National Park Service
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Greater Yellowstone Network Water Quality Monitoring Annual Report

January 2007–December 2008

Natural Resource Data Series NPS/GRYN/NRDS—2009/013

ON THE COVER
From top left, clockwise: Crooked Creek in Bighorn Canyon National Recreation Area, Snake River in Grand Teton National Park, Sylvan Lake in Yellowstone National Park.
Photographs by: NPS

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U.S. Department of the Interior
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The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Executive Summary

The Greater Yellowstone Network (GRYN) was established by the National Park Service Inventory and Monitoring (I&M) Program in 2000 to help enhance the scientific basis for stewardship and management of natural resources in Bighorn Canyon National Recreation Area, Grand Teton National Park including the John D. Rockefeller, Jr. Memorial Parkway, and Yellowstone National Park.

Aquatic resources across the GRYN face numerous and varied threats, including atmospheric deposition, altered hydrology, mining, agriculture, pollution from boats, introduction of nonnative species, soil or streambank erosion, leaking underground storage tanks, improper sewage-plant or drain field operations, and stormwater runoff. In 2006, GRYN parks began monitoring water chemistry and benthic macroinvertebrates at fixed monitoring sites as part of the vital signs monitoring program. In 2007, water quality monitoring was further expanded to include high alpine lakes in Grand Teton due to their significance as receptors sensitive to atmospheric deposition of sulfur and nitrogen. The GRYN is using a "targeted" sampling design for monitoring water chemistry and aquatic macroinvertebrates, which reflects the need to continue collection of historical-trend data from the U.S. Geological Survey (USGS) and to meet budgetary constraints.

Results of the water quality monitoring program in the GRYN are compared to federal and state standards to identify potential water quality degradation issues in network parks (appendix A). Land uses and geology within and upstream of each park present specific concerns with regard to potential water quality impacts and likely sources of contamination. Specific locations where water quality did not meet applicable standards are identified for each park.

- Several water quality samples collected at sampling sites in Bighorn Canyon did not meet state and/or national standards for *Escherichia coli* in 2007 and 2008. Detected concentrations greater than applicable standards for *E. coli* may be related in part to agricultural activities upstream of the monitoring sites that may have resulted in animal waste-contaminated runoff.
- Several water quality samples collected at sampling sites in Grand Teton did not meet state and/or national standards; constituents were dissolved copper (2007), and total iron and pH (2008). In general, observed metals concentrations are likely related to the site-specific geology. Field pHs greater than state and/or federal standards were identified in 2008 via multi-parameter probe at Amphitheatre, Surprise, and Delta lakes. While outside of the range recommended for natural waters of Wyoming, the pH of these water bodies is within acceptable ranges for the sensitive alpine headwater lakes.
- Samples collected at 5 of 20 sites monitored in Yellowstone in 2007 did not meet state and/or federal standards. Constituents not in compliance with these standards included minimum flow, total iron and pH. In 2008, samples collected at 6 of 20 sites monitored were not in compliance with state and/or federal standards. Constituents of concern included pH, water temperature and dissolved iron. Concentrations detected in samples collected in Yellowstone can generally be attributed to the unique geology and geothermal activity occurring in the park. Minimum flow standards not met at Reese Creek in 2007 were met in 2008 due to altered irrigation demands.

1 Introduction

Ecosystem "vital signs" are key to the National Park Service's (NPS) Inventory and Monitoring (I&M) Program. A vital sign is a physical, chemical, or biological component of the air, water, or land. It is rarely possible to monitor all indicators of ecosystem health; therefore, vital signs are chosen because they are most representative of the ecosystem as a whole and/or are most critical to ecosystem function. A goal of NPS vital signs monitoring is to report ecosystem status and trends and to document the level of confidence in the results. A summary of vital signs monitoring is provided in *An Overview of Vital Signs Monitoring and its Central Role in Natural Resource Stewardship and Performance Management* (National Park Service):

> Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources. …Vital signs monitoring is a key component in the Service's strategy to provide scientific data and information needed for management decision-making and education. Vital signs [monitoring] also contributes information needed to understand and to measure performance regarding the condition of watersheds, landscapes, marine resources, and biological communities.

