanzolone	integrated Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	point Sanzolone	
pH	7.90	7.12	7.55	-	8.50	7.63	7.64	7.95	8.16	7.93	8.04	7.00	8.49	
Conductivity Temperature Flow	uS/cm °C CFS	- 9.1 0.002	- 15.1 500	- 17.1 56	- 13.9 9.0	- 7.9 3.2	- 7.9 7.9	- 17.7 1.0	- 8.8 1.0	- 10.4 10.7	- 11.6 0.5	- 16.0 0.001	- 21	
Alkalinity Sum CO ₂ HCO ₃ HCO ₃	Mg/L as CaCO ₃ mM mM uM	70 - - -	35 - - -	35 - - -	35 - - -	60 - - -	50 - - -	55 - - -	70 - - -	150 - - -	110 - - -	100 - - -	75 - - -	50 - - -
Comments	-	-	-	duplicate	abundant suspended sed	-	drainage not on 7.5 map	-	-	-	-	-	-	
Cl	mg/L	IC-Aq	0.6	0.2	0.2	0.3	0.3	0.3	0.5	0.4	0.4	0.3	0.2	
F	mg/L	IC-Aq	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.1	0.2	0.2	0.2	
NO ₃	mg/L	IC-Aq	< 0.1	< 0.1	< 0.1	< 0.1	0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	
SO ₄	mg/L	IC-Aq	30	2.3	4.4	4.4	0.8	1.2	1.2	3.3	4.9	2.5	< 0.5	
Ag	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
Al	ug/L	ICPMS	27	15	14	12	15	16	4.5	24	5.2	3.4	29	
As	ug/L	ICPMS	0.3	0.4	0.5	0.5	0.7	0.3	0.2	0.6	0.3	< 0.2	< 0.2	
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
B	ug/L	ICPAES	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	
Ba	ug/L	ICPMS	23	8.7	13	13	16	33	29	32	280	66	7.9	
Be	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
Ca	mg/L	ICPAES	14	5.8	3.9	3.9	11	10	11	40	31	12	14	
Cd	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Ce	ug/L	ICPMS	0.09	0.07	0.06	0.05	0.2	0.09	0.02	0.1	0.03	0.02	0.4	
Co	ug/L	ICPMS	0.04	0.04	< 0.02	< 0.02	0.1	< 0.02	< 0.02	0.05	0.07	0.09	< 0.02	
Cr	ug/L	ICPMS	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	
Cs	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	0.01	< 0.01	< 0.01	0.01	0.02	
Cu	ug/L	ICPMS	0.8	< 0.5	< 0.5	< 0.5	0.5	< 0.5	< 0.5	< 0.5	0.5	< 0.5	2	
Dy	ug/L	ICPMS	0.04	0.005	0.008	0.01	0.01	0.006	< 0.005	0.01	0.01	< 0.005	0.14	
Er	ug/L	ICPMS	0.02	< 0.005	< 0.005	0.007	0.008	< 0.005	< 0.005	0.01	< 0.005	< 0.005	0.11	
Eu	ug/L	ICPMS	0.006	< 0.005	< 0.005	< 0.005	< 0.005	0.005	< 0.005	< 0.005	0.02	0.01	0.007	
Fe	ug/L	ICPMS	38	27	14	10	190	32	23	59	96	80	33	
Ga	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Gd	ug/L	ICPMS	0.052	0.006	0.008	< 0.005	0.02	0.009	< 0.005	0.03	< 0.005	< 0.005	0.18	
Ge	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.02	< 0.02	< 0.02	< 0.02	
Hf	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Ho	ug/L	ICPMS	0.01	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	0.05	0.008	
In	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
K	mg/L	ICPAES	2.2	1.4	1.4	1.4	2.7	2.2	2.3	2.4	1.5	1.1	1.7	
La	ug/L	ICPMS	0.3	0.05	0.05	0.04	0.1	0.04	< 0.01	0.08	0.02	0.01	0.4	
Li	ug/L	ICPMS	1.8	< 0.1	< 0.1	< 0.1	< 0.1	0.4	0.6	0.5	1.0	0.6	1.7	
Mg	mg/L	ICPAES	12	2.5	1.5	1.5	4.0	1.7	1.5	3.5	15	10	3.2	
Mn	ug/L	ICPMS	0.19	5.9	1.1	0.91	43	1.1	0.08	8.8	9.9	12	5.0	
Mo	ug/L	ICPMS	0.1	0.2	0.3	0.3	0.2	0.07	0.06	0.09	0.5	0.54	0.3	
Nb	ug/L	ICPMS	4.9	3.7	7.7	7.7	4.3	2.8	2.6	3.1	10	5.1	3.0	
Nd	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Ni	ug/L	ICPMS	0.30	0.05	0.04	0.04	0.07	0.04	0.01	0.08	0.02	0.01	0.53	
P	ug/L	ICPMS	1.4	0.7	0.3	0.3	0.8	0.5	0.4	0.9	1.6	1.6	0.5	
Pb	ug/L	ICPMS	< 0.05	< 0.05	1.3	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Pr	ug/L	ICPMS	0.07	0.01	0.01	0.01	0.03	0.01	< 0.01	0.02	< 0.01	< 0.01	0.06	
Rb	ug/L	ICPMS	2.6	1.6	1.9	1.8	2.8	2.5	2.2	0.86	0.88	1.7	1.9	
Re	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Sb	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.04	0.03	< 0.02	< 0.02	
Sc	ug/L	ICPMS	2	0.9	1	1	1	2	1	1	0.3	0.4	0.6	
Se	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.2	< 0.2	< 0.2	
SiO ₂	mg/L	ICPMS	41	23	26	25	27	37	33	29	10	9.2	30	
Sm	ug/L	ICPMS	0.06	0.02	0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	0.1	
Sn	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Sr	ug/L	ICPMS	110	35	27	25	57	46	42	61	350	230	44	
Ta	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Tb	ug/L	ICPMS	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	
Te	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	
Th	ug/L	ICPMS	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.008	0.005	
Ti	ug/L	ICPMS	0.2	0.1	< 0.1	< 0.1	0.2	0.1	< 0.1	0.2	< 0.1	< 0.1	0.3	
Tl	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Tm	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	
U	ug/L	ICPMS	0.02	0.02	0.02	0.01	0.10	0.06	0.08	0.10	0.48	0.32	0.05	
V	ug/L	ICPMS	3	3	3	3	3	2	2	3	0.2	0.2	2	
W	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.03	
Y	ug/L	ICPMS	0.2	0.03	0.04	0.04	0.06	0.04	0.01	0.1	0.06	0.04	0.95	
Yb	ug/L	ICPMS	0.02	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	< 0.01	< 0.01	0.1	0.03	
Zn	ug/L	ICPMS	3	0.9	0.7	< 0.5	1	0.5	0.5	0.7	1	0.5	1	
Zr	ug/L	ICPMS	0.4	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.1	< 0.05	< 0.05	0.2	
Hg	ng/L	Hg CVAF	< 5	< 5	< 5	< 5	< 5	< 5	< 5	5	< 5	< 5	< 5	
δ ¹⁸ O vs VSMOW	permil	ISO1	-18.5	-18.1	-18.5	-18.5	-16.8	-19.4	-19.6	-18.7	-18.6	-18.3	-18.4	
δD vs VSMOW	permil	ISO2	-139.5	-136.4	-137.6	-138.5	-131.3	-144.9	-148.6	-142.9	-141.0	-139.5	-139.2	
δ ³⁴ S vs CDT	permil	ISO3	-	-	-	-								

Appendix 1. Site and analytical data from creeks and water column profiles—Continued.

Field no. Drainage/ description	RS-27-98	RS-28-98	RS-29-98	RS-30-98	RS-31-98	RS-32-98	RS-33-98	RS-34-98	RS-35-98	RS-36-98	RS-37-98	RS-38-98	RS-39-98		
	Alluvium Cr														
	Columbine Cr			Meadow Cr			Clear Cr			Cub Cr			Little Cr		Sedge Cr
Latitude	44°21'47"N	44°22'37"N	44°23'9"N	44°23'41"N	44°23'48"N	44°24'3"N	44°25'37"N	44°27'7"N	44°28'35"N	44°28'47"N	44°29'23"N	44°30'2"N	44°31'26"N		
Longitude	W	W	W	W	W	110°15'7"W	110°17'8"W	W	110°16'8"W	W	W	W	110°16'43"W		
NPS no.	1103	1101	1100	None	None	1099	1097	1096	1095	1094	1093	1091	1089		
Date	08/31/98	08/31/98	08/31/98	08/31/98	08/31/98	09/01/98	09/01/98	09/01/98	09/01/98	09/01/98	09/01/98	09/01/98	09/02/98		
Depth	m	-	-	-	-	-	-	-	-	-	-	-	-		
Treatment/ Sample type	point	point	point	point	point	point	point	point	integrated	point	point	point	point		
Collector	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone		
pH	7.77	2.95	2.52	2.74	6.61	6.94	7.31	7.09	7.98	7.31	8.07	7.93	3.43		
Conductivity	uS/cm	-	-	-	-	-	-	-	-	-	-	-	-		
Temperature	°C	6.8	10.3	12.0	19.5	13.6	9.6	9.6	8.1	14.2	9.5	14	12		
Flow	CFS	1.3	0.2	0.3	-	-	14	3	0.004	21.4	0.6	7.5	0.8		
Alkalinity	Mg/L as CaCO ₃	125	-	-	-	75	55	30	25	45	45	90	50		
Sum CO ₂	mM	-	-	-	-	-	-	-	-	-	-	-	-		
HCO ₃	mM	-	-	-	-	-	-	-	-	-	-	-	-		
HCO ₃	uM	measured	-	-	-	-	-	-	-	-	-	-	-		
HCO ₃	uM	calculated	-	-	-	-	-	-	-	-	-	-	-		
Comments	-	no surface flow to lake	-	tributary to Columbine Cr -2.2 CFS	Columbine Cr above 30, Fe stain, vents, 5 CFS	murky water	no surface flow to lake	no surface flow to lake	-	no surface flow to lake	-	-	-		
Cl	mg/L	IC-Aq	0.5	1.1	2.0	1.1	0.4	0.4	0.3	0.5	0.3	0.4	0.5	5.1	
F	mg/L	IC-Aq	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.3	0.3	
NO ₃	mg/L	IC-Aq	< 0.1	< 0.1	0.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	
SO ₄	mg/L	IC-Aq	83	560	820	360	21	87	1.8	2.7	3.1	1.8	17	84	
Ag	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
Al	ug/L	ICPMS	73	30000	73000	19000	80	49	29	190	9.7	120	26	94	
As	ug/L	ICPMS	< 0.2	< 0.2	0.2	0.4	< 0.2	< 0.2	0.2	< 0.2	0.2	0.3	0.6	5.3	
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
B	ug/L	ICPAES	< 10	< 10	< 10	< 10	30	25	< 10	< 10	< 10	24	< 10	650	
Ba	ug/L	ICPMS	21	16	12	22	28	30	7.9	9.8	11	11	24	17	
Be	ug/L	ICPMS	< 0.05	1.1	2.3	1.1	< 0.05	< 0.05	< 0.05	0.1	< 0.05	0.08	< 0.05	< 0.05	
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
Ca	mg/L	ICPAES	34	53	49	22	15	20	5.6	5.8	9.2	5.5	16	11	
Cd	ug/L	ICPMS	< 0.02	0.03	0.07	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Ce	ug/L	ICPMS	0.06	25	63	88	1.8	0.85	0.4	2.3	0.09	1.3	0.08	0.50	
Co	ug/L	ICPMS	0.2	4.5	7.6	0.85	0.4	0.76	< 0.02	< 0.02	< 0.02	0.03	< 0.02	0.59	
Cr	ug/L	ICPMS	< 1	30	74	14	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	
Cs	ug/L	ICPMS	0.02	0.33	0.91	0.42	0.03	0.07	0.01	0.01	< 0.01	0.01	0.06	< 0.01	
Cu	ug/L	ICPMS	0.8	6	10	1	< 0.5	< 0.5	0.7	0.9	0.6	< 0.5	0.6	0.5	
Dy	ug/L	ICPMS	< 0.005	0.99	2.6	4.3	0.096	0.02	0.14	0.52	0.03	0.39	0.02	0.098	
Er	ug/L	ICPMS	0.01	0.56	1.4	2.6	0.058	0.02	0.11	0.35	0.02	0.28	0.02	0.068	
Eu	ug/L	ICPMS	< 0.005	0.37	0.93	0.40	< 0.005	0.006	0.007	0.02	< 0.005	0.02	< 0.005	0.008	
Fe	ug/L	ICPMS	73	1700	1800	1800	71	40	33	48	37	100	40	870	
Ga	ug/L	ICPMS	< 0.02	0.56	1.6	1.2	< 0.02	< 0.02	< 0.02	0.04	< 0.02	0.03	< 0.02	0.02	
Gd	ug/L	ICPMS	0.01	1.4	3.7	5.2	0.099	0.04	0.18	0.57	0.03	0.44	0.02	0.088	
Ge	ug/L	ICPMS	< 0.02	0.08	0.1	0.1	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.2	
Hf	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Ho	ug/L	ICPMS	0.006	0.18	0.56	0.95	0.02	0.008	0.05	0.11	0.005	0.099	< 0.005	0.02	
In	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
K	mg/L	ICPAES	2.6	5.9	11	6.7	2.5	3.2	1.1	1.1	< 1	1.1	1.8	2.1	
La	ug/L	ICPMS	0.05	11	23	35	0.80	0.50	0.4	2.0	0.07	1.3	0.07	0.4	
Li	ug/L	ICPMS	9.5	15	19	15	6.0	7.8	1.7	1.1	4.2	0.8	14	2.5	
Mg	mg/L	ICPAES	35	50	37	15	9.8	14	2.0	1.8	2.3	1.6	10	6.8	
Mn	ug/L	ICPMS	49	510	670	370	79	210	5.0	0.69	3.9	3.6	8.3	0.55	
Mo	ug/L	ICPMS	0.06	< 0.02	< 0.02	0.04	0.2	0.1	0.52	0.2	0.81	0.2	0.92	0.3	
Na	mg/L	ICPAES	9.3	15	23	10	15	15	2.9	2.8	4.7	2.8	18	6.5	
Nb	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Nd	ug/L	ICPMS	0.05	8.7	23	28	0.54	0.27	0.53	2.2	0.1	1.5	0.06	0.38	
Ni	ug/L	ICPMS	3.0	24	22	4.0	2.0	3.2	0.5	0.7	0.6	0.9	0.7	0.8	
P	ug/L	ICPMS	-	-	-	-	-	-	-	-	-	-	-	-	
Pb	ug/L	ICPMS	< 0.05	0.06	< 0.05	0.2	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.07	< 0.05	< 0.05	
Pr	ug/L	ICPMS	0.01	2.7	7.2	8.7	0.2	0.06	0.1	0.59	0.02	0.41	0.02	0.1	
Rb	ug/L	ICPMS	3.7	13	34	18	5.3	7.5	1.7	1.5	1.3	4.4	2.5	5.1	
Re	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Sb	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.3	
Sc	ug/L	ICPMS	2	4	5.4	2	1	1	0.6	0.7	0.5	0.7	0.7	0.4	
Se	ug/L	ICPMS	< 0.2	< 0.2	0.2	0.5	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	
SiO ₂	mg/L	ICPMS	43	88	95	63	31	37	22	24	17	21	27	28	
Sm	ug/L	ICPMS	< 0.01	1.3	3.6	4.6	0.08	0.03	0.1	0.42	0.02	0.32	0.02	0.08	
Sn	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Sr	ug/L	ICPMS	240	570	650	240	96	130	44	50	88	50	180	120	
Ta	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Tb	ug/L	ICPMS	< 0.005	0.19	0.54	0.79	0.01	0.005	0.02	0.085	< 0.005	0.069	< 0.005	0.02	
Te	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	
Th	ug/L	ICPMS	< 0.005	0.14	0.45	0.34	< 0.005	< 0.005	0.008	0.02	< 0.005	0.04	< 0.005	0.009	
Ti	ug/L	ICPMS	0.4	17	20	14	< 0.1	0.3	0.1	0.5	< 0.1	0.4	< 0.1	0.4	
Tl	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	
Tm	ug/L	ICPMS	< 0.005	0.063	0.18	0.34	0.006	< 0.005	0.02	0.04	< 0.005	0.04	< 0.005	0.01	
U	ug/L	ICPMS	0.08	0.12	0.36	0.08	0.01	0.009	0.05	0.06	0.12	0.07	0.32	0.10	
V	ug/L	ICPMS	1	4	8.2	10	< 0.1	< 0.1	0.6	0.4	0.6	0.2	0.5	1	
W	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.04	< 0.02	< 0.02	0.4	
Y	ug/L	ICPMS	0.07	4.6	12	22	0.53	0.2	0.95	2.8	0.2	2.1	0.1	0.57	
Yb	ug/L	ICPMS	< 0.01	0.48	1.2	2.2	0.04	0.02	0.1	0.31	0.02	0.25	0.02	0.08	
Zn	ug/L	ICPMS	2	20	37	10	6	7	2	1	2	1	1	4	
Zr	ug/L	ICPMS	< 0.05	0.08	< 0.05	0.2	< 0.05	< 0.05	0.2	0.66	< 0.05	0.50	< 0.05	0.3	
Hg	ng/L	Hg CVAF	< 5	< 5	< 5	7	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	
δ ¹⁸ O vs VSMOW	permil	ISO1	-18.8	-18.2	-19.7	-18.7	-18.0	-18.2	-18.0	-17.8	-18.0	-18.1	-18.3	-17.5	
δD vs VSMOW	permil	ISO2	-139.8	-132.8	-144.4	-140.6	-138.8	-140.0	-138.9	-136.6	-136.4	-139.1	-140.8	-137.9	
δ ³⁴ S vs CDT	permil	ISO3	-	-	-	-	-	-	-	-	-	-	-	-	
δ ³⁶ S vs CDT	permil	ISO4	1.15	0.225	-0.14	0.35	2.53	0.92	-	-	-	-	3.74	6.05	

Appendix 1. Site and analytical data from creeks and water column profiles—Continued.