Through the NPS I&M Program, 270 national park units were organized into 32 networks that share similar geographic and natural resource characteristics. The networks improve efficiency and reduce costs by sharing funding and a core professional staff and conduct long-term ecological monitoring. The Greater Yellowstone Network (GRYN) comprises Bighorn Canyon National Recreation Area, Grand Teton National Park, including John D. Rockefeller, Jr. Memorial Parkway, and Yellowstone National Park.

Freshwater quality monitoring is funded through a NPS Water Resources Division initiative and is a significant network vital sign. The significance of water resources within the GRYN is reflected in the network's ranking of freshwater quality as third among all of the potential vital signs identified and prioritized by the GRYN. Freshwater quality has *direct* impact on several other indicators, including fish assemblages, amphibians, and reptiles considered to be at risk or considered to be species of concern; riparian habitat; wetlands; and aquatic macroinvertebrates. Freshwater quality has *indirect* impacts on all plant and animal life as well as human consumption, recreation, and enjoyment (i.e., the intrinsic value of water). Terrestrial chemistry, for better or worse, is frequently transferred to water via surface runoff and subsurface flow or base flow (groundwater). Therefore, not only is water quality an indicator of the health of aquatic systems, but it is an important indicator of overall ecosystem health.

1.1 Background

Aquatic resources across the GRYN face numerous and varied threats, including atmospheric deposition, altered hydrology, mining, agriculture, pollution from boats, nonnative species introduction, soil and streambank erosion, leaking underground storage tanks, improper sewage-plant or drainfield operations, and stormwater runoff. Water quality monitoring to assess the effects of these threats has been underway for more than 50 years, though not as a coordinated, comprehensive program focused on ecosystem health.

In 2005, the GRYN began monitoring water bodies identified by the states of Montana and Wyoming as "water-quality impaired" following a draft version of the network's Regulatory

Water Quality Monitoring Protocol (O'Ney 2006). These streams were Soda Butte and Reese creeks in Yellowstone, and the Bighorn and Shoshone rivers in Bighorn Canyon. Standard operating procedures were established for measuring core parameters (water temperature, pH, dissolved oxygen, conductivity) and discharge, and for collecting samples for analysis of metals in water and sediment, nutrients (e.g., nitrates, phosphates), *Escherichia coli,* and benthic macroinvertebrates.

In 2006, GRYN parks began monitoring water chemistry and benthic macroinvertebrates at fixed monitoring sites as part of the vital signs monitoring program. The objective for monitoring water chemistry at fixed sites was to determine the status and long-term trends in water chemistry (major ions and nutrients), conductivity, dissolved oxygen, pH, water temperature, and discharge in perennial rivers and streams at fixed stations in all GRYN parks and also in Yellowstone Lake. Water chemistry is critical for interpreting the biotic condition and ecological processes of aquatic resources. Chemical stressors can result in impaired functioning or loss of a sensitive species and a change in community structure. Water chemistry also affects the bioavailability of contaminants and the metabolism of aquatic species.

In 2007, water quality monitoring was further expanded to include high alpine lakes in Grand Teton. Headwater lakes in the park are potentially sensitive to the atmospheric deposition of sulfur and nitrogen compounds. Surprise, Delta, and Amphitheater lakes were identified as being particularly sensitive because of their dilute chemistry and low acid neutralizing capacity.

1.2 Study areas

1.2.1 Bighorn Canyon National Recreation Area

The diverse water resources of Bighorn Canyon, located in southeastern Montana and north-central Wyoming, encompass approximately 15% of the surface area of the recreation area. These resources include Bighorn Lake, the reservoir created by Yellowtail Dam in 1966; 8–16 kilometers of the Bighorn River (variation due to fluctuating lake levels); and 3–5 kilometers of the Shoshone River above the pool of Bighorn (variation due to fluctuating pool levels). The recreation area also includes several small ponds constructed in the Yellowtail Wildlife Habitat Management Area and in other park locations for wildlife and water management, the extreme lower reaches of several small streams that flow into the east and west sides of Bighorn Lake, a small number of seeps and springs primarily located at the base of the Pryor Mountains in the western portion of the park, and wetland and riparian areas associated with these systems.

The Bighorn River and its tributaries are part of the Bighorn and Wind River basins of the Missouri River Basin. Most of the park is contained within the Bighorn Lake hydrologic unit, with a small portion in the Lower Bighorn hydrologic unit (fig. 1). The Yellowtail Dam, operated by the Bureau of Reclamation and located near the northern edge of the recreation area, dominates Bighorn Canyon's hydrology and aquatic resources. The Shoshone hydrologic unit provides additional surface water inputs to Bighorn Lake. Bighorn Lake winds through approximately 113 kilometers of spectacular, sheer canyons carved by the Bighorn River.

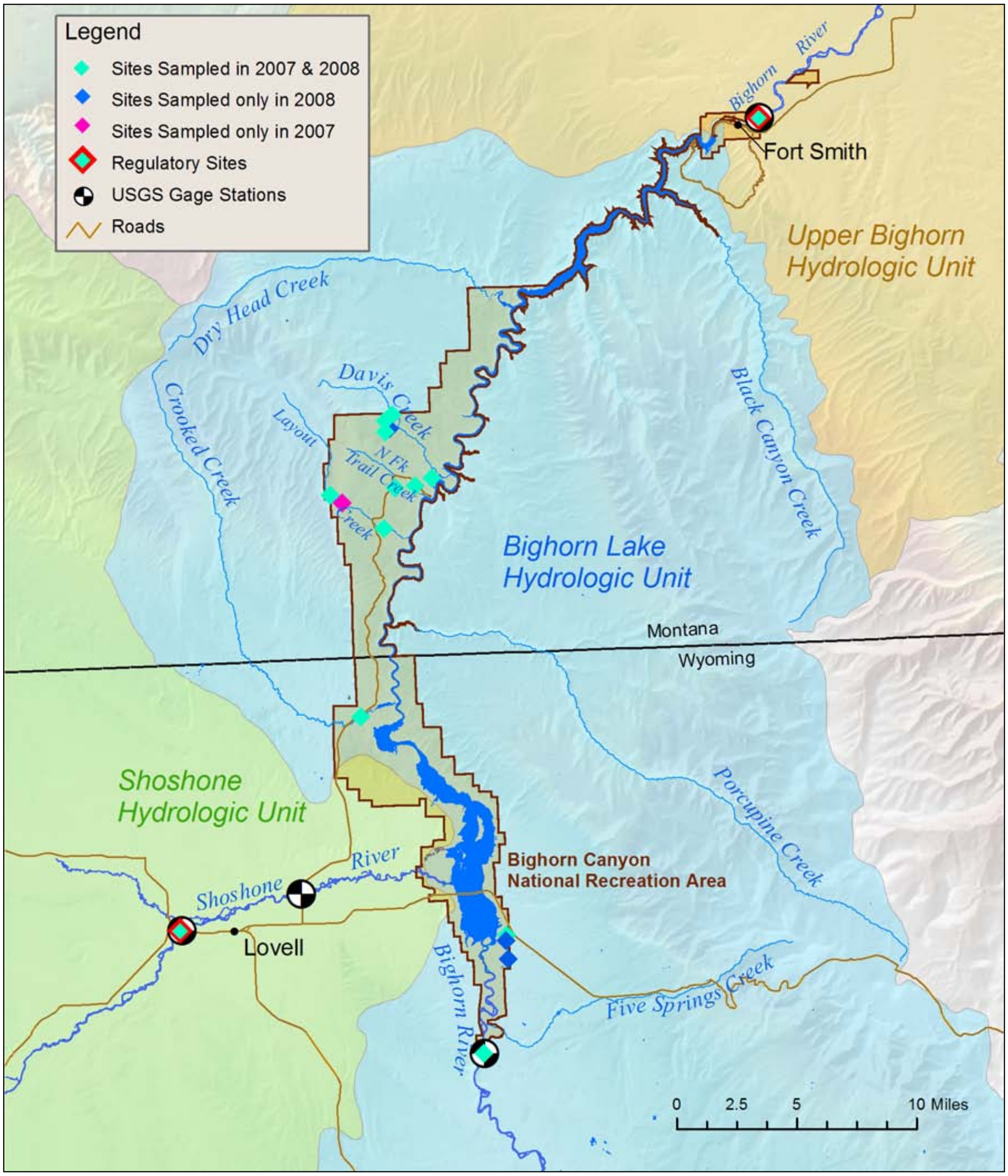


Figure 1. Water quality monitoring sites in Bighorn Canyon National Recreation Area.