Field no. Drainage/ description			RS-17-99 Beaver Dam Creek	RS-18-99 Trail Creek	RS-19A-99 no name	RS-19B-99 no name	RS-20-99 no name	RS-23-99 Grouse Creek	RS-26-99 Chipmunk Creek	RS-32-99 Columbine Cr	RS-33-99 Meadow Cr	RS-35-99 Clear Cr	RS-37-99 Cub Cr	RS-39-99 Sedge Cr
Latitude			44°19'24"N	44°17'29.9"N	44°17'21.9"N	44°17'21.3"N	44°17'22.2"N	44°16'54.3"N	44°17'16.6"N	44°24'3"N	44°25'37"N	44°28'35"N	44°29'23"N	44°31'26"N
Longitude			110°11'4.8"W	110°12'4"W	110°12'24.8"W	110°12'20.4"W	110°12'31.4"W	110°20'13.6"W	110°17'0.8"W	110°15'7"W	110°17'8"W	110°16'8"W	W	110°16'43"W
Date			07/20/99	07/20/99	07/20/99	07/20/99	07/20/99	07/21/99	07/21/99	07/16/99	07/16/99	07/13/99	07/13/99	07/12/99
Depth	m		-	-	-	-	-	-	-	-	-	-	-	-
Treatment/ Sample type			integrated	integrated	point	point	point	point	point	integrated	integrated	integrated	integrated	integrated
Collector			Gemery/WRD	Gemery/WRD	Gemery/WRD	Gemery/WRD	Gemery/WRD	Gemery/WRD	Gemery/WRD	Sanzolone	Sanzolone	Sanzolone	Sanzolone	Sanzolone
pH			7.38	7.86	8.03	7.83	8.09	8.24	8.04	6.58	6.75	7.25	7.60	3.66
Conductivity	uS/cm		-	-	-	-	-	-	-	-	-	-	-	-
Temperature	°C		7.5	21	9	9	7	11	15.5	4.3	5.7	8.4	8.8	16.0
Flow	CFS		85.1	4.67	0.92	0.66	3.52	10.5	34.7	63	6.4	132	57	48
Alkalinity	Mg/L as CaCO ₃		-	-	-	-	-	-	-	20	20	22	30	-
Sum CO ₂	mM		-	-	-	-	-	-	-	-	-	-	-	-
HCO ₃	mM	measured	-	-	-	-	-	-	-	-	-	-	-	-
HCO ₃	uM	calculated	-	-	-	-	-	-	-	-	-	-	-	-
Comments			-	-	-	-	-	-	-	-	-	-	-	-
Cl	mg/L	IC-Aq	0.2	0.4	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2	1.7
F	mg/L	IC-Aq	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.2	0.2
NO ₃	mg/L	IC-Aq	<1	<1	<1	<1	0.2	0.1	<1	<1	<1	<1	<1	<1
SO ₄	mg/L	IC-Aq	1.9	1.1	1.2	1.2	1.2	4.2	0.7	14	1.4	1.9	3.6	31
Ag	ug/L	ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al	ug/L	ICPMS	4.6	12	5.2	20	<0.5	<0.5	5.5	170	38	14	40	140
As	ug/L	ICPMS	<0.4	0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	5
Au	ug/L	ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
B	ug/L	ICPAES	5.65	9.57	6.08	6.31	5	6.74	<5	12.1	9.8	8.19	10.1	234
Ba	ug/L	ICPMS	11	21	34	25	32	58	24	11	9.2	8.2	9.4	18
Be	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	0.08
Bi	ug/L	ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	mg/L	ICPAES	2.6	7.38	9.15	5.97	9.5	25.4	7.31	4.83	4.31	5.74	4.7	3.95
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	0.04	0.2	0.06	0.1	<0.01	<0.01	0.07	1.8	0.56	0.2	0.4	0.93
Co	ug/L	ICPMS	<0.02	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	0.1	0.04	<0.02	<0.02	0.2
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	<0.01	0.02	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01	<0.01	0.03	1.4
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	0.01	0.02	0.008	0.02	<0.005	0.01	0.01	0.11	0.26	0.073	0.14	0.13
Er	ug/L	ICPMS	0.006	0.006	<0.005	0.02	<0.005	<0.005	0.005	0.069	0.17	0.05	0.084	0.078
Eu	ug/L	ICPMS	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.01	0.02	0.006	0.007	0.02
Fe	ug/L	ICPMS	<30	100	<30	<30	<30	<30	<30	30	<30	<30	<30	290
Ga	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Gd	ug/L	ICPMS	<0.005	0.03	<0.005	0.007	<0.005	<0.005	0.01	0.13	0.22	0.065	0.13	0.12
Ge	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.1
Hf	ug/L	ICPMS	-	-	-	-	-	-	-	-	-	-	-	-
Ho	ug/L	ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.02	0.056	0.02	0.03	0.03
In	ug/L	ICPMS	-	-	-	-	-	-	-	-	-	-	-	-
K	mg/L	ICPAES	1.03	1.85	2.01	2	2.06	0.96	1.6	1	0.898	0.46	0.628	1.12
La	ug/L	ICPMS	0.07	0.2	0.04	0.1	0.02	0.01	0.06	0.94	0.75	0.2	0.57	0.54
Li	ug/L	ICPMS	5.9	6.3	6.9	5.8	6.6	6.2	6.6	6.8	7	7.1	9.9	24
Mg	mg/L	ICPAES	1.02	2.51	1.54	1.61	1.46	8.38	1.6	2.63	1.65	1.26	2.17	1.91
Mn	ug/L	ICPMS	0.42	18	0.33	0.22	0.056	5.9	3	27	9.3	2.9	7.8	27
Mo	ug/L	ICPMS	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	<0.2	0.3	0.3	0.3	0.3	0.2
Na	mg/L	ICPAES	3.1	2.76	2.48	2.29	2.35	3.54	1.75	3.19	2.28	2.12	3.86	4.23
Nb	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nd	ug/L	ICPMS	0.08	0.2	0.05	0.1	0.02	0.01	0.09	0.82	0.92	0.29	0.57	0.68
Ni	ug/L	ICPMS	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	0.2	0.5	0.4	2.5	0.4	1
P	ug/L	ICPMS	20	74	62	43	69	<1	24	<1	3	<1	<1	4
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.4	<0.05	0.07
Pr	ug/L	ICPMS	0.02	0.04	0.01	0.03	<0.01	<0.01	0.02	0.25	0.23	0.06	0.1	0.2
Rb	ug/L	ICPMS	1.5	2.6	2.8	3	2.7	0.84	2.3	2	1.7	0.82	1.6	2.3
Re	ug/L	ICPMS	-	-	-	-	-	-	-	-	-	-	-	-
Sb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.2
Sc	ug/L	ICPMS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Se	ug/L	ICPMS	<0.3	<0.3	<0.3	<0.3	<0.3	0.4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
SiO ₂	mg/L	ICPMS	19	15	29	26	29	6.6	20	18	19	10	14	17
Sm	ug/L	ICPMS	<0.01	0.03	<0.01	0.01	<0.01	<0.01	0.02	0.2	0.21	0.06	0.1	0.2
Sn	ug/L	ICPMS	-	-	-	-	-	-	-	-	-	-	-	-
Sr	ug/L	ICPMS	21	46	48	39	45	160	47	41	39	67	53	38
Ta	ug/L	ICPMS	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tb	ug/L	ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.02	0.04	0.01	0.02	0.02
Te	ug/L	ICPMS	-	-	-	-	-	-	-	-	-	-	-	-
Th	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ti	ug/L	ICPMS	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	0.5
Tl	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tm	ug/L	ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	0.02	0.007	0.01	0.01
U	ug/L	ICPMS	0.007	0.04	0.06	0.03	0.08	0.27	0.03	0.008	0.06	0.05	0.06	0.04
V	ug/L	ICPMS	1.6	2.6	2.3	2.2	1.9	<0.2	1.8	0.4	0.61	0.52	0.3	0.96
W	ug/L	ICPMS	0.15	0.21	0.14	0.13	0.1	0.08	0.06	0.64	0.52	0.4	0.39	0.71
Y	ug/L	ICPMS	0.06	0.09	0.03	0.1	0.02	0.04	0.06	0.57	1.3	0.4	0.7	0.62
Yb	ug/L	ICPMS	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.06	0.2	0.04	0.09	0.1
Zn	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	2	0.7	1	1
Zr	ug/L	ICPMS	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	14	<0.2	<0.2	<0.2	<0.2
Hg	ng/L	Hg CVAF	-	-										

Appendix 1. Site and analytical data from creeks and water column profiles—Continued.

Field no. Drainage/ description		51 West Thumb (WT1) water column	52 West Thumb (WT1) water column	53 West Thumb (WT1) water column	54 West Thumb (WT1) water column	55 West Thumb (WT2) water column	56 West Thumb (WT2) water column	57 West Thumb (WT2) water column	58 West Thumb (WT2) water column	59 West Thumb (WT2) water column	60 West Thumb (WT2) water column	61 West Thumb (WT2) water column
Latitude		44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N	44°24'59.3"N
Longitude		110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W	110°34'0"W
NPS no.		-	-	-	-	-	-	-	-	-	-	-
Date		07/24/97	07/24/97	07/24/97	07/25/97	07/25/97	07/25/97	07/25/97	07/25/97	07/25/97	07/25/97	07/25/97
Depth	m	4	5	5.9	0	2	4	5	8	0	2	4
Treatment/ Sample type		Raw and acidified	Raw and acidified	Raw and acidified	Filtered and acidified	Filtered and acidified	Filtered and acidified	Filtered and acidified	Filtered and acidified	Raw and acidified	Raw and acidified	Raw and acidified
Collector		-	-	-	-	-	-	-	-	-	-	-
pH		-	-	-	7.96	7.74	7.71	7.64	7.44	-	-	-
Conductivity	uS/cm	-	-	-	117	115	116	118	118	-	-	-
Temperature	°C	-	-	-	12.3	11.8	11.7	11.5	10.3	-	-	-
Flow	CFS	-	-	-	-	-	-	-	-	-	-	-
Alkalinity	Mg/L as CaCO ₃	-	-	-	-	-	-	-	-	-	-	-
Sum CO ₂	mM	-	-	-	0.72	0.68	0.65	0.68	0.70	-	-	-
HCO ₃	mM	-	-	-	0.7	0.6	0.6	0.6	0.6	-	-	-
HCO ₃	uM	-	-	-	514	481	499	486	506	-	-	-
Comments		-	-	-	-	-	-	-	-	-	-	-
Cl	mg/L	IC-Aq	-	-	5.8	5.5	5.5	5.7	5.9	-	-	-
F	mg/L	IC-Aq	-	-	-	-	-	-	-	-	-	-
NO ₃	mg/L	IC-Aq	-	-	-	-	-	-	-	-	-	-
SO ₄	mg/L	IC-Aq	-	-	6.9	7.3	7.2	7.2	7.1	-	-	-
Ag	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Al	ug/L	ICPMS	10	8.8	10	< 0.01	< 0.01	< 0.01	< 0.01	19	10	16
As	ug/L	ICPMS	18	18	18	22	18	19	18	20	18	19
Au	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005
B	ug/L	ICPAES	94	95	94	100	97	96	95	100	99	94
Ba	ug/L	ICPMS	8.8	8.9	8.9	8.6	8.8	8.9	8.9	8.9	8.9	9.1
Be	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	5.6	5.6	5.6	5.6	5.9	5.6	5.7	5.7	5.7	5.6
Cd	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ce	ug/L	ICPMS	0.04	0.04	0.04	0.02	0.01	0.01	0.02	0.01	0.07	0.05
Co	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Cr	ug/L	ICPMS	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Cs	ug/L	ICPMS	3.7	3.7	3.7	4.4	3.6	3.8	3.8	4.1	4.5	3.7
Cu	ug/L	ICPMS	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Dy	ug/L	ICPMS	0.008	0.007	0.005	0.006	< 0.005	0.005	< 0.005	0.006	0.006	0.007
Er	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005	< 0.005	0.005	< 0.005
Eu	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fe	ug/L	ICPMS	< 10	< 10	< 10	< 10	< 10	< 10	< 10	11	< 10	11
Ga	ug/L	ICPMS	0.02	0.02	0.02	0.03	0.02	0.02	< 0.02	0.03	0.04	< 0.02
Gd	ug/L	ICPMS	0.005	0.006	< 0.005	< 0.005	0.01	< 0.005	< 0.005	0.009	0.02	0.01
Ge	ug/L	ICPMS	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.4	0.4
Hf	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ho	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
In	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
K	mg/L	ICPAES	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.8	1.8	1.8
La	ug/L	ICPMS	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.04
Li	ug/L	ICPMS	44	44	43	51	43	45	45	48	50	43
Mg	mg/L	ICPAES	2.4	2.3	2.4	2.4	2.4	2.3	2.3	2.4	2.3	2.4
Mn	ug/L	ICPMS	0.82	0.85	0.87	0.48	0.25	0.38	0.24	0.41	1.5	1.0
Mo	ug/L	ICPMS	1.5	1.6	1.6	1.7	1.5	1.6	1.5	1.6	1.7	1.5
Na	mg/L	ICPAES	10	10	10	11	10	10	10	11	11	10
Nb	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Nd	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ni	ug/L	ICPMS	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4
P	ug/L	ICPMS	74	77	68	71	63	62	66	61	66	80
Pb	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Pr	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Rb	ug/L	ICPMS	6.3	6.2	6.0	6.5	6.0	6.1	6.2	6.6	6.2	6.1
Re	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Sb	ug/L	ICPMS	0.78	0.77	0.78	0.89	0.74	0.80	0.77	0.83	0.91	0.78
Sc	ug/L	ICPMS	0.2	0.3	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.2
Se	ug/L	ICPMS	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
SiO ₂	mg/L	ICPMS	9.9	9.7	9.7	10	9.5	10	9.6	9.8	10	9.5
Sm	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sn	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Sr	ug/L	ICPMS	40	40	40	40	40	40	40	40	40	40
Ta	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Tb	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Te	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Th	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ti	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Tl	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Tm	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U	ug/L	ICPMS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
V	ug/L	ICPMS	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
W	ug/L	ICPMS	3.0	3.0	2.9	3.5	3.0	3.2	3.1	3.3	3.5	2.9
Y	ug/L	ICPMS	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04
Yb	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zn	ug/L	ICPMS	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Zr	ug/L	ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Hg	ng/L	Hg CVAF	-	-	-	-	-	-	-	-	-	-
δ ¹⁸ O vs VSMOW	permil	ISO1	-	-	-	-16.3	-16.3	-16.2	-16.4	-16.4	-	-
δD vs VSMOW	permil	ISO2	-	-	-	-127.6	-125.2	-124.9	-125.6	-126.4	-	-
δ ³⁴ S vs CDT	permil	ISO3	-	-	-	2.6	1.8	2.0	2.2	-	-	-
δ ³⁴ S vs CDT	permil	ISO4	-	-	-	-	-	-	2.1	-	-	-

Appendix 2. Site and analytical data from hydrothermal vents in Yellowstone Lake—Continued.