1.2.2 Grand Teton National Park

Grand Teton is located in western Wyoming approximately 15 miles north of Jackson. Roughly 10% (125 square km^2) of the park is covered by surface water, most of which is contained in six piedmont lakes along the eastern front of the Teton Range. Jackson Lake is the largest of the six piedmont lakes and was created as a result of glacial moraine-damming of the Snake River and was enlarged by a dam constructed 1911–1916. About 100 alpine lakes (varying from 0.004 to 0.24 km^2) are within the Teton Range, mostly above 304.5 meters elevation. Approximately 75

pothole ponds of less than 0.00002 to more than 0.14 square kilometers occur in the glacial drift area south and east of Jackson Lake.

All surface water and groundwater in the park drains into the Snake River, which originates in highlands of the Teton Wilderness, flows north and west through part of Yellowstone, south through the John D. Rockefeller, Jr. Memorial Parkway, and into Jackson Lake in the park. From Jackson Lake, the Snake River flows east and then south for about 40 kilometers before crossing the park's south boundary. Seven streams originating in the Teton Range drain east into Jackson Lake, six others drain into Cottonwood Creek and the Snake River near Moose, Wyoming and three drain the southern portion of the Teton Range into Lake and Fish creeks, which flow into the Snake River south of the park. Eight major streams drain highlands in the Bridger-Teton National Forest north and east of the park and flow into Jackson Lake or the Snake River within the park. The entire park is part of the Snake River hydrologic unit (fig. 2).

1.2.3 Yellowstone National Park
Yellowstone encompasses approximately 9,065 square kilometers of watersheds that preserve one of the most significant, near-pristine aquatic environments in the United States, and contribute to two of the nation's farthest-reaching drainages: the Missouri and Columbia rivers. About 5% of the park is covered by water, including more than 220 lakes and 1,000 streams. Yellowstone Lake, which lies at an altitude of 2,356 meters, covers 352 square kilometers and is 122 meters deep, is the largest lake at high elevation in North America. As a result of both natural topography and early preservation actions, the headwaters of five major river systems (Fall, Gallatin, Madison, Snake, and Yellowstone) are either in or just upstream of the park. More than 50% of the park's surface waters are located within the Yellowstone Headwaters hydrologic unit. Hydrologic units within park boundaries include the Madison, Snake Headwaters, Upper and Lower Henrys, North Fork Shoshone, and the Gallatin (fig. 2).

1.3 Objectives
The objective of the annual report is to summarize water quality results for the previous calendar year. The summary report presented here covers 2007–2008 plus any lab data not previously reported (e.g., 2006 macroinvertebrate results). The purpose of this report is to:

1. Summarize monitoring activities and data. For each park, a description of the number of samples taken and analyses conducted is provided.

2. Describe the current condition of the resource relative to state and/or Environmental Protection Agency criteria.

3. Highlight notable events and observations.

4. Discuss recommendations, including modifications to the monitoring program and the need for special studies.

5. Provide a basis for communication within the parks and network.

The target audiences for this report include park managers, park and network resource managers, and state water quality managers.