Field No. Description	Y00-D12.1 West Thumb, NE of Grant	98-13A West Thumb off Bluff Point (Otter Vent)	98-13B West Thumb off Bluff Point (Otter Vent) (0.5m above 98-13A)	D03-8.1 WT, Otter vent	D03-8.2 WT, Otter vent	Y00-D18.1 West Thumb, N of Bluff Point	Y00-D18.2 West Thumb, N of Bluff Point (same vent as Y00-D18.1)	96-5 Steamboat Point vent	96-6-1 Steamboat Point vent
Latitude	44°24'26.7"N	44°26'36.0"N	44°26'36.0"N	44°26'35.998"N	44°26'35.998"N	44°26'56.8"N	44°26'56.8"N	44°31'35.7"N	44°31'35.7"N
Longitude	110°33'33.0"W	110°33'56.1"W	110°33'56.1"W	110°33'56.1"W	110°33'56.1"W	110°33'30.5"W	110°33'30.5"W	110°17'39.5"W	110°17'39.5"W
Date	7/30/00	7/18/98	7/18/98	8/16/03	8/16/03	8/2/00	8/2/00	-	-
Temp °C	31.7	68	-	66.9	66.9	42.0	49.3	89	93
pH	-	8.6	8.3	8.1	8	7.1	7.3	-	-
Depth m	23	5	5	1.7	1.7	59	59	-	-
Treatment	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Raw	Raw
sum CO2 mM	-	0.91	0.79	-	-	-	-	0.98	1.17
HCO3 mM measured	-	0.884	0.774	-	-	-	-	-	-
HCO3 uM calc	-	1384	948	-	-	-	-	-	-
Cl mg/L IC-Aq	5.3	1.8	3.3	5	4.7	4.6	4.6	-	-
F mg/L IC-Aq	0.7	-	-	0.5	1.6	2.7	3.1	-	-
NO3 mg/L IC-Aq	<.08	-	-	<.08	<.08	<.08	0.2	-	-
SO4 mg/L IC-Aq	8.4	-	-	6.9	6.6	6.3	6.1	-	-
Ag ug/L ICPMS	<0.01	< 0.01	< 0.01	<0.01	<0.01	<0.01	<0.01	< 0.05	< 0.05
Al ug/L ICPMS	30	21	11	4.4	3.3	3.7	4.5	58	40
As ug/L ICPMS	18	9.2	14	14	13	15	16	11	15
Au ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B ug/L ICPAES	-	35	62	-	-	-	-	-	-
Ba ug/L ICPMS	9.5	5	7.7	7.8	7.9	9.7	9.9	25	11
Be ug/L ICPMS	<0.05	< 0.05	0.07	<0.05	<0.05	<0.05	<0.05	< 0.2	< 0.2
Bi ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.03	< 0.03	< 0.01	< 0.01	< 0.05	< 0.05
Ca mg/L ICPAES	-	3.2	3.8	-	-	-	-	-	-
Ca mg/L ICPMS	4.3	3.6	4.5	4.2	4.2	3.8	3.7	5.5	4.9
Cd ug/L ICPMS	0.04	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.1	< 0.1
Ce ug/L ICPMS	0.04	0.5	0.04	< 0.01	< 0.01	0.04	0.07	0.2	0.1
Co ug/L ICPMS	0.02	0.2	0.1	< 0.02	< 0.02	< 0.02	0.03	< 0.1	< 0.1
Cr ug/L ICPMS	<1	< 1	< 1	<1	<1	<1	<1	< 5	< 5
Cs ug/L ICPMS	3.5	9.3	5.2	3	2.8	3.6	4	1.3	1.2
Cu ug/L ICPMS	<0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	0.9	0.6
Dy ug/L ICPMS	0.005	0.01	< 0.005	< 0.005	< 0.005	0.005	< 0.005	< 0.05	< 0.05
Er ug/L ICPMS	< 0.005	0.006	< 0.005	< 0.005	< 0.005	0.007	0.005	< 0.05	< 0.05
Eu ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.05	< 0.05
Fe ug/L ICPMS	13	< 10	< 10	< 2	< 2	8.2	10	< 500	< 500
Ga ug/L ICPMS	< 0.02	2.4	0.83	0.087	0.054	0.02	0.02	0.2	< 0.1
Gd ug/L ICPMS	0.008	< 0.005	0.006	< 0.005	< 0.005	0.006	0.008	< 0.05	< 0.05
Ge ug/L ICPMS	0.5	1.4	0.7	0.47	0.38	0.7	0.9	0.2	0.3
Hf ug/L ICPMS	-	0.3	< 0.05	< 5	< 5	-	-	< 0.05	< 0.05
Ho ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.05	< 0.05
In ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05
K mg/L ICPAES	-	< 1	1.0	-	-	-	-	-	-
K ug/L ICPMS	1700	680	1400	1400	1400	2200	2400	2200	1600
La ug/L ICPMS	0.04	0.03	0.02	< 0.01	< 0.01	0.05	0.05	0.1	0.07
Li ug/L ICPMS	50	120	77	50	47	64	69	34	40
Lu ug/L ICPMS	-	-	-	-	-	-	-	< 0.05	< 0.05
Mg mg/L ICPAES	-	< 1	1.3	-	-	-	-	-	-
Mg mg/L ICPMS	2	0.20	1.7	1.9	1.9	1.7	1.6	1.8	1.9
Mn ug/L ICPMS	4	6.9	2.8	1.2	0.9	13	17	6.4	9.5
Mo ug/L ICPMS	1.6	16	7.5	2.4	1.9	4.2	5.1	1.4	1.2
Na mg/L ICPAES	-	25	14	-	-	-	-	-	-
Na mg/L ICPMS	10	29	17	9.4	8.5	13	14	7.2	7.2
Nb ug/L ICPMS	-	< 0.02	< 0.02	-	-	-	-	< 0.1	< 0.1
Nd ug/L ICPMS	0.03	0.05	0.03	< 0.01	< 0.01	0.03	0.06	0.1	0.07
Ni ug/L ICPMS	0.4	< 0.1	0.2	0.6	0.42	0.4	0.3	0.3	0.5
P ug/L ICPMS	8	43	110	< 1	< 1	9	9	-	-
Pb ug/L ICPMS	0.08	0.2	< 0.05	< 0.05	< 0.05	0.06	0.06	0.2	0.09
Pr ug/L ICPMS	< 0.01	0.03	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.05	< 0.05
Rb ug/L ICPMS	6.8	5.2	5.5	4.7	4.6	11	12	8.2	4.6
Re ug/L ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.05
Sb ug/L ICPMS	1.1	0.54	0.82	0.81	0.8	0.89	1.6	0.4	0.6
Sc ug/L ICPMS	-	< 0.1	< 0.1	-	-	-	-	< 0.5	< 0.5
Se ug/L ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 5	< 5
SiO2 mg/L ICPMS	12	97	45	14	11	41	47	17	12
Sm ug/L ICPMS	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.05	< 0.05
Sn ug/L ICPMS	-	< 0.05	< 0.05	-	-	-	-	< 1	< 1
Sr ug/L ICPMS	40	6.6	30	36	37	35	35	50	38
Ta ug/L ICPMS	-	0.04	< 0.02	-	-	-	-	< 0.05	< 0.05
Tb ug/L ICPMS	< 0.005	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.05	< 0.05
Te ug/L ICPMS	-	< 0.1	< 0.1	-	-	-	-	< 0.5	< 0.5
Th ug/L ICPMS	< 0.005	0.04	0.01	< 0.08	< 0.08	< 0.005	< 0.005	< 0.05	< 0.05
Ti ug/L ICPMS	-	0.1	< 0.1	-	-	-	-	1	0.8
Tl ug/L ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.1	0.1
Tm ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.05	< 0.05
U ug/L ICPMS	0.009	0.03	0.008	0.012	0.008	0.02	0.02	< 0.02	< 0.02
V ug/L ICPMS	0.75	0.2	0.7	0.82	0.86	0.63	0.69	0.9	1.3
W ug/L ICPMS	2.8	9.1	4.7	3.1	2.7	3.9	4.2	2.2	2.5
Y ug/L ICPMS	0.05	0.03	0.01	< 0.01	0.01	0.04	0.06	< 0.1	< 0.1
Yb ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.05	< 0.05
Zn ug/L ICPMS	2	41	10	0.59	< 0.5	4	6	12	21
Zr ug/L ICPMS	-	6.9	0.4	-	-	-	-	< 0.1	< 0.1
Hg ng/L Hg CVAF	0.019	36	12	-	-	< 0.005	0.007	-	-
δ ¹⁸ O vs VSMOW per mil	ISO1	-16.3	-19.12	-17.39	-16.3	-16.0	-17.0	-	-
δD vs VSMOW per mil	ISO2	-129.1	-145.4	-137.8	-134.8	-131.9	-131.5	-132.2	-
δ ³⁴ S ₂₀₄ vs CDT per mil	ISO3	-	-	-	-	-	-	-	-
δ ³⁴ S ₂₀₄ vs CDT per mil	ISO4	-	-	-	-	2.4	-	-	-
δ ¹³ C _{org} vs VPDB per mil	ISO5	-	-	-	-5.8	-5.5	-	-	-

Appendix 2. Site and analytical data from hydrothermal vents in Yellowstone Lake—Continued.

Field No. Description	97-12r		98-26A		98-27A		98-27B		YNP-99-12-1		YNP-99-12-2		YNP-99-13-1		YNP-99-13-2		97-1		97-2	
	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole (0.5m above 98-27A)	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay deep hole	Mary Bay nearshore	Mary Bay nearshore	Mary Bay nearshore	Mary Bay nearshore	Mary Bay nearshore	Mary Bay nearshore
Latitude	44°32'42.8"N	44°32'42.8"N	44°32'42.8"N	44°32'42.8"N	44°32'42.8"N	44°32'43.5"N	44°32'43.5"N	44°32'43.5"N	44°32'43.5"N	44°32'43.5"N	44°32'43.5"N	44°32'43.5"N	44°32'43.5"N	44°33'6"N	44°33'6"N	44°33'6"N	44°33'6"N	44°33'6"N	44°33'6"N	44°33'6"N
Longitude	110°18'39.1"W	110°18'39.1"W	110°18'39.1"W	110°18'39.1"W	110°18'39.1"W	110°18'38.5"W	110°18'38.5"W	110°18'38.5"W	110°18'38.5"W	110°18'38.5"W	110°18'38.5"W	110°18'38.5"W	110°18'38.5"W	110°18'9"W	110°18'9"W	110°18'9"W	110°18'9"W	110°18'9"W	110°18'9"W	110°18'9"W
Date	7/26/97	7/24/98	7/24/98	7/24/98	7/24/98	7/22/99	7/22/99	7/22/99	7/22/99	7/22/99	7/22/99	7/22/99	7/22/99	7/26/97	7/26/97	7/26/97	7/26/97	7/26/97	7/26/97	7/26/97
Temp °C	35.0	50	66; max 103	95	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	30.1	7.3	7.3	7.3	7.3	7.3	7.3	7.3
pH	5.1	5.2	5.9	6.6	5.4	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Depth m	-	50	48	47	41	41	41	41	41	41	41	41	46	-	-	-	-	-	-	-
Treatment	Raw	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Raw
sum CO2 mM	-	8.35	2.28	0.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HCO3 mM measured	-	0.551	0.588	0.578	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HCO3 uM calc	-	468	582	624	514	447	320	447	320	447	320	447	320	-	-	-	-	-	-	-
Cl mg/L IC-Aq	-	6.0	5.7	5.8	5.4	5.2	5.1	5.3	4.7	5.3	4.7	5.3	4.7	-	-	-	-	-	-	-
F mg/L IC-Aq	-	-	-	-	0.5	0.5	0.5	0.5	-	0.5	-	0.5	-	-	-	-	-	-	-	-
NO3 mg/L IC-Aq	-	-	-	-	<1	<1	<35	<35	-	<35	-	<35	-	-	-	-	-	-	-	-
SO4 mg/L IC-Aq	-	-	-	-	11.0	7.7	14.0	8.1	8.3	8.1	8.3	8.1	8.3	-	-	-	-	-	-	-
Ag ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	0.61	0.01	0.09	<0.01	<0.01	0.09	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al ug/L ICPMS	230	110	23	4.2	14	<0.5	110	2	9.3	2	9.3	2	9.3	210	210	210	210	210	210	210
As ug/L ICPMS	13	17	32	19	14	13	8.1	14	12	13	14	12	13	13	13	13	13	13	13	13
Au ug/L ICPMS	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.007	<0.01	<0.01	<0.01	<0.01	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
B ug/L ICPAES	-	80	88	85	143	95.9	88.8	97.2	-	88.8	97.2	88.8	97.2	-	-	-	-	-	-	-
Ba ug/L ICPMS	13	14	15	10	67	9.6	33	9.7	11	33	9.7	33	9.7	9.9	9.9	9.9	9.9	9.9	9.9	11
Be ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	0.09	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bi ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca mg/L ICPAES	-	3.7	4.0	4.3	6.32	5.31	5.33	5.42	-	5.31	5.33	5.42	-	-	-	-	-	-	-	-
Ca mg/L ICPMS	3.6	5.0	5.2	5.7	5.4	4.3	4.4	4.3	4.1	4.3	4.4	4.3	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Cd ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce ug/L ICPMS	0.5	0.3	0.2	0.04	0.1	0.03	0.3	0.04	0.1	0.03	0.3	0.04	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Co ug/L ICPMS	0.06	0.05	0.2	0.05	0.07	0.06	0.04	0.04	0.06	0.04	0.04	0.04	0.06	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cr ug/L ICPMS	3	<1	<1	<1	<1	<1	<1	<1	3	<1	<1	<1	3	3	3	3	3	3	3	3
Cs ug/L ICPMS	4.0	4.1	4.3	4.1	3.4	3	3.8	3	2.5	3	3.8	3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Cu ug/L ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy ug/L ICPMS	0.03	0.03	0.01	0.007	0.01	<0.005	0.05	<0.005	0.009	0.05	<0.005	0.05	<0.005	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Er ug/L ICPMS	0.02	0.03	0.01	0.007	0.007	<0.005	0.03	<0.005	0.009	<0.005	0.03	<0.005	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Eu ug/L ICPMS	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	0.006	<0.005	0.007	<0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Fe ug/L ICPMS	150	360	520	13	<30	<30	87	<30	32	<30	87	<30	32	150	150	150	150	150	150	150
Ga ug/L ICPMS	<0.02	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Gd ug/L ICPMS	0.02	0.03	0.03	0.008	0.01	<0.005	0.056	0.006	0.02	<0.005	0.056	0.006	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Ge ug/L ICPMS	0.2	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Hf ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ho ug/L ICPMS	0.006	<0.005	0.008	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
In ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	-	-	-	-	<0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
K mg/L ICPAES	-	1.3	1.5	1.4	2.22	1.62	1.74	1.64	-	1.62	1.74	1.64	-	-	-	-	-	-	-	-
K ug/L ICPMS	1200	1400	1500	1500	2000	1400	1600	1500	1300	1400	1600	1500	1300	1300	1300	1300	1300	1300	1300	1300
La ug/L ICPMS	0.2	0.1	0.1	0.02	0.05	0.03	0.03	0.03	0.06	0.03	0.03	0.03	0.06	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Li ug/L ICPMS	45	54	55	59	51	50	46	51	36	50	46	51	36	36	36	36	36	36	36	36
Lu ug/L ICPMS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg mg/L ICPAES	-	1.7	1.7	1.8	2.9	2.25	2.39	2.28	-	2.25	2.39	2.28	-	-	-	-	-	-	-	-
Mg mg/L ICPMS	1.8	2.5	2.6	2.7	2.6	2	2.1	2.1	2.0	2	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Mn ug/L ICPMS	6.2	23	28	3.6	26	1.4	12	1.4	14	1.4	12	1.4	14	16	16	16	16	16	16	16
Mo ug/L ICPMS	0.53	0.2	0.81	1.0	0.6	1.1	0.2	1	1.1	0.6	1.1	0.2	1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Na mg/L ICPAES	-	7.4	8.2	8.4	9.9	9.44	9.1	9.7	-	9.44	9.1	9.7	-	-	-	-	-	-	-	-
Na mg/L ICPMS	7.3	9.1	9.7	9.7	8.3	7.8	7.4	7.8	7.2	7.8	7.4	7.8	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Nb ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	0.2	0.2	0.1	0.1	<0.02	0.2	0.1	0.1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nd ug/L ICPMS	0.20	0.20	0.09	0.03	0.06	0.05	0.21	0.04	0.2	0.05	0.21	0.04	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ni ug/L ICPMS	0.5	0.4	0.5	0.4	0.3	0.4	0.2	0.5	0.4	0.3	0.4	0.2	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7
P ug/L ICPMS	120	300	360	110	25	1	28	3	86	1	28	3	86	86	86	86	86	86	86	86
Pb ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Pr ug/L ICPMS	0.05	0.04	0.02	<0.01	0.02	<0.01	0.05	<0.01	0.05	<0.01										