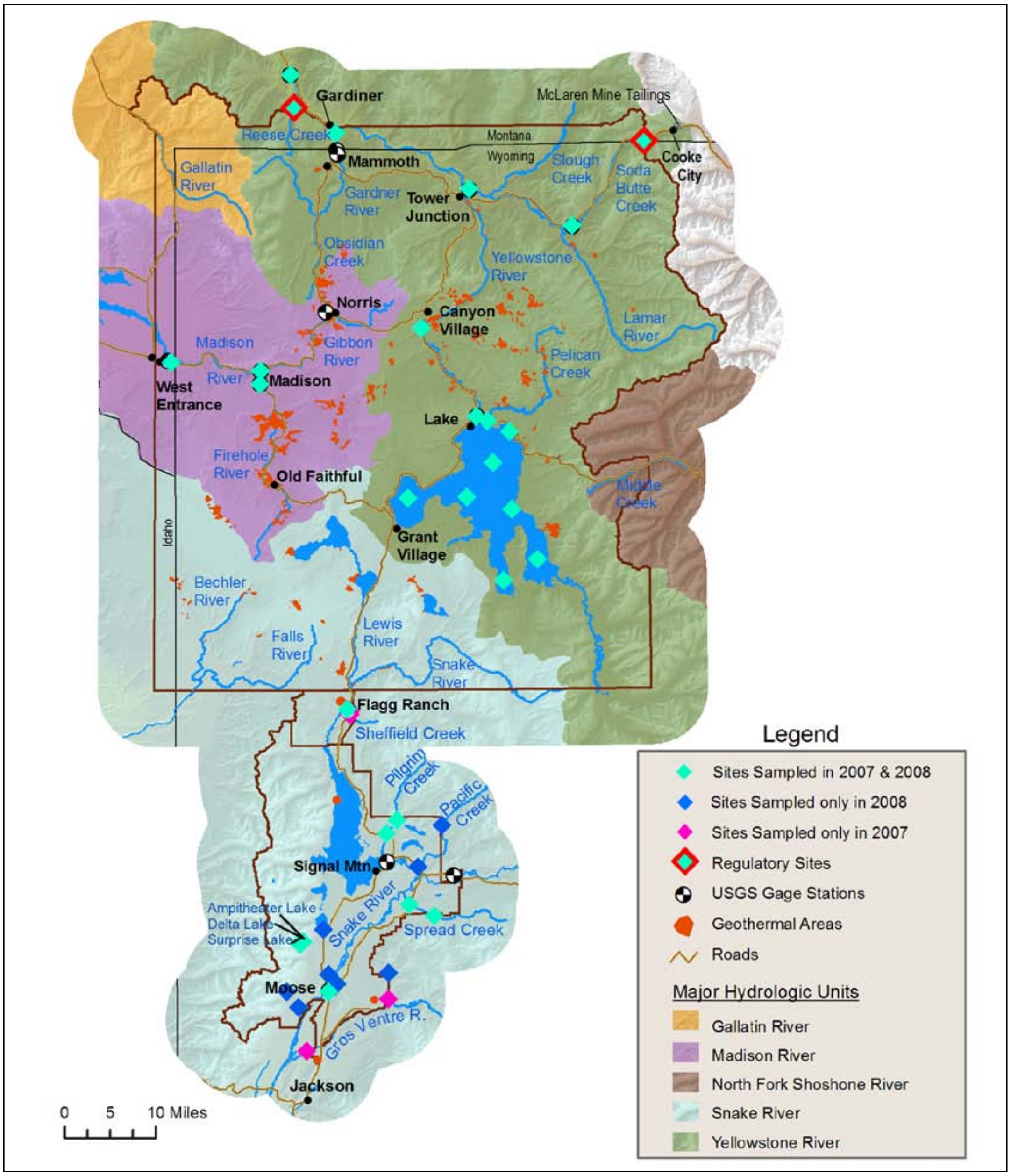


Figure 2. Water quality monitoring sites in Grand Teton and Yellowstone national parks.

2 Methods

The GRYN is using a "targeted" sampling design for monitoring water chemistry and aquatic macroinvertebrates, which reflects the need to continue collection of historical-trend data from the U.S. Geological Survey (USGS) and to meet budget constraints. Fixed monitoring sites were selected (table 1) that target specific waters of concern and/or act as integrator sites (i.e., located at outlets of drainage basins with relatively homogeneous land-use and physiographic conditions, intended to reflect conditions within that basin). Many of these sites have sufficient access to enable year-round monitoring and are co-located with USGS gaging stations that have long-term records useful to the interpretation of water-quality data. As such, these are important data sources to the parks, which have placed high value on maintaining their continued monitoring.

2.1 Field methods

Water samples were collected at 48 stations in 2007 and 52 stations in 2008 (figs. 1 and 2; table 1), following the collection procedures described in the GRYN's Regulatory Water Quality Monitoring Protocol, Version 2.0, and Standard Operating Procedures #1–11 (O'Ney 2006).

Table 1. Water quality and macroinvertebrate monitoring stations sampled in the GRYN

Location	Drainage basin	Station ID	Station name	Year(s) sampled	Impaired/303(d) regulatory stream (Y/N)
Bighorn Canyon National Recreation Area	Lower Bighorn Drainage	BICA_BHR1	Bighorn River near St. Xavier	2007, 2008	Y
	Bighorn Lake Drainage	BICA_BHR2	Bighorn River at Kane	2007, 2008	N
		BICA_CCR1	Crooked Creek	2007, 2008	N
		BICA_DACR1	Davis Creek	2007, 2008	N
		BICA_LCR1	Layout Creek at Headgate	2007	N
		BICA_LCR2	Layout Creek below road	2007, 2008	N
		BICA_LAYOUTSPR1	Layout Spring	2007, 2008	N
		BICA_TRC1	North Trail Creek	2007, 2008	N
	Shoshone River Drainage	BICA_SHR2	Shoshone River near Lovell, WY	2007, 2008	Y
		BICA_HDGTSEEP1	Headgate Seep	2007	N
		BICA_MASLOVSPR1	Mason-Lovell Spring	2007	N
		BICA_HLSBMNSPR1	Hillsboro Main Spring	2007, 2008	N
		BICA_NDAVISPR1	North Davis Spring	2007, 2008	N
		BICA_LOCKPNDSPR1	Lockhart Stockpond Spring	2007, 2008	N
		BICA_FINLEYSPR1	Finley Spring	2007, 2008	N
		BICA_LCKSOSPR1	South Lockhart Spring	2008	N
		BICA_MLS_SPR1	Mason Lovell South Spring	2008	N
		BICA_HAILSPR1	Hailstorm Spring	2008	N
Yellowstone National Park	Madison River Drainage	YELL_FH001.8C	Firehole River at Madison Junction	2007, 2008	N
		YELL_GB000.2M	Gibbon River at Madison Junction	2007, 2008	N
		YELL_MD133.2T	Madison River at West Yellowstone	2007, 2008	N
	Yellowstone River Drainage	YELL_GN002.9M	Gardner River at Rescue Creek trail crossing	2007, 2008	N
		YELL_LM000.5M	Lamar River at Tower Junction	2007, 2008	N
		YELL_SB015.7A	Soda Butte Creek near Silver Gate, MT	2007, 2008	Y
		YELL_SB001.5M	Soda Butte Creek at Buffalo Ranch	2007, 2008	N
		YELL_PC000.4M	Pelican Creek at Lake	2007, 2008	N
		YELL_YS616.4M	Yellowstone River at Fishing Bridge	2007, 2008	N
		YELL_YS600.5M	Yellowstone River at Canyon	2007, 2008	N
		YELL_YS549.7M	Yellowstone River at Corwin Springs	2007, 2008	N
		YELL_RC000.9A	Reese Creek	2007, 2008	Y
		YELL_RC000.9B	Reese Creek Diversion Ditch	2007, 2008	Y
		YELL_YL001.0M	Yellowstone Lake at Signal Point	2007, 2008	N

Table 2. Water quality and macroinvertebrate monitoring stations sampled in the GRYN (continued)

Location	Drainage basin	Station ID	Station name	Year(s) sampled	Impaired/303(d) regulatory stream (Y/N)
Yellowstone National Park (continued)	Yellowstone River Drainage (continued)	YELL_YL002.0M	Yellowstone Lake at Dot Island	2007, 2008	N
		YELL_YL003.0M	Yellowstone Lake at West Thumb	2007, 2008	N
		YELL_YL004.0M	Yellowstone Lake at Stevenson Island	2007, 2008	N
		YELL_YL005.0M	Yellowstone Lake at Mary Bay	2007, 2008	N
		YELL_YL006.0M	Yellowstone Lake at Southeast Arm	2007, 2008	N
		YELL_YL007.0M	Yellowstone Lake at South Arm	2007, 2008	N
	Snake River Drainage	YELL_SN999.9M	Snake River at Flagg Ranch	2007, 2008	N
Grand Teton National Park	Snake River Drainage	GRTE_GVR01	Gros Ventre River at eastern park and forest service boundary	2007	N
		GRTE_GVR02	Gros Ventre River at USGS gaging station at Zenith	2007	N
		GRTE_SHC01	Sheffield Creek at Forest Service boundary	2007	N
		GRTE_SHC02	Sheffield Creek at confluence with Snake River	2007	N
		GRTE_SNR01	Snake River at old Flagg Ranch 1000 feet below bridge	2007, 2008	N
		GRTE_SNR02	Snake River below site of new visitor center	2007, 2008	N
		GRTE_AMP01	Amphitheatre Lake	2007, 2008	N
		GRTE_SUR01	Surprise Lake	2007, 2008	N
		GRTE_DEL01	Delta Lake	2007, 2008	N
		GRTE_PIC01	Pilgrim Creek at Forest Service boundary	2007, 2008	N
		GRTE_PIC02	Pilgrim Creek at Hwy 89 Bridge	2007, 2008	N
		GRTE_SPC01	Spread Creek Forest Service above dam	2007, 2008	N
		GRTE_SPC02	Spread Creek at Hwy 89 bridge	2007, 2008	N
		GRTE_COC01	Cottonwood Creek at Jenny Lake	2008	N
		GRTE_COC02	Lower Cottonwood Creek near Snake River	2008	N
		GRTE_DIC01	Ditch Creek above Teton Science School	2008	N
		GRTE_DIC02	Ditch Creek at Hwy 89	2008	N
		GRTE_LAC01	Lake Creek at inlet to Phelps Lake	2008	N
		GRTE_LAC02	Lake Creek at Moose-Wilson Road	2008	N
		GRTE_PAC01	Pacific Creek at USFS Campground	2008	N
		GRTE_PAC02	Pacific Creek at Hwy 89	2008	N