Appendix 2. Site and analytical data from hydrothermal vents in Yellowstone Lake—Continued.

Field No. Description		D02-10.1 Inflated Plain- hydrothermal vent	D02-10.2 Inflated Plain- hydrothermal vent	D02-12.1 Inflated Plain- hydrothermal vent	D02-12.2 Inflated Plain- hydrothermal vent	D02-13.1 Inflated Plain- hydrothermal vent	D02-6.1 Inflated Plain- hydrothermal vent	D03-1.1 Inflated Plain- hydrothermal vent	D03-1.2 Inflated Plain- hydrothermal vent	D03-2.1 Inflated Plain- hydrothermal vent	D03-3.1 Inflated Plain- hydrothermal vent
Latitude		44°32'10.4"N	44°32'10.4"N	44°32'10.2"N	44°32'10.2"N	44°32'10.2"N	44°32'8.6"N	44°32'5.161"N	44°32'5.161"N	44°32'5.323"N	44°32'8.206"N
Longitude		110°21'15.8"W	110°21'15.8"W	110°21'18.5"W	110°21'18.5"W	110°21'18.5"W	110°21'15.3"W	110°21'15.624"W	110°21'15.624"W	110°21'15.432"W	110°21'15.75"W
Date		9/26/02	9/26/02	9/27/02	9/27/02	9/27/02	8/20/02	8/7/03	8/7/03	8/9/03	8/9/03
Temp	°C	35	63	85	22	-	77.8	45	61	69	39
pH		5.2	5.8	5.9	6.7	-	-	5.47	6.69	6.7	6.8
Depth	m	29	29	15	16	13	10	23.9	28.4	29.7	7.9
Treatment		Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered
sum CO2	mM	-	-	-	-	-	-	-	-	-	-
HCO3	mM measured	-	-	-	-	-	-	-	-	-	-
HCO3	uM calc	-	-	-	-	-	-	-	-	-	-
Cl	mg/L IC-Aq	5.2	5.1	5.1	5.2	5.2	-	4.7	4.8	4.9	4.9
F	mg/L IC-Aq	0.6	0.6	0.7	0.6	0.6	-	0.6	0.5	0.5	0.5
NO3	mg/L IC-Aq	<.18	<.18	<.18	2	0.3	-	<.08	<.08	<.08	<.08
SO4	mg/L IC-Aq	12	11	10	8.9	12	-	15	8.6	8.8	7.8
Ag	ug/L ICPMS	<0.01	<0.01	0.2	<0.01	<0.01	< 3	0.062	0.013	<0.01	<0.01
Al	ug/L ICPMS	3	3.5	3.2	2.1	2.3	218	28	5.3	4.7	3.7
As	ug/L ICPMS	15	14	13	13	13	21.8	19	14	13	13
Au	ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-	0.052	0.013	< 0.01	< 0.01
B	ug/L ICPAES	-	-	-	-	-	-	-	-	-	-
Ba	ug/L ICPMS	2	2	3	3	3	23.2	13	9.1	8.8	9
Be	ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	< 0.05	<0.05	<0.05	<0.05	<0.05
Bi	ug/L ICPMS	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.2	< 0.03	< 0.03	< 0.03	< 0.03
Ca	mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
Ca	mg/L ICPMS	4.8	4.7	4.7	4.7	4.6	4.0	4.3	4.3	4.3	4.2
Cd	ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	0.06	<0.02	<0.02	<0.02	<0.02
Ce	ug/L ICPMS	0.02	0.01	0.01	0.01	0.01	0.11	0.16	0.052	0.032	0.034
Co	ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	0.12	0.03	0.068	<0.02	<0.02
Cr	ug/L ICPMS	2	2	1	2	1	< 1	5.4	3.2	< 1	< 1
Cs	ug/L ICPMS	2.4	2.4	2.4	2.4	2.3	2.83	2.5	2.4	2.4	2.5
Cu	ug/L ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	10.8	<0.5	0.6	<0.5	<0.5
Dy	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.008	0.015	0.0054	0.005	< 0.005
Er	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.005	0.0074	< 0.005	< 0.005	< 0.005
Eu	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fe	ug/L ICPMS	9	8.3	7	6.2	6.5	87	22	< 2	< 2	< 2
Ga	ug/L ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.05	< 0.02	< 0.02	< 0.02	< 0.02
Gd	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01	0.013	< 0.005	0.005	0.0079
Ge	ug/L ICPMS	0.3	0.3	0.3	0.3	0.3	0.33	0.31	0.32	0.31	0.33
Hf	ug/L ICPMS	-	-	-	-	-	-	< 5	< 5	20	< 5
Ho	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
In	ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-	< 0.01	< 0.01	< 0.01	< 0.01
K	mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
K	ug/L ICPMS	1700	1700	1600	1600	1600	2000	1600	1500	1500	1500
La	ug/L ICPMS	0.01	0.02	< 0.01	0.01	< 0.01	0.04	0.079	0.034	0.029	0.024
Li	ug/L ICPMS	43	43	42	42	42	37.2	43	47	44	44
Lu	ug/L ICPMS	-	-	-	-	-	< 0.1	-	-	-	-
Mg	mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
Mg	mg/L ICPMS	2.4	2.4	2.3	2.3	2.3	1.76	2.1	2.1	2.1	2
Mn	ug/L ICPMS	0.81	0.076	0.7	0.53	3.8	12.5	2.5	1.6	1.1	1.3
Mo	ug/L ICPMS	3	2	1.7	1.8	1.6	< 2	4.7	2.8	2	1.8
Na	mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
Na	mg/L ICPMS	9.1	9.2	9	9	8.9	10.1	7.9	8	8	7.8
Nb	ug/L ICPMS	-	-	-	-	-	< 0.2	-	-	-	-
Nd	ug/L ICPMS	0.01	0.02	0.01	< 0.01	0.01	0.08	0.091	0.032	0.027	0.022
Ni	ug/L ICPMS	0.4	0.5	0.3	0.4	0.4	1.3	1.4	3	1.1	1.3
P	ug/L ICPMS	9	6	5	3	< 3	0.02	7.6	5.3	5	1
Pb	ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05	<0.05
Pr	ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.023	0.01	< 0.01	< 0.01
Rb	ug/L ICPMS	4.8	4.9	4.8	4.8	4.7	7.16	4.7	4.6	4.5	4.6
Re	ug/L ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	-	< 0.02	< 0.02	< 0.02	< 0.02
Sb	ug/L ICPMS	0.95	0.85	0.72	0.77	0.89	0.75	0.55	0.92	0.82	0.9
Sc	ug/L ICPMS	-	-	-	-	-	2.5	-	-	-	-
Se	ug/L ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 1	< 0.2	< 0.2	< 0.2	< 0.2
SiO2	mg/L ICPMS	10	10	9.9	9.1	9.4	10	9.2	8.5	8.3	8.4
Sm	ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	0.017	< 0.01	< 0.01	< 0.01
Sn	ug/L ICPMS	-	-	-	-	-	-	-	-	-	-
Sr	ug/L ICPMS	37	38	37	37	37	45.8	39	39	39	39
Ta	ug/L ICPMS	-	-	-	-	-	< 0.02	-	-	-	-
Tb	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Te	ug/L ICPMS	-	-	-	-	-	-	-	-	-	-
Th	ug/L ICPMS	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.2	< 0.08	< 0.08	< 0.08	< 0.08
Ti	ug/L ICPMS	-	-	-	-	-	< 0.5	-	-	-	-
Tl	ug/L ICPMS	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05	< 0.05	< 0.05	< 0.05
Tm	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U	ug/L ICPMS	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.1	0.055	0.023	0.015	0.012
V	ug/L ICPMS	0.9	1	0.9	0.9	0.9	2.5	1.1	0.81	0.84	1.1
W	ug/L ICPMS	4.2	3.1	3	2.7	2.5	0.82	2.2	2.3	2.2	2.2
Y	ug/L ICPMS	0.01	0.02	< 0.01	< 0.01	0.01	0.04	0.082	0.032	0.027	0.024
Yb	ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.007	0.01	< 0.01	< 0.01	< 0.01
Zn	ug/L ICPMS	0.5	< 0.5	< 0.5	< 0.5	< 0.5	31.4	5.1	5.9	5.8	5.4
Zr	ug/L ICPMS	-	-	-	-	-	< 0.2	-	-	-	-
Hg	ng/L Hg CVAF	20	10	22	20	16	-	-	-	-	-
δ ¹⁸ O vs VSMOW	per mil ISO1	-16.2	-16.3	-16.2	-15.9	-16.0	-	-16.2	-16.3	-16.1	-16.1
δD vs VSMOW	per mil ISO2	-127.2	-127.4	-127	-125	-126.8	-	-130.3	-129.7	-128.5	-129.7
δ ³⁴ S _{SO4} vs CDT	per mil ISO3	-	-	-	-	-	-	-	-	-	-
δ ³⁴ S _{SO4} vs CDT	per mil ISO4	-	-	-	-	-	-	2.4	2.6	2.1	2.7
δ ¹³ C _{SO4} vs VPDB	per mil ISO5	-	-	-	-	-	-	-1.5	-6.9	-5.7	-3.4

Appendix 2. Site and analytical data from hydrothermal vents in Yellowstone Lake—Continued.

Field No. Description	D03-7.1 Inflated Plain- hydrothermal vent	D03-7.2 Inflated Plain- hydrothermal vent	D03-9.1 Inflated Plain- hydrothermal vent	D04-5.1 Inflated Plain: water sample in sediment plume just above vent	D04-5.2 Inflated Plain: water sample- bubbler from edge of plume hole	D04-7.1 Inflated Plain: water sample from bubbler	D04-9.1 Inflated Plain: same site as D02- 12 and D03-7	D04-9.2 Inflated Plain: same site as D02- 12 and D03-7	D04-12.3 Inflated Plain: same as D04-5	D02-5.1 Vent in Elliott's Crater
Latitude	44°32'9.281"N	44°32'9.281"N	44°32'5.489"N	44°32'4.98"N	44°32'4.98"N	44°32'10.163"N	44°32'15.521"N	44°32'15.521"N	44°32'8.135"N	44°31'46.4"N
Longitude	110°21'17.964"W	110°21'17.964"W	110°21'16.23"W	110°21'14.7"W	110°21'14.7"W	110°21'30.305"W	110°21'29.921"W	110°21'29.921"W	110°21'15.455"W	110°19'25.6"W
Date	8/14/03	8/14/03	8/17/03	8/10/04	8/10/04	8/11/04	8/13/04	8/13/04	8/13/04	8/20/02
Temp	70	99.3	87.4				12.1	15.2	4.9	57.2
pH	6.5	7.3	6.6	6.5	6.7	6.9	7.0	6.4	4.9	-
Depth	13.7	13.7	28.4	15.4	11.2	11.4	12.3	11.9	11.1	61
Treatment	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered
sum CO2	mM	-	-	-	-	-	-	-	-	-
HCO3	mM measured	-	-	0.50	0.52	0.42	0.52	0.52	-	-
HCO3	uM calc	-	-	-	-	-	-	-	-	-
Cl	mg/L IC-Aq	5	7.3	4.8	4.8	4.9	4.9	4.9	5.1	5
F	mg/L IC-Aq	0.5	0.5	0.9	0.54	0.54	0.57	0.66	0.62	0.5
NO3	mg/L IC-Aq	<.08	<.08	<.08	<.08	<.08	<.08	<.08	0.14	<.08
SO4	mg/L IC-Aq	7.1	7.4	6.5	8.4	7.9	8.3	7.8	9.8	8.2
Ag	ug/L ICPMS	<0.01	<0.01	0.012	<3	<3	<3	<3	<3	<3
Al	ug/L ICPMS	7.1	3.6	4.2	4	2.7	2.5	4.3	9	432
As	ug/L ICPMS	12	12	12	16.1	15.5	12.8	15.2	14.8	2
Au	ug/L ICPMS	0.011	<0.01	0.018	-	-	-	-	-	-
B	ug/L ICPAES	-	-	-	-	-	-	-	-	-
Ba	ug/L ICPMS	9.2	8.5	9.2	9.47	9.11	8.83	10.1	9.57	16.8
Be	ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bi	ug/L ICPMS	<0.03	<0.03	<0.03	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ca	mg/L ICPAES	-	-	-	-	-	-	-	-	-
Ca	mg/L ICPMS	4.2	4.3	4.4	5.43	5.45	4.86	5.23	5.18	5.13
Cd	ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L ICPMS	0.03	0.015	0.04	0.02	0.03	0.14	0.04	0.04	0.03
Co	ug/L ICPMS	<0.02	<0.02	<0.02	0.03	0.06	0.31	0.03	0.04	0.02
Cr	ug/L ICPMS	<1	<1	<1	<1	<1	<1	<1	<1	7.6
Cs	ug/L ICPMS	2.4	2.4	2.5	2.73	2.78	2.65	2.79	2.76	3.61
Cu	ug/L ICPMS	1.8	<0.5	<0.5	0.52	0.87	<0.5	<0.5	<0.5	0.87
Dy	ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Er	ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Eu	ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007
Fe	ug/L ICPMS	<2	<2	<2	<50	<50	<50	<50	<50	78
Ga	ug/L ICPMS	<0.02	<0.02	<0.02	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Gd	ug/L ICPMS	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	0.03
Ge	ug/L ICPMS	0.33	0.33	0.32	0.38	0.36	0.38	0.38	0.36	<0.05
Hf	ug/L ICPMS	7	<5	10	-	-	-	-	-	-
Ho	ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005
In	ug/L ICPMS	<0.01	<0.01	<0.01	-	-	-	-	-	-
K	mg/L ICPAES	-	-	-	-	-	-	-	-	-
K	ug/L ICPMS	1500	1500	1500	1.79	1.81	1.71	1.72	1.7	2.4
La	ug/L ICPMS	0.023	0.011	0.031	0.02	0.02	0.07	0.03	0.02	0.16
Li	ug/L ICPMS	42	42	43	46	46.4	45.9	45.6	45.5	47.2
Lu	ug/L ICPMS	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Mg	mg/L ICPAES	-	-	-	-	-	-	-	-	-
Mg	ug/L ICPMS	2	2	2	2.4	2.34	2.16	2.29	2.28	2.11
Mn	ug/L ICPMS	1.2	1.1	1.2	1.3	1.4	48.9	2.4	2	19.2
Mo	ug/L ICPMS	1.2	1.3	1.3	<2	<2	<2	<2	<2	<2
Na	mg/L ICPAES	-	-	-	-	-	-	-	-	-
Na	ug/L ICPMS	7.5	7.6	7.8	9.73	9.62	9.38	9.4	9.2	10.4
Nb	ug/L ICPMS	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nd	ug/L ICPMS	0.026	0.012	0.032	0.01	0.02	0.06	0.02	0.02	0.23
Ni	ug/L ICPMS	0.61	0.72	0.52	1	1.1	0.8	0.6	0.7	1.1
P	ug/L ICPMS	<1	<1	5	<0.01	<0.01	<0.01	<0.01	<0.01	0.2
Pb	ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pr	ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	0.06
Rb	ug/L ICPMS	4.5	4.4	4.6	5.45	5.41	5.13	5.34	5.3	8.42
Re	ug/L ICPMS	<0.02	<0.02	<0.02	-	-	-	-	-	-
Sb	ug/L ICPMS	0.71	1	0.69	0.87	0.84	1.18	0.85	0.76	<0.3
Sc	ug/L ICPMS	-	-	-	0.8	0.7	0.7	0.7	0.7	2
Se	ug/L ICPMS	<0.2	<0.2	<0.2	<1	<1	<1	<1	<1	<1
SiO2	mg/L ICPMS	8.4	8.4	8.1	10.4	9.8	9.6	9.9	9.8	27.1
Sm	ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.04
Sn	ug/L ICPMS	-	-	-	-	-	-	-	-	-
Sr	ug/L ICPMS	39	39	40	44.8	44	40.4	44.3	43.2	47.3
Ta	ug/L ICPMS	-	-	-	0.08	0.07	0.06	0.04	0.03	0.02
Tb	ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Te	ug/L ICPMS	-	-	-	-	-	-	-	-	-
Th	ug/L ICPMS	<0.08	<0.08	<0.08	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Ti	ug/L ICPMS	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Tl	ug/L ICPMS	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tm	ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
U	ug/L ICPMS	0.0095	0.01	0.0077	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
V	ug/L ICPMS	0.98	0.87	0.94	1.1	1	1.9	1.1	2.8	0.9
W	ug/L ICPMS	2.1	2.1	2.2	1.81	1.6	2.11	1.6	1.55	1.08
Y	ug/L ICPMS	0.021	0.014	0.028	0.02	0.02	0.06	0.03	0.02	0.15
Yb	ug/L ICPMS	<0.01	<0.01	<0.01	<0.005	<0.005	<0.005	<0.005	<0.005	0.02
Zn	ug/L ICPMS	0.85	2.7	1.4	3.9	5.5	1.7	1.4	1.9	1.6
Zr	ug/L ICPMS	-	-	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Hg	ng/L Hg CVAF	-	-	-	<5	<5	<5	<5	<5	17
δ ¹⁸ O vs VSMOW	per mil ISO1	-16.0	-15.7	-16.1	-15.8	-15.8	-15.8	-15.7	-16.0	-16.2
δD vs VSMOW	per mil ISO2	-128.7	-123.5	-129.8	-128.8	-129.8	-128.2	-127.7	-127.0	-126.9
δ ³⁴ S _{SO4} vs CDT	per mil ISO3	-	-	-	-	-	-	-	-	-
δ ³⁴ S _{SO4} vs CDT	per mil ISO4	2.7	2.4	-	-	-	-	-	-	-
δ ¹³ C _{org} vs VPDB	per mil ISO5	-2.5	-4.0	-4.8	-	-	-	-	-	-

Appendix 2. Site and analytical data from hydrothermal vents in Yellowstone Lake—Continued.

Field No. Description	D02-3.1 Elliott's Crater rim- Sucker Vent	D02-3.2 Elliott's Crater rim- Sucker Vent	D02-4.1 Elliott's Crater rim- Sucker Vent	D02-4.2 Elliott's Crater rim- Sucker Vent	D03-4.1 Elliott's Crater rim- Sucker Vent	D03-4.2 Elliott's Crater rim- Sucker Vent	D03-5.1 Elliott's Crater rim- Sucker Vent	D03-5.2 Elliott's Crater rim- Sucker Vent	D04-2.1 Chico/Sucker- water sample- vent	D04-6.1 Bubbler N of Stevenson: water sample- near edge of lava flow
Latitude	44°31'39.6"N	44°31'39.6"N	44°31'39.6"N	44°31'39.6"N	44°31'39.694"N	44°31'39.695"N	44°31'39.695"N	44°31'39.695"N	44°31'39.179"N	44°32'5.927"N
Longitude	110°19'29.6"W	110°19'29.6"W	110°19'29.6"W	110°19'29.6"W	110°19'30.138"W	110°19'30.138"W	110°19'30.138"W	110°19'30.138"W	110°19'30.24"W	110°22'45.299"W
Date	8/19/02	8/19/02	8/19/02	8/19/02	8/12/03	8/12/03	8/12/03	8/12/03	8/9/04	8/11/04
Temp °C	91.1	29.1	59.1	82.2	61	61	96	30	6.9	7.2
pH	-	-	-	-	7	7.5	7.1	7.5	6.9	7.2
Depth m	12	12	14	13	10.2	-	11.1	-	11.9	36.3
Treatment	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered	Filtered
sum CO2 mM	-	-	-	-	-	-	-	-	-	-
HCO3 mM measured	-	-	-	-	-	-	-	-	0.50	0.48
HCO3 uM calc	-	-	-	-	-	-	-	-	-	-
Cl mg/L IC-Aq	5.7	23	7.3	15	4.7	4.7	4.9	6.9	6.7	4.9
F mg/L IC-Aq	0.5	0.8	0.5	0.6	0.5	0.5	0.5	0.5	0.54	0.55
NO3 mg/L IC-Aq	<.08	<.08	0.4	<.08	<.08	<.08	<.08	<.08	<.08	<.08
SO4 mg/L IC-Aq	7.6	12	8	9.8	9.4	7.4	9.3	7.4	7.8	7.5
Ag ug/L ICPMS	<3	<3	<3	<3	<0.01	<0.01	<0.01	<0.01	<3	<3
Al ug/L ICPMS	6.2	8	60.3	5.6	3.6	2.9	3.2	3.4	4.8	2.1
As ug/L ICPMS	13.7	41.5	17.2	33.9	16	13	18	13	17.9	16.5
Au ug/L ICPMS	-	-	-	-	<0.01	<0.01	<0.01	<0.01	-	-
B ug/L ICPAES	-	-	-	-	-	-	-	-	-	-
Ba ug/L ICPMS	10.2	44.7	14.3	32.2	13	8.9	14	8.9	13	10.5
Be ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bi ug/L ICPMS	<0.2	<0.2	<0.2	<0.2	<0.03	<0.03	<0.03	<0.03	<0.2	<0.2
Ca mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
Ca mg/L ICPMS	4.1	6.2	4.3	5.3	4.5	4.2	4.5	4.2	5.6	5.45
Cd ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce ug/L ICPMS	0.02	0.03	0.04	0.03	0.021	0.013	0.028	0.022	0.01	0.04
Co ug/L ICPMS	<0.02	0.02	0.23	0.02	<0.02	<0.02	<0.02	<0.02	0.05	0.03
Cr ug/L ICPMS	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cs ug/L ICPMS	3.18	15.6	4.49	9.94	4.2	2.6	4.9	2.6	4.28	2.73
Cu ug/L ICPMS	<0.5	0.5	0.53	<0.5	<0.5	0.51	0.5	<0.5	<0.5	0.54
Dy ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	0.005
Er ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Eu ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fe ug/L ICPMS	<50	<50	56	<50	<2	<2	<2	<2	<50	<50
Ga ug/L ICPMS	<0.05	0.07	0.05	<0.05	0.027	<0.02	0.026	<0.02	<0.05	<0.05
Gd ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007
Ge ug/L ICPMS	0.33	1.5	0.46	0.98	0.53	0.34	0.56	0.33	0.54	0.4
Hf ug/L ICPMS	-	-	-	-	<5	<5	<5	<5	-	-
Ho ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
In ug/L ICPMS	-	-	-	-	<0.01	<0.01	<0.01	<0.01	-	-
K mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
K ug/L ICPMS	1430	3160	1610	2470	1700	1500	1800	1500	2	1.8
La ug/L ICPMS	0.02	0.02	0.03	0.02	0.019	0.016	0.022	0.015	0.01	0.04
Li ug/L ICPMS	47	158	58.5	108	59	46	62	44	60.3	47.2
Lu ug/L ICPMS	<0.1	<0.1	0.5	<0.1	-	-	-	-	<0.1	<0.1
Mg mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
Mg mg/L ICPMS	2.04	2.84	2.12	2.55	2.1	2	2.2	2	2.46	2.39
Mn ug/L ICPMS	1.6	16.2	4.1	12.9	3	1	4	0.96	3	4
Mo ug/L ICPMS	<2	<2	<2	<2	1.6	1.6	1.4	1.4	<2	<2
Na mg/L ICPAES	-	-	-	-	-	-	-	-	-	-
Na mg/L ICPMS	8.99	26.8	16.9	18.9	10	8	11	7.9	12	9.7
Nb ug/L ICPMS	<0.2	<0.2	<0.2	<0.2	-	-	-	-	<0.2	<0.2
Nd ug/L ICPMS	0.01	0.01	0.02	0.02	0.018	0.012	0.02	0.02	<0.01	0.03
Ni ug/L ICPMS	0.6	0.6	190	0.5	0.78	0.79	0.4	0.51	1	0.9
P ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	<1	<1	4	<1	<0.01	<0.01
Pb ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pr ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Rb ug/L ICPMS	5.02	15	6.2	11	6	4.6	6.3	4.7	6.49	5.54
Re ug/L ICPMS	-	-	-	-	<0.02	<0.02	<0.02	<0.02	-	-
Sb ug/L ICPMS	1.56	2.64	1.3	2.15	0.92	1.2	1.3	1.1	1.04	0.84
Sc ug/L ICPMS	1.3	4.2	1.6	2.9	-	-	-	-	1.1	0.8
Se ug/L ICPMS	<1	<1	<1	<1	<0.2	<0.2	<0.2	<0.2	<1	<1
SiO2 mg/L ICPMS	4.6	16.6	5.7	11.2	12	8.6	12	8.4	14	10
Sm ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sn ug/L ICPMS	-	-	-	-	-	-	-	-	-	-
Sr ug/L ICPMS	38.6	89.4	45.2	69.2	46	40	47	40	49.9	44.9
Ta ug/L ICPMS	0.04	0.04	0.04	0.04	-	-	-	-	0.08	0.07
Tb ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Te ug/L ICPMS	-	-	-	-	-	-	-	-	-	-
Th ug/L ICPMS	<0.2	<0.2	<0.2	<0.2	<0.08	<0.08	<0.08	<0.08	<0.2	<0.2
Ti ug/L ICPMS	<0.5	<0.5	2.2	<0.5	-	-	-	-	<0.5	<0.5
Tl ug/L ICPMS	<0.1	<0.1	<0.1	<0.1	<0.05	<0.05	<0.05	<0.05	<0.1	<0.1
Tm ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
U ug/L ICPMS	<0.1	<0.1	<0.1	<0.1	0.013	0.012	0.012	0.013	<0.1	<0.1
V ug/L ICPMS	0.9	0.8	1	1	0.88	0.89	0.9	0.89	1	1
W ug/L ICPMS	1.41	3.94	2.14	3.24	2.7	2.3	2.9	2.3	1.59	1.52
Y ug/L ICPMS	0.01	0.02	0.02	0.02	0.018	0.015	0.021	0.017	0.01	0.05
Yb ug/L ICPMS	<0.005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01	<0.01	<0.005	<0.005
Zn ug/L ICPMS	<0.5	0.8	3.3	<0.5	4.8	5.1	3.1	2.9	0.8	1.8
Zr ug/L ICPMS	<0.2	<0.2	<0.2	<0.2	-	-	-	-	<0.2	<0.2
Hg ng/L Hg CVAF	<5	18	10	15	-	-	-	-	<5	<5
δ ¹⁸ O vs VSMOW per mil	IS01	-16.1	-16.3	-16.1	-16.2	-16.2	-16.2	-16.1	-15.8	-15.9
δD vs VSMOW per mil	IS02	-127	-130.6	-126.8	-131.1	-131.7	-128.5	-130.7	-129.5	-125.4
δ ³⁴ S _{org} vs CDT per mil	IS03	-	-	-	-	-	-	-	-	-
δ ³⁴ S _{sed} vs CDT per mil	IS04	-	-	-	-	2.4	2.4	2.2	-	-
δ ¹³ C _{org} vs VPDB per mil	IS05	-	-	-	-	-4.6	-	-7.0	-	-

Appendix 3. Site and analytical data from the 1999 mixing experiments.