2.2 Analytical methods

Environmental Testing and Consulting, Inc. (ETC) of Memphis, Tennessee, was contracted to conduct laboratory analysis of water quality samples from all locations except the alpine lakes in Grand Teton. In Yellowstone and Grand Teton, samples were chilled and shipped overnight to ETC at the end of each sampling day. Samples collected in Bighorn Canyon were chilled in a laboratory refrigerator and sent overnight to ETC on the Monday following collection. Alpine lake samples were sent to the USDA Forest Service (USDA-FS)/USGS Water Chemistry and Passive Ozone Laboratory in Fort Collins, Colorado. Table 2 outlines the analytes and the corresponding analytical method employed.

Table 2. Analytical methods for samples collected in the GRYN

Analyte	Method	Laboratory
Acid Neutralizing Capacity (Alpine Lake)	Gran Titration	USFS/USGS
Arsenic, Calcium, Copper, Hardness as CaCO3, Iron, Magnesium, Potassium, Selenium, Sodium	200.7	ETC
Ammonia	4500NH3D	ETC
Ammonium	Ion Chromatography	USDA-FS/USGS
Bicarbonate Alkalinity, Carbonate Alkalinity, Total Alkalinity	2320 B	ETC
Chloride, Fluoride, Nitrate-N, Nitrite-N, Phosphorus, Orthophospate (as P), Sulfate	300.0	ETC
Conductivity, Dissolved Oxygen, Temperature, pH, Alkalinity*	**	—
Escherichia coli	m-TEC MF method	Performed on-site (Bighorn Canyon)
Phosphate	4500 PB5	ETC

* alkalinity measured as field alkalinity at spring sites in Bighorn Canyon.

** field parameters collected via method described in Gibs, J., et. al, 2007, Use of multiparameter instruments for routine field measurements.

ETC = Environmental Testing and Consulting, Inc.

USDA-FS/USGS = USDA Forest Service/USGS Water Chemistry and Passive Ozone Laboratory

Identification of macroinvertebrates was performed by Aquatic Biology Associates, Inc. in Corvallis, Oregon. Field parameters (pH, conductivity, temperature and dissolved oxygen) were collected at each site using an In-Situ Troll 9500 (or equivalent). Conductivity and pH probes were calibrated prior to each sampling event; dissolved oxygen was calibrated at the beginning and end of the season.

2.3 Quality assurance and quality control

All data collected for the GRYN water quality monitoring program are verified and validated for quality assurance and quality control purposes. Data verification is a systematic process that evaluates data collection performance for completeness, correctness, and consistency. Data validation is the process used to qualify the data and reject or accept the information with no conditions or qualifications. During the validation review, any deviations from standard operating procedures must be documented and their potential effect on the usability and quality of the monitoring data must be evaluated and discussed. Data verification and validation reports are available at the GRYN offices in Bozeman, Montana (Arnold 2008a and 2008b; Arnold 2009a and 2009b; Bromley and Thomas 2008a and 2008b; O'Ney 2008a and 2008b; Rumelhart 2008a and 2008b; Schmitz and Carrithers 2009a and 2009b).