Field no. Sample name/ description		G1 diss Norris/Green Dragon	G1 tot Norris/Green Dragon	G2 diss Norris/Green Dragon	G2 tot Norris/Green Dragon	G3 diss Norris/Green Dragon	G3 tot Norris/Green Dragon	G4 diss Norris/Green Dragon
Latitude		44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N
Longitude		110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W
Collection date		07/22/99	07/22/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99
Temp at filter	°C	16.1	16.1	19.1	19.1	17.5	17.5	20.4
pH		7.2	7.2	6.6	6.6	6.2	6.2	5.3
Conductivity	uS/cm	87	87	162	162	223	223	395
Cl	mg/L IC-Aq	4.7	-	21	-	37	-	80
F	mg/L IC-Aq	0.5	-	0.8	-	1	-	1.6
NO ₃	mg/L IC-Aq	<.35	-	<.35	-	<.35	-	<.35
SO ₄	mg/L IC-Aq	7.2	-	14	-	20	-	37
Ag	ug/L ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al	ug/L ICPMS	2.4	2	120	140	190	240	570
As	ug/L ICPMS	11	11	81	82	140	140	310
Au	ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L ICPAES	89.4	82.4	355	354	603	602	1260
Ba	ug/L ICPMS	8.5	8.4	10	10	11	11	14
Be	ug/L ICPMS	<0.05	<0.05	0.1	0.09	0.2	0.1	0.5
Bi	ug/L ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L ICPAES	5.1	5.1	5.04	4.91	5.02	5.06	4.82
Cd	ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L ICPMS	0.03	0.03	0.4	0.5	0.79	0.86	1.9
Co	ug/L ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L ICPMS	<1	<1	<1	<1	<1	<1	<1
Cs	ug/L ICPMS	2.2	2.2	17	17	29	29	62
Cu	ug/L ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L ICPMS	< 0.005	0.005	0.052	0.054	0.088	0.11	0.21
Er	ug/L ICPMS	0.005	< 0.005	0.03	0.04	0.054	0.053	0.12
Eu	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.01
Fe	ug/L ICPMS	<30	<30	<30	<30	<30	<30	100
Ga	ug/L ICPMS	< 0.02	< 0.02	< 0.02	0.02	0.03	0.04	0.04
Gd	ug/L ICPMS	< 0.005	< 0.005	0.066	0.054	0.093	0.091	0.21
Ge	ug/L ICPMS	0.2	0.2	1.3	1.3	2.1	2.1	4.6
Ho	ug/L ICPMS	< 0.005	< 0.005	0.01	0.02	0.02	0.02	0.04
K	mg/L ICPAES	1.7	1.6	3.72	3.84	5.8	5.62	10.8
La	ug/L ICPMS	0.03	0.02	0.2	0.3	0.4	0.4	0.9
Li	ug/L ICPMS	42	42	210	210	350	340	740
Mg	mg/L ICPAES	2.23	2.18	2.06	2.09	2.04	2	1.78
Mn	ug/L ICPMS	0.45	0.48	7.2	7.4	13	13	29
Mo	ug/L ICPMS	0.95	0.92	1.9	2	2.9	3	5.8
Na	mg/L ICPAES	8.75	8.48	20.3	19.7	29.8	30	55.2
Nb	ug/L ICPMS	0.07	0.06	0.07	0.05	0.06	0.05	0.06
Nd	ug/L ICPMS	0.04	0.03	0.22	0.25	0.36	0.42	0.86
Ni	ug/L ICPMS	0.4	0.4	0.4	0.4	0.3	0.4	0.3
P	ug/L ICPMS	1	4	4.2	4	< 1	3	4
Pb	ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pr	ug/L ICPMS	< 0.01	< 0.01	0.05	0.06	0.1	0.1	0.21
Rb	ug/L ICPMS	4.1	4.1	21	22	35	36	76
Sb	ug/L ICPMS	0.47	0.45	2.1	2.1	3.4	3.4	5.8
Sc	ug/L ICPMS	0.2	0.2	0.2	0.1	< 0.1	< 0.1	< 0.1
Se	ug/L ICPMS	< 0.3	< 0.3	< 0.3	< 0.3	0.3	0.4	0.9
SiO ₂	mg/L ICPMS	9.7	9.8	25	25	38	37	74
Sm	ug/L ICPMS	< 0.01	< 0.01	0.06	0.05	0.08	0.09	0.2
Sr	ug/L ICPMS	36	36	34	35	33	34	31
Ta	ug/L ICPMS	0.04	0.05	0.06	0.08	0.08	0.04	0.06
Tb	ug/L ICPMS	< 0.005	< 0.005	0.009	0.009	0.02	0.01	0.04
Th	ug/L ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti	ug/L ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Tl	ug/L ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.1
Tm	ug/L ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	0.008	0.007	0.02
U	ug/L ICPMS	0.01	0.02	0.02	0.02	0.02	0.03	0.03
V	ug/L ICPMS	0.77	0.76	0.85	0.74	0.76	0.7	0.8
W	ug/L ICPMS	0.89	0.97	2.6	2.8	4.5	4.6	9.4
Y	ug/L ICPMS	0.03	0.03	0.3	0.3	0.4	0.53	1.2
Yb	ug/L ICPMS	< 0.01	< 0.01	0.02	0.03	0.05	0.06	0.1
Zn	ug/L ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2
Zr	ug/L ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L Hg CVAF	<5	<5	9	<5	6	6	26
δ ¹⁸ O vs VSMOW	permil ISO1	-16.72	-	-16.28	-	-16.08	-	-15.41

Appendix 3. Site and analytical data from the 1999 mixing experiments—*Continued.*

Field no. Sample name/ description			G4 tot Norris/Green Dragon	G5 diss Norris/Green Dragon	G5 tot Norris/Green Dragon	G6 diss Norris/Green Dragon	G6 tot Norris/Green Dragon	G7 diss Norris/Green Dragon	G7 tot Norris/Green Dragon
Latitude			44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N
Longitude			110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W
Collection date			07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99
Temp at filter	°C		20.4	25.6	25.6	24.9	24.9	26.5	26.5
pH			5.3	3.6	3.6	3.1	3.1	2.9	2.9
Conductivity	uS/cm		395	665	665	965	965	1285	1285
Cl	mg/L	IC-Aq	-	130	-	190	-	240	-
F	mg/L	IC-Aq	-	1.6	-	2.1	-	2.7	-
NO ₃	mg/L	IC-Aq	-	<.35	-	0.7	-	<.35	-
SO ₄	mg/L	IC-Aq	-	57	-	78	-	100	-
Ag	ug/L	ICPMS	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Al	ug/L	ICPMS	560	980	980	1900	1900	2500	2500
As	ug/L	ICPMS	320	520	520	860	870	1100	1100
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	1260	2080	2090	2860	2900	3670	3680
Ba	ug/L	ICPMS	14	18	18	23	23	26	26
Be	ug/L	ICPMS	0.4	0.7	0.9	1.7	1.7	1.9	2
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	4.82	4.72	4.63	4.54	4.5	4.4	4.32
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	1.9	3.2	3.2	4.6	4.9	6.1	6.1
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	63	100	100	150	150	200	200
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	0.23	0.36	0.4	0.53	0.57	0.71	0.74
Er	ug/L	ICPMS	0.13	0.23	0.21	0.28	0.31	0.39	0.41
Eu	ug/L	ICPMS	0.01	0.02	0.006	0.02	0.02	0.02	0.03
Fe	ug/L	ICPMS	100	190	190	360	370	480	480
Ga	ug/L	ICPMS	0.05	0.07	0.08	0.1	0.1	0.2	0.2
Gd	ug/L	ICPMS	0.18	0.33	0.32	0.47	0.47	0.62	0.55
Ge	ug/L	ICPMS	4.6	7.4	7.5	12	13	16	16
Ho	ug/L	ICPMS	0.04	0.072	0.068	0.1	0.11	0.15	0.14
K	mg/L	ICPAES	10.9	17.2	17.2	24.2	24	31.2	30.6
La	ug/L	ICPMS	0.95	1.6	1.6	2.3	2.3	3	3
Li	ug/L	ICPMS	750	1200	1200	2500	2600	3400	3500
Mg	mg/L	ICPAES	1.78	1.51	1.51	1.24	1.25	0.953	0.949
Mn	ug/L	ICPMS	28	48	48	83	82	110	100
Mo	ug/L	ICPMS	6	9.5	11	15	16	20	21
Na	mg/L	ICPAES	55.6	88.2	86.8	120	122	154	151
Nb	ug/L	ICPMS	0.05	0.06	0.06	0.08	0.08	0.09	0.08
Nd	ug/L	ICPMS	0.87	1.4	1.6	2	2	2.5	2.7
Ni	ug/L	ICPMS	0.3	0.2	0.2	0.2	0.2	0.2	0.2
P	ug/L	ICPMS	4.3	8.1	7.6	21	21	20	20
Pb	ug/L	ICPMS	0.08	0.2	0.2	0.2	0.2	0.3	0.3
Pr	ug/L	ICPMS	0.22	0.37	0.4	0.55	0.55	0.72	0.72
Rb	ug/L	ICPMS	76	120	120	200	200	250	250
Sb	ug/L	ICPMS	5.6	4.8	5.9	7.2	7	7.9	7.2
Sc	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Se	ug/L	ICPMS	1.2	1.8	1.9	2.9	2.7	3.8	3.8
SiO ₂	mg/L	ICPMS	74	120	120	230	230	300	300
Sm	ug/L	ICPMS	0.23	0.33	0.32	0.43	0.52	0.55	0.57
Sr	ug/L	ICPMS	31	27	27	27	27	22	23
Ta	ug/L	ICPMS	0.05	0.06	0.05	0.04	0.04	0.04	0.04
Tb	ug/L	ICPMS	0.03	0.054	0.063	0.084	0.088	0.11	0.11
Th	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti	ug/L	ICPMS	0.3	0.5	0.6	1.2	1.3	1.6	1.6
Tl	ug/L	ICPMS	0.1	0.2	0.2	0.3	0.3	0.4	0.4
Tm	ug/L	ICPMS	0.02	0.03	0.03	0.04	0.05	0.058	0.058
U	ug/L	ICPMS	0.04	0.05	0.07	0.06	0.08	0.08	0.09
V	ug/L	ICPMS	0.82	0.78	0.84	1.3	1.3	1.3	1.3
W	ug/L	ICPMS	9.7	15	18	21	24	30	32
Y	ug/L	ICPMS	1.2	1.9	2	3.2	3.3	4.2	4.3
Yb	ug/L	ICPMS	0.1	0.2	0.2	0.24	0.26	0.3	0.31
Zn	ug/L	ICPMS	2	3	3	5	5	7	6
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	21	51	35	25	55	7	62
δ ¹⁸ O vs VSMOW	permil	ISO1	-	-14.62	-	-14.05	-	-13.70	-

Appendix 3. Site and analytical data from the 1999 mixing experiments—Continued.

Field no. Sample name/ description			G8 diss Norris/Green Dragon	G8 tot Norris/Green Dragon	G9 diss Norris/Green Dragon	G9 tot Norris/Green Dragon	G10 diss Norris/Green Dragon	G10 tot Norris/Green Dragon	E1 diss Norris/Echinus
Latitude			44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'12.2"N	44°43'19.5"N
Longitude			110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'23"W	110°42'4.9"W
Collection date			07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/22/99
Temp at filter	°C		30.6	30.6	32.1	32.1	30.1	30.1	19.9
pH			2.7	2.7	2.6	2.6	2.6	2.6	7.3
Conductivity	uS/cm		1603	1603	1785	1785	1984	1984	87
Cl	mg/L	IC-Aq	300	-	330	-	330	-	4.5
F	mg/L	IC-Aq	3.1	-	5.6	-	5.6	-	0.4
NO ₃	mg/L	IC-Aq	<.35	-	<.35	-	<.35	-	<.35
SO ₄	mg/L	IC-Aq	120	-	130	-	150	-	7.2
Ag	ug/L	ICPMS	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01
Al	ug/L	ICPMS	3100	3200	3600	3500	4000	4000	1
As	ug/L	ICPMS	1400	1400	1500	1500	1700	1700	24
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	4370	4440	4920	4930	5430	5460	124
Ba	ug/L	ICPMS	31	30	32	32	35	35	8.9
Be	ug/L	ICPMS	2.8	2.8	2.6	3.4	3.5	3.6	<0.05
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	4.23	4.21	4.18	4.07	4.02	4.02	5
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	7.5	7.4	8.3	8.3	9.1	9	0.02
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	240	240	260	270	300	300	2.3
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	0.87	0.85	0.94	0.95	1	1	0.005
Er	ug/L	ICPMS	0.49	0.45	0.5	0.53	0.55	0.57	< 0.005
Eu	ug/L	ICPMS	0.03	0.03	0.03	0.03	0.04	0.03	< 0.005
Fe	ug/L	ICPMS	600	600	660	660	750	750	<30
Ga	ug/L	ICPMS	0.2	0.2	0.2	0.2	0.3	0.2	< 0.02
Gd	ug/L	ICPMS	0.75	0.75	0.79	0.84	0.84	0.94	0.008
Ge	ug/L	ICPMS	20	20	22	23	25	25	0.2
Ho	ug/L	ICPMS	0.19	0.18	0.19	0.19	0.2	0.21	< 0.005
K	mg/L	ICPAES	37.6	37.4	42	41	45.8	45.7	1.68
La	ug/L	ICPMS	3.7	3.7	4	4	4.4	4.5	0.03
Li	ug/L	ICPMS	4300	4700	5400	5500	6200	6400	44
Mg	mg/L	ICPAES	0.659	0.671	0.502	0.505	0.316	0.316	2.19
Mn	ug/L	ICPMS	130	130	140	140	160	160	0.38
Mo	ug/L	ICPMS	26	26	28	29	32	33	5.9
Na	mg/L	ICPAES	186	188	206	203	224	227	9.19
Nb	ug/L	ICPMS	0.1	0.08	0.09	0.08	0.08	0.08	< 0.02
Nd	ug/L	ICPMS	3.3	3.2	3.6	3.6	3.9	4	0.03
Ni	ug/L	ICPMS	0.1	0.1	<0.1	0.1	<0.1	<0.1	0.3
P	ug/L	ICPMS	21	20	19	17	17	15	< 1
Pb	ug/L	ICPMS	0.4	0.4	0.6	0.5	0.52	0.5	<0.05
Pr	ug/L	ICPMS	0.86	0.87	0.97	0.95	1	1.1	< 0.01
Rb	ug/L	ICPMS	310	310	350	350	390	390	4.2
Sb	ug/L	ICPMS	8	5.6	6.4	4.2	5.6	6	1.7
Sc	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Se	ug/L	ICPMS	4.4	4.5	4.7	4.4	4.7	4.5	< 0.3
SiO ₂	mg/L	ICPMS	370	380	420	420	470	480	8.9
Sm	ug/L	ICPMS	0.75	0.73	0.8	0.82	0.84	0.88	< 0.01
Sr	ug/L	ICPMS	18	18	16	16	13	13	36
Ta	ug/L	ICPMS	0.06	0.04	0.05	0.05	0.05	0.05	< 0.03
Tb	ug/L	ICPMS	0.13	0.13	0.15	0.15	0.16	0.16	< 0.005
Th	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti	ug/L	ICPMS	2.1	1.7	2.1	2	2.1	2.3	< 0.2
Tl	ug/L	ICPMS	0.5	0.5	0.52	0.52	0.58	0.58	<0.05
Tm	ug/L	ICPMS	0.065	0.07	0.078	0.074	0.087	0.083	< 0.005
U	ug/L	ICPMS	0.11	0.12	0.12	0.12	0.13	0.14	0.01
V	ug/L	ICPMS	1.4	1.4	1.4	1.3	1.4	1.4	0.92
W	ug/L	ICPMS	40	40	43	45	50	50	11
Y	ug/L	ICPMS	5.2	5.2	5.8	5.9	6.6	6.6	0.02
Yb	ug/L	ICPMS	0.4	0.37	0.44	0.45	0.51	0.5	< 0.01
Zn	ug/L	ICPMS	8	8	9	9	10	10	<0.5
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	0.86	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	8	71	10	67	7	80	330
δ ¹⁸ O vs VSMOW	permil	ISO1	-12.56	-	-12.09	-	-11.59	-	-16.65

Appendix 3. Site and analytical data from the 1999 mixing experiments—Continued.

Field no.		E1 tot	E2 diss	E2 tot	E3 diss	E3 tot	E4 diss
Sample name/ description		Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus
Latitude		44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N
Longitude		110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W
Collection date		07/22/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99
Temp at filter	°C	19.9	20.2	20.2	21.7	21.7	20.2
pH		7.3	6.8	6.8	6.7	6.7	6.2
Conductivity	uS/cm	87	158	158	196	196	313
Cl	mg/L	IC-Aq	13	-	17	-	34
F	mg/L	IC-Aq	1	-	1.1	-	1.5
NO ₃	mg/L	IC-Aq	<.35	-	<.35	-	0.4
SO ₄	mg/L	IC-Aq	22	-	31	-	61
Ag	ug/L	ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01
Al	ug/L	ICPMS	2	120	120	170	330
As	ug/L	ICPMS	16	31	30	38	66
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	102	246	242	321	603
Ba	ug/L	ICPMS	9	12	12	14	20
Be	ug/L	ICPMS	<0.05	0.5	0.4	0.6	1.6
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	5.09	4.98	5	5.08	5.04
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	0.03	2.3	2.4	3.5	7.1
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	2.3	7.7	7.9	11	20
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	< 0.005	0.41	0.44	0.6	1.3
Er	ug/L	ICPMS	< 0.005	0.23	0.23	0.35	0.72
Eu	ug/L	ICPMS	< 0.005	0.01	0.009	0.02	0.04
Fe	ug/L	ICPMS	<30	63	66	120	300
Ga	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gd	ug/L	ICPMS	< 0.005	0.32	0.38	0.47	1
Ge	ug/L	ICPMS	0.2	0.8	0.8	1.1	2.2
Ho	ug/L	ICPMS	< 0.005	0.088	0.092	0.12	0.25
K	mg/L	ICPAES	1.64	4.75	4.71	6.44	11.7
La	ug/L	ICPMS	0.03	0.63	0.73	1.1	2.1
Li	ug/L	ICPMS	46	110	110	150	260
Mg	mg/L	ICPAES	2.2	2.05	2.04	2	1.8
Mn	ug/L	ICPMS	0.42	14	14	21	44
Mo	ug/L	ICPMS	2.8	2.5	2.1	2.1	2.5
Na	mg/L	ICPAES	8.66	19.1	19.1	24.9	42.5
Nb	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Nd	ug/L	ICPMS	0.04	1.2	1.3	1.8	3.8
Ni	ug/L	ICPMS	0.4	0.3	0.3	0.3	0.2
P	ug/L	ICPMS	< 1	< 1	< 1	< 1	< 1
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05
Pr	ug/L	ICPMS	< 0.01	0.29	0.28	0.42	0.9
Rb	ug/L	ICPMS	4.2	27	28	39	77
Sb	ug/L	ICPMS	1	0.86	0.79	0.73	0.7
Sc	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Se	ug/L	ICPMS	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
SiO ₂	mg/L	ICPMS	9.2	23	23	30	54
Sm	ug/L	ICPMS	< 0.01	0.33	0.35	0.46	1
Sr	ug/L	ICPMS	37	34	35	34	30
Ta	ug/L	ICPMS	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Tb	ug/L	ICPMS	< 0.005	0.065	0.069	0.1	0.21
Th	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	0.05
Ti	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	0.2
Tl	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	0.08
Tm	ug/L	ICPMS	< 0.005	0.03	0.03	0.04	0.098
U	ug/L	ICPMS	0.01	0.14	0.14	0.21	0.4
V	ug/L	ICPMS	0.9	0.79	0.72	0.62	0.53
W	ug/L	ICPMS	6.3	5.2	4	3.8	3.5
Y	ug/L	ICPMS	0.03	2	2.2	3.1	6.6
Yb	ug/L	ICPMS	< 0.01	0.2	0.2	0.29	0.58
Zn	ug/L	ICPMS	<0.5	<0.5	0.5	1	3
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	<5	13	<5	5	5
δ ¹⁸ O vs VSMOW	permil	ISO1	-	-16.65	-	-16.63	-

Appendix 3. Site and analytical data from the 1999 mixing experiments—*Continued.*

Field no.			E4 tot	E5 diss	E5 tot	E6 diss	E6 tot	E7 diss
Sample name/ description			Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus
Latitude			44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N
Longitude			110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W
Collection date			07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99
Temp at filter	°C		20.2	24.1	24.1	25.9	25.9	28.3
pH			6.2	5.8	5.8	5.1	5.1	3.7
Conductivity	uS/cm		313	463	463	627	627	814
Cl	mg/L	IC-Aq	-	53	-	78	-	98
F	mg/L	IC-Aq	-	2.3	-	4.3	-	2.8
NO ₃	mg/L	IC-Aq	-	<.35	-	0.5	-	0.7
SO ₄	mg/L	IC-Aq	-	95	-	140	-	180
Ag	ug/L	ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	0.56
Al	ug/L	ICPMS	370	610	620	910	880	1300
As	ug/L	ICPMS	66	100	100	150	150	200
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	604	927	945	1320	1330	1690
Ba	ug/L	ICPMS	20	28	28	36	36	42
Be	ug/L	ICPMS	1.3	2.4	2.5	3.5	3.5	4.9
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.048
Ca	mg/L	ICPAES	4.93	5	5.03	4.97	4.98	4.93
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	7.7	12	13	18	18	23
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	20	32	31	45	44	54
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	1.4	2.3	2.4	3.3	3.3	4.3
Er	ug/L	ICPMS	0.76	1.2	1.3	1.7	1.9	2.3
Eu	ug/L	ICPMS	0.03	0.061	0.056	0.083	0.088	0.11
Fe	ug/L	ICPMS	310	550	560	810	820	1300
Ga	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gd	ug/L	ICPMS	1.1	1.9	2	2.6	2.8	3.7
Ge	ug/L	ICPMS	2.1	3.5	3.5	4.9	4.9	6.8
Ho	ug/L	ICPMS	0.28	0.45	0.46	0.65	0.68	0.84
K	mg/L	ICPAES	11.8	18.1	18.5	25.8	26	34.5
La	ug/L	ICPMS	2.2	3.7	3.7	5.2	5.3	6.6
Li	ug/L	ICPMS	260	410	410	570	570	690
Mg	mg/L	ICPAES	1.81	1.55	1.57	1.31	1.32	1.11
Mn	ug/L	ICPMS	43	74	72	100	110	170
Mo	ug/L	ICPMS	2.3	3.1	3	3.6	3.6	7.6
Na	mg/L	ICPAES	41.6	65.3	65.6	90.1	90.3	117
Nb	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	0.03	< 0.02	0.64
Nd	ug/L	ICPMS	4.1	6.4	6.6	9.1	9.7	12
Ni	ug/L	ICPMS	0.3	0.2	0.2	0.2	0.2	0.2
P	ug/L	ICPMS	< 1	< 1	< 1	1	< 1	6.5
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	0.09
Pr	ug/L	ICPMS	0.9	1.5	1.6	2.2	2.2	2.8
Rb	ug/L	ICPMS	77	130	130	180	180	250
Sb	ug/L	ICPMS	0.69	0.75	0.73	0.79	0.74	1.4
Sc	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	3
Se	ug/L	ICPMS	0.3	0.8	0.5	0.9	0.9	2.1
SiO ₂	mg/L	ICPMS	54	88	88	120	120	180
Sm	ug/L	ICPMS	1.1	1.7	1.7	2.5	2.6	3.3
Sr	ug/L	ICPMS	30	28	28	22	22	19
Ta	ug/L	ICPMS	< 0.03	0.04	< 0.03	< 0.03	0.03	0.53
Tb	ug/L	ICPMS	0.22	0.35	0.38	0.53	0.52	0.66
Th	ug/L	ICPMS	0.05	0.12	0.16	0.22	0.2	0.35
Ti	ug/L	ICPMS	< 0.2	0.5	0.5	1	1	2.5
Tl	ug/L	ICPMS	0.08	0.1	0.2	0.2	0.2	0.58
Tm	ug/L	ICPMS	0.11	0.17	0.18	0.23	0.25	0.31
U	ug/L	ICPMS	0.47	0.65	0.75	0.94	1.1	1.4
V	ug/L	ICPMS	0.55	0.4	0.5	0.4	0.3	1
W	ug/L	ICPMS	3.3	3.3	3.3	3.2	3	2.1
Y	ug/L	ICPMS	7	12	12	17	18	24
Yb	ug/L	ICPMS	0.63	0.95	1.1	1.5	1.5	1.8
Zn	ug/L	ICPMS	3	5	5	7	8	10
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.2
Hg	ng/L	Hg CVAF	<5	10	<5	7	<5	9
δ ¹⁸ O vs VSMOW	permil	ISO1	-	-16.77	-	-16.65	-	-16.60

Appendix 3. Site and analytical data from the 1999 mixing experiments—Continued.

Field no.			E7 tot	E8 diss	E8 tot	E9 diss	E9 tot	E10 diss
Sample name/ description			Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus	Norris/Echinus
Latitude			44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N	44°43'19.5"N
Longitude			110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W	110°42'4.9"W
Collection date			07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99
Temp at filter	°C		28.3	31.8	31.8	34.5	34.5	35.4
pH			3.7	3.4	3.4	3.2	3.2	3.2
Conductivity	uS/cm		814	1008	1008	1144	1144	1272
Cl	mg/L	IC-Aq	-	120	-	130	-	150
F	mg/L	IC-Aq	-	3.9	-	4.3	-	4.8
NO ₃	mg/L	IC-Aq	-	<.35	-	<.35	-	<.35
SO ₄	mg/L	IC-Aq	-	210	-	240	-	260
Ag	ug/L	ICPMS	0.2	0.1	0.09	0.07	0.05	0.04
Al	ug/L	ICPMS	1300	1600	1600	1800	1800	2000
As	ug/L	ICPMS	200	240	240	270	260	290
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	1700	2060	2060	2310	2300	2540
Ba	ug/L	ICPMS	42	48	49	55	55	60
Be	ug/L	ICPMS	4.8	5.8	5.9	6.4	6.5	7
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	4.95	4.88	4.83	4.81	4.82	4.74
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	23	28	28	32	31	36
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	54	66	65	74	73	81
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	4.2	5.4	5.4	6.2	5.9	6.7
Er	ug/L	ICPMS	2.4	2.9	2.9	3.4	3.3	3.5
Eu	ug/L	ICPMS	0.12	0.14	0.14	0.15	0.16	0.17
Fe	ug/L	ICPMS	1300	1600	1500	1700	1700	1900
Ga	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gd	ug/L	ICPMS	3.6	4.4	4.4	5	5	5.6
Ge	ug/L	ICPMS	6.6	8.1	8.1	8.8	8.9	9.9
Ho	ug/L	ICPMS	0.88	1.1	1.1	1.2	1.2	1.3
K	mg/L	ICPAES	35.1	42.4	42.1	47.3	47.2	51.9
La	ug/L	ICPMS	6.5	8.1	8.2	9.4	8.9	10
Li	ug/L	ICPMS	720	900	890	1000	1000	1100
Mg	mg/L	ICPAES	1.09	0.848	0.842	0.666	0.664	0.499
Mn	ug/L	ICPMS	160	200	190	210	210	230
Mo	ug/L	ICPMS	4.8	5.4	5.1	5.8	5.5	6
Na	mg/L	ICPAES	117	143	140	158	156	172
Nb	ug/L	ICPMS	0.5	0.4	0.3	0.3	0.2	0.2
Nd	ug/L	ICPMS	12	15	14	16	16	18
Ni	ug/L	ICPMS	0.3	0.2	0.1	0.1	<0.1	<0.1
P	ug/L	ICPMS	7.6	7.5	6.4	6.6	4.9	3
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	0.07	0.05	<0.05
Pr	ug/L	ICPMS	2.8	3.5	3.4	3.9	3.9	4.2
Rb	ug/L	ICPMS	240	290	280	310	310	350
Sb	ug/L	ICPMS	0.85	0.87	0.8	0.82	0.8	0.82
Sc	ug/L	ICPMS	2	1	0.5	0.4	< 0.1	< 0.1
Se	ug/L	ICPMS	1.6	1.6	1.6	1.8	1.8	1.7
SiO ₂	mg/L	ICPMS	180	220	220	250	240	270
Sm	ug/L	ICPMS	3.3	4	3.9	4.7	4.5	4.9
Sr	ug/L	ICPMS	19	14	13	10	10	7
Ta	ug/L	ICPMS	0.43	0.36	0.31	0.31	0.26	0.23
Tb	ug/L	ICPMS	0.66	0.86	0.84	0.96	0.99	1
Th	ug/L	ICPMS	0.34	0.45	0.56	0.57	0.6	0.66
Ti	ug/L	ICPMS	2.4	3	2.6	3	3	3.2
Tl	ug/L	ICPMS	0.4	0.5	0.4	0.5	0.5	0.53
Tm	ug/L	ICPMS	0.32	0.41	0.41	0.42	0.45	0.48
U	ug/L	ICPMS	1.4	1.8	1.8	2	2	2.3
V	ug/L	ICPMS	0.67	0.5	0.4	0.3	<0.2	<0.2
W	ug/L	ICPMS	2	2.1	2.2	2.3	2.2	2.1
Y	ug/L	ICPMS	23	29	28	32	31	34
Yb	ug/L	ICPMS	1.8	2.2	2.3	2.6	2.6	2.9
Zn	ug/L	ICPMS	10	10	10	20	10	20
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	7	10	8	12	10	<5
δ ¹⁸ O vs VSMOW	permil	ISO1	-	-16.62	-	-16.59	-	-16.53

Appendix 3. Site and analytical data from the 1999 mixing experiments—Continued.

Field no.		E10 tot		P1 diss		P1 tot		P2 diss		P2 tot		P3 diss		P3 tot	
Sample name/ description		Norris/Echinus		Norris/Pork chop		Norris/ Pork chop		Norris/ Pork chop		Norris/ Pork chop		Norris/ Pork chop		Norris/ Pork chop	
Latitude		44°43'19.5"N		44°43'21"N		44°43'21"N		44°43'21"N		44°43'21"N		44°43'21"N		44°43'21"N	
Longitude		110°42'4.9"W		110°42'28"W		110°42'28"W		110°42'28"W		110°42'28"W		110°42'28"W		110°42'28"W	
Collection date		07/23/99		07/22/99		07/22/99		07/23/99		07/23/99		07/23/99		07/23/99	
Temp at filter	°C	35.4		14.6		14.6		15.8		15.8		14.6		14.6	
pH		3.2		7.5		7.5		7.4		7.4		7.3		7.3	
Conductivity	uS/cm	1272		87		87		223		223		287		287	
Cl	mg/L	IC-Aq	-	4.7	-	41	-	60	-	-	-	60	-	-	-
F	mg/L	IC-Aq	-	0.5	-	0.7	-	0.9	-	-	-	0.9	-	-	-
NO ₃	mg/L	IC-Aq	-	<.35	-	0.4	-	<.35	-	-	-	<.35	-	-	-
SO ₄	mg/L	IC-Aq	-	7.2	-	8.6	-	9	-	-	-	9	-	-	-
Ag	ug/L	ICPMS	0.03	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Al	ug/L	ICPMS	1900	2	2	1	1	0.9	1	1	0.9	1	1	1	1
As	ug/L	ICPMS	280	11	11	170	170	260	170	170	260	260	170	260	260
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	2590	78	77.2	659	669	940	669	669	940	933	669	933	933
Ba	ug/L	ICPMS	59	8.6	8.7	8.8	8.9	8.8	8.9	8.9	8.8	8.8	8.9	8.8	8.8
Be	ug/L	ICPMS	7.6	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	4.74	5.27	5.19	5.3	5.31	5.28	5.3	5.31	5.28	5.17	5.3	5.17	5.17
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	36	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	81	2.2	2.2	37	38	54	38	38	54	55	38	55	55
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	6.8	0.006	< 0.005	< 0.005	< 0.005	0.005	< 0.005	< 0.005	0.005	0.008	< 0.005	0.008	0.008
Er	ug/L	ICPMS	3.5	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Eu	ug/L	ICPMS	0.17	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fe	ug/L	ICPMS	1800	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Ga	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Gd	ug/L	ICPMS	5.4	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ge	ug/L	ICPMS	9.6	0.2	0.2	2.3	2.2	3.2	2.2	2.2	3.2	3.2	2.2	3.2	3.2
Ho	ug/L	ICPMS	1.4	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
K	mg/L	ICPAES	52	1.51	1.56	4.87	4.95	6.49	4.95	4.95	6.49	6.39	4.95	6.39	6.39
La	ug/L	ICPMS	10	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Li	ug/L	ICPMS	1100	42	42	400	400	570	400	400	570	580	400	580	580
Mg	mg/L	ICPAES	0.504	2.22	2.23	2.09	2.11	2.03	2.11	2.11	2.03	2	2.11	2	2
Mn	ug/L	ICPMS	220	0.42	0.42	2.3	2.1	2.9	2.1	2.1	2.9	2.9	2.1	2.9	2.9
Mo	ug/L	ICPMS	5.9	0.87	0.86	12	13	20	13	13	20	20	13	20	20
Na	mg/L	ICPAES	172	8.58	8.62	32.1	32.2	42.9	32.2	32.2	42.9	41.9	32.2	41.9	41.9
Nb	ug/L	ICPMS	0.2	0.1	0.09	0.1	0.1	0.09	0.1	0.1	0.09	0.09	0.1	0.09	0.09
Nd	ug/L	ICPMS	18	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Ni	ug/L	ICPMS	<0.1	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
P	ug/L	ICPMS	2	1	2	2	2	1	2	2	1	2	2	1	2
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pr	ug/L	ICPMS	4.2	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Rb	ug/L	ICPMS	340	4	4	31	31	44	31	31	44	45	31	45	45
Sb	ug/L	ICPMS	0.79	0.47	0.47	8.8	9.1	14	9.1	9.1	14	13	9.1	13	13
Sc	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	0.3	0.2	0.4	0.2	0.2	0.4	0.3	0.2	0.3	0.3
Se	ug/L	ICPMS	1.6	< 0.3	< 0.3	0.5	0.6	0.8	0.6	0.6	0.8	0.9	0.6	0.9	0.9
SiO ₂	mg/L	ICPMS	260	9	9.1	26	26	35	26	26	35	35	26	35	35
Sm	ug/L	ICPMS	5.1	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sr	ug/L	ICPMS	6.8	35	36	35	34	34	35	34	34	35	35	34	35
Ta	ug/L	ICPMS	0.21	0.11	0.09	0.12	0.1	0.11	0.1	0.1	0.11	0.08	0.1	0.08	0.08
Tb	ug/L	ICPMS	1	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Th	ug/L	ICPMS	0.6	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti	ug/L	ICPMS	2.6	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Tl	ug/L	ICPMS	0.51	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	0.05	0.08	0.08	<0.05	0.08	0.08
Tm	ug/L	ICPMS	0.51	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U	ug/L	ICPMS	2.2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
V	ug/L	ICPMS	<0.2	0.82	0.85	1.3	1.2	1.3	1.2	1.2	1.3	1.4	1.2	1.4	1.4
W	ug/L	ICPMS	2.2	1.4	1.3	6.8	7.9	11	7.9	7.9	11	11	7.9	11	11
Y	ug/L	ICPMS	34	0.03	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.02	0.03	0.02	0.02
Yb	ug/L	ICPMS	2.9	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zn	ug/L	ICPMS	20	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	8	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
δ ¹⁸ O vs VSMOW	permil	ISO1	-	-16.60	-	-16.85	-	-16.62	-	-	-16.62	-	-	-	-

Appendix 3. Site and analytical data from the 1999 mixing experiments—*Continued.*

Field no. Sample name/ description		P4 diss Norris/ Pork chop	P4 tot Norris/ Pork chop	P5 diss Norris/ Pork chop	P5 tot Norris/ Pork chop	P6 diss Norris/ Pork chop	P6 tot Norris/ Pork chop	P7 diss Norris/ Pork chop	
Latitude		44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N	
Longitude		110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W	
Collection date		07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	
Temp at filter	°C	17.1	17.1	19.6	19.6	22.4	22.4	25.6	
pH		7.2	7.2	7.1	7.1	7.0	7.0	6.8	
Conductivity	uS/cm	591	591	905	905	1220	1220	1565	
Cl	mg/L	IC-Aq	150	-	230	-	330	-	430
F	mg/L	IC-Aq	1.4	-	2.4	-	2.8	-	4.4
NO ₃	mg/L	IC-Aq	0.5	-	1.3	-	<.35	-	<.35
SO ₄	mg/L	IC-Aq	14	-	22	-	25	-	22
Ag	ug/L	ICPMS	0.03	0.03	0.04	0.03	0.04	0.03	0.04
Al	ug/L	ICPMS	4.9	3.8	2.8	3	9.7	1	<0.5
As	ug/L	ICPMS	820	830	1300	1300	1800	1800	2200
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	2250	2300	3620	3560	4970	4880	6340
Ba	ug/L	ICPMS	11	10	10	10	11	11	11
Be	ug/L	ICPMS	<0.05	<0.05	0.1	<0.05	0.1	<0.05	0.1
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	5.2	5.38	5.32	5.12	5.22	5.14	5.19
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	0.02	0.02	0.02	0.02	0.02	0.01	< 0.01
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	150	150	230	240	320	320	410
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	0.006	< 0.005	< 0.005
Er	ug/L	ICPMS	< 0.005	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Eu	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fe	ug/L	ICPMS	<30	<30	<30	<30	<30	<30	<30
Ga	ug/L	ICPMS	< 0.02	< 0.02	0.03	< 0.02	< 0.02	< 0.02	0.02
Gd	ug/L	ICPMS	< 0.005	< 0.005	0.01	0.008	< 0.005	< 0.005	< 0.005
Ge	ug/L	ICPMS	10	10	16	16	22	22	27
Ho	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
K	mg/L	ICPAES	13.9	14.3	21.8	22.2	30.5	30	39.1
La	ug/L	ICPMS	0.02	0.03	0.02	0.03	0.02	0.02	< 0.01
Li	ug/L	ICPMS	2200	2200	3500	3400	5000	5000	6500
Mg	mg/L	ICPAES	1.72	1.76	1.43	1.4	1.1	1.08	0.747
Mn	ug/L	ICPMS	9.3	9.3	14	14	19	19	23
Mo	ug/L	ICPMS	64	65	100	110	150	150	190
Na	mg/L	ICPAES	93.1	96.7	151	150	202	200	262
Nb	ug/L	ICPMS	0.2	0.2	0.2	0.1	0.2	0.2	0.2
Nd	ug/L	ICPMS	0.03	0.03	0.02	0.02	0.02	0.01	0.02
Ni	ug/L	ICPMS	0.4	0.4	0.3	0.3	0.2	0.2	0.1
P	ug/L	ICPMS	16	14	16	17	16	14	13
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pr	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Rb	ug/L	ICPMS	130	130	200	200	280	280	350
Sb	ug/L	ICPMS	39	40	62	62	86	84	110
Sc	ug/L	ICPMS	0.5	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Se	ug/L	ICPMS	2.8	2.9	4.5	4.7	6.3	6.5	8.3
SiO ₂	mg/L	ICPMS	110	110	170	170	230	230	290
Sm	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sr	ug/L	ICPMS	40	39	33	33	30	30	24
Ta	ug/L	ICPMS	0.15	0.16	0.16	0.12	0.16	0.14	0.17
Tb	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Th	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	0.4	0.2	0.4
Tl	ug/L	ICPMS	0.2	0.3	0.4	0.4	0.6	0.59	0.77
Tm	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U	ug/L	ICPMS	0.01	0.01	0.009	0.008	< 0.005	< 0.005	< 0.005
V	ug/L	ICPMS	2.8	2.6	2.7	2.4	2.5	2.4	2.5
W	ug/L	ICPMS	32	34	55	57	79	79	100
Y	ug/L	ICPMS	0.02	0.02	0.02	0.02	0.01	0.02	0.01
Yb	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zn	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	<5	15	<5	<5	10	7	7
δ ¹⁸ O vs VSMOW	permil	ISO1	-15.98	-	-15.47	-	-15.00	-	-14.34

Appendix 3. Site and analytical data from the 1999 mixing experiments—Continued.

Field no. Sample name/ description		P7 tot Norris/ Pork chop	P8 diss Norris/ Pork chop	P8 tot Norris/ Pork chop	P9 diss Norris/ Pork chop	P9 tot Norris/ Pork chop	P10 diss Norris/ Pork chop	P10 tot Norris/ Pork chop
Latitude		44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N	44°43'21"N
Longitude		110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W	110°42'28"W
Collection date		07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99	07/23/99
Temp at filter	°C	25.6	25.3	25.3	28.9	28.9	31.5	31.5
pH		6.8	6.9	6.9	6.7	6.7	6.6	6.6
Conductivity	uS/cm	1565	1865	1865	2080	2080	2300	2300
Cl	mg/L	-	530	-	600	-	620	-
F	mg/L	-	5.1	-	5.7	-	6.5	-
NO ₃	mg/L	-	0.5	-	0.5	-	0.5	-
SO ₄	mg/L	-	28	-	30	-	32	-
Ag	ug/L	ICPMS	0.03	0.04	0.04	0.03	0.03	0.02
Al	ug/L	ICPMS	1	<0.5	<0.5	<0.5	<0.5	<0.5
As	ug/L	ICPMS	2200	2700	2600	2800	2800	3100
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	6200	7390	7470	8400	8330	9250
Ba	ug/L	ICPMS	11	11	11	11	11	11
Be	ug/L	ICPMS	0.1	3.6	3	5.5	5.8	5.2
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	4.93	5	4.99	5.16	4.93	5.16
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	410	490	480	530	530	580
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	0.006	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Er	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Eu	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fe	ug/L	ICPMS	<30	<30	<30	<30	<30	<30
Ga	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	0.02	0.02	< 0.02
Gd	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Ge	ug/L	ICPMS	27	33	35	35	36	40
Ho	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
K	mg/L	ICPAES	37.9	46	45.8	52.1	50.8	57.9
La	ug/L	ICPMS	0.01	0.01	0.01	< 0.01	< 0.01	< 0.01
Li	ug/L	ICPMS	6600	7900	7900	8900	8900	10000
Mg	mg/L	ICPAES	0.73	0.443	0.448	0.232	0.23	<0.1
Mn	ug/L	ICPMS	24	28	28	30	30	33
Mo	ug/L	ICPMS	190	230	230	250	250	280
Na	mg/L	ICPAES	257	306	309	347	342	383
Nb	ug/L	ICPMS	0.2	0.2	0.1	0.1	0.1	0.1
Nd	ug/L	ICPMS	0.02	< 0.01	0.01	< 0.01	< 0.01	< 0.01
Ni	ug/L	ICPMS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
P	ug/L	ICPMS	12	9.7	9.4	6.8	6.4	5.6
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pr	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Rb	ug/L	ICPMS	350	420	410	460	460	490
Sb	ug/L	ICPMS	110	130	130	140	140	150
Sc	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Se	ug/L	ICPMS	7.7	9.6	9.2	10	10	9.8
SiO ₂	mg/L	ICPMS	300	350	350	380	380	410
Sm	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Sr	ug/L	ICPMS	24	20	20	17	17	14
Ta	ug/L	ICPMS	0.15	0.14	0.15	0.12	0.12	0.15
Tb	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Th	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti	ug/L	ICPMS	< 0.2	0.3	< 0.2	0.3	0.3	0.2
Tl	ug/L	ICPMS	0.76	0.94	0.92	1	1	1.2
Tm	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
V	ug/L	ICPMS	2.4	2.7	2.6	2.7	2.7	2.8
W	ug/L	ICPMS	110	130	130	140	140	160
Y	ug/L	ICPMS	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Yb	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zn	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	<5	14	5	10	<5	<5
δ ¹⁸ O vs VSMOW	permil	ISO1	-	-13.93	-	-13.50	-	-13.03

Appendix 3. Site and analytical data from the 1999 mixing experiments—Continued

Field no.			W1 diss	W1 tot	W2 diss	W2 tot	W3 diss	W3 tot	W4 diss	W4 tot
Sample name/ description			West Thumb/ Black pool	West Thumb/ Black pool	West Thumb/ Black pool	West Thumb/ Black pool	West Thumb/ Black pool	West Thumb/ Black pool	West Thumb/ Black pool	West Thumb/ Black pool
Latitude			44°25'6"N	44°25'6"N	44°25'6"N	44°25'6"N	44°25'6"N	44°25'6"N	44°25'6"N	44°25'6"N
Longitude			110°34'17"W	110°34'17"W	110°34'17"W	110°34'17"W	110°34'17"W	110°34'17"W	110°34'17"W	110°34'17"W
Collection date			07/22/99	07/22/99	07/24/99	07/24/99	07/24/99	07/24/99	07/24/99	07/24/99
Temp at filter	°C		16.5	16.5	16.6	16.6	19.8	19.8	21.3	21.3
pH			7.5	7.5	7.6	7.6	7.6	7.6	7.7	7.7
Conductivity	uS/cm		87	87	172	172	303	303	490	490
Cl	mg/L	IC-Aq	4.7	-	15	-	35	-	62	-
F	mg/L	IC-Aq	0.5	-	1.7	-	3.8	-	7	-
NO ₃	mg/L	IC-Aq	0.5	-	0.4	-	<.35	-	0.5	-
SO ₄	mg/L	IC-Aq	7.2	-	8.7	-	11	-	14	-
Ag	ug/L	ICPMS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Al	ug/L	ICPMS	1	2	14	14	34	33	62	63
As	ug/L	ICPMS	12	12	94	98	240	240	440	460
Au	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
B	ug/L	ICPAES	105	90.4	221	220	432	432	770	782
Ba	ug/L	ICPMS	8.5	8.6	8.3	8.2	7.6	7.8	7	7.3
Be	ug/L	ICPMS	<0.05	<0.05	0.2	0.2	0.7	0.6	1.3	1.3
Bi	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Ca	mg/L	ICPAES	4.87	4.93	4.84	4.85	4.59	4.52	4.19	4.17
Cd	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ce	ug/L	ICPMS	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.03
Co	ug/L	ICPMS	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr	ug/L	ICPMS	<1	<1	<1	<1	<1	<1	<1	<1
Cs	ug/L	ICPMS	2.3	2.2	16	16	38	37	66	67
Cu	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dy	ug/L	ICPMS	< 0.005	< 0.005	0.007	0.009	< 0.005	0.007	< 0.005	< 0.005
Er	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Eu	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Fe	ug/L	ICPMS	<30	<30	<30	<30	<30	<30	<30	<30
Ga	ug/L	ICPMS	< 0.02	< 0.02	0.4	0.4	1.1	1.2	2.2	2.2
Gd	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	0.008	< 0.005	0.005	< 0.005
Ge	ug/L	ICPMS	0.2	0.2	2.1	2.1	5.1	5.1	9.5	9.7
Ho	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
K	mg/L	ICPAES	1.65	1.56	2.25	2.24	3.32	3.42	4.92	4.98
La	ug/L	ICPMS	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
Li	ug/L	ICPMS	40	41	200	200	440	450	810	820
Mg	mg/L	ICPAES	2.16	2.16	2.1	2.08	1.94	1.97	1.74	1.74
Mn	ug/L	ICPMS	0.4	0.44	0.47	0.51	0.62	0.62	0.78	0.78
Mo	ug/L	ICPMS	1.6	1.2	4.6	4.8	11	11	21	22
Na	mg/L	ICPAES	8.76	8.44	26.3	26.3	53.9	53.1	93.5	93.5
Nb	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	0.06	0.04	0.1	0.1
Nd	ug/L	ICPMS	0.03	0.03	0.02	0.03	0.03	0.04	0.02	0.03
Ni	ug/L	ICPMS	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2
P	ug/L	ICPMS	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Pb	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pr	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Rb	ug/L	ICPMS	3.9	4	11	11	23	23	39	40
Sb	ug/L	ICPMS	1.6	0.94	5.2	5.2	12	12	23	23
Sc	ug/L	ICPMS	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Se	ug/L	ICPMS	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	0.6	0.7
SiO ₂	mg/L	ICPMS	8.4	8.7	19	19	36	36	62	63
Sm	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01
Sr	ug/L	ICPMS	35	34	33	35	33	32	28	29
Ta	ug/L	ICPMS	< 0.03	< 0.03	0.04	< 0.03	0.14	0.11	0.25	0.2
Tb	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Th	ug/L	ICPMS	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Ti	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.2
Tl	ug/L	ICPMS	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tm	ug/L	ICPMS	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
U	ug/L	ICPMS	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
V	ug/L	ICPMS	0.64	0.7	0.69	0.68	0.62	0.63	0.6	0.6
W	ug/L	ICPMS	5.1	3.3	14	15	38	40	77	81
Y	ug/L	ICPMS	0.03	0.02	0.02	0.03	0.03	0.03	0.02	0.02
Yb	ug/L	ICPMS	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Zn	ug/L	ICPMS	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zr	ug/L	ICPMS	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Hg	ng/L	Hg CVAF	5	<5	8	<5	5	<5	9	<5
δ ¹⁸ O vs VSMOW	permil	ISO1	-16.17	-	-16.57	-	-16.56	-	-15.98	-