2.4 Water quality criteria

Results of the water quality monitoring program in the GRYN are compared to national and state standards to identify potential water quality degradation issues in network parks (see appendix A for standards). In many cases, the water quality of the network parks meets or exceeds (is better than) existing standards. The results from 2007 and 2008 discussed in this report are compared to published aquatic life standards from and prior to 2008 (MTDEQ 2008; EPA 1987; EPA 2006; WYDEQ 2007; EPA 2000; appendix A). Future reports will compare results to the most recent and possibly more restrictive standards.

3 Results and Discussion

Results for GRYN's water quality monitoring program are entered into park databases (NPSTORET), which are uploaded annually to the Environmental Protection Agency's national water quality database, EPA STORET (EPA STOrage and RETrieval), http://www.epa.gov/storet/. The results for the stations monitored in 2007 and 2008 have been added to the EPA STORET database.

3.1 Bighorn Canyon National Recreation Area

3.1.1 River monitoring

The water quality at Bighorn Canyon was monitored at a combination of regulatory and non-regulatory monitoring sites. During the 2007 and 2008 calendar year, water chemistry samples were collected quarterly from the two 303(d) regulatory water quality stations: Bighorn River near St. Xavier, Montana (BHR1), and Shoshone River near Lovell, Wyoming (SHR1).

In addition, four sampling rounds were conducted for *E. coli* at the Shoshone River near Lovell, Wyoming. For each *E. coli* sampling round, a sample was collected and analyzed on five consecutive days. The geometric mean of the results was compared to state standards.

The sample design also calls for the six non-regulatory sites to be visited quarterly; however, in September 2007, the Layout Creek at Headgate (BICA_LCR1) station was replaced with the Layout Spring (BICA_LAYOUTSPR2) station. Thus, Layout Creek at Headgate was sampled only twice in 2007. Basic water quality parameters, including water temperature, dissolved oxygen, pH, specific conductivity, and turbidity, were collected *in situ* at each site. Water samples were analyzed in the laboratory for additional chemical parameters: dissolved anions (chloride, sulfate, and total alkalinity), dissolved cations (calcium, magnesium, potassium, and sodium), and nutrients (nitrate, nitrite, and ortho-phosphate).

Samples collected in Bighorn Canyon were chilled in a laboratory refrigerator and sent overnight on ice to ETC on the Monday following collection. Analyses for *E. coli* were conducted by Bighorn Canyon personnel.

The water quality sampling effort in Bighorn Canyon during 2007 comprised a total of 20 site visits and 619 results (table 1; Schmidt and Carrithers, 2009a). In 2008, a total of 50 visits yielded approximately 446 results (table 1; Schmidt and Carrithers, 2009a). Results include field observations, multi-probe measurements, and laboratory analysis.

A summary of sampling locations (by drainage) not in compliance with applicable water quality standards follows. Bighorn Canyon resource personnel are concerned about parameters such as phosphate, sulfate and turbidity; however, these parameters were not measured at concentrations greater than standards referenced in this report (appendix A).

- **Bighorn Lake Drainage:** Samples collected within the Bighorn Lake Drainage during 2007 and 2008 met federal and/or state standards.

- **Lower Bighorn Drainage:** Samples collected within the Lower Bighorn Drainage during 2007 and 2008 met federal and/or state standards.

- **Shoshone River Drainage:** The Shoshone, a regulated river system adjacent to multiple populated areas, was monitored for *E. coli* in 2007 and 2008. In order to meet state standards for contact recreation, the geometric mean of five consecutive sampling days should not exceed 126 colony forming units (cfu) of *E. coli* per 100 milliliter.

  All calculated means at the Shoshone River regulatory monitoring site collected in 2007 and one calculated mean (June) from 2008 did not meet this standard (table 3). Probable sources of *E. coli* include sewage, agricultural and domestic waste, wildlife waste, and septic systems. The presence of *E. coli* can be dangerous to human health. The Shoshone River will continue to be monitored in June, July, August, and September of future sampling years.

Table 3. 2007–2008 water quality sampling locations in the Shoshone River basin of Bighorn Canyon where constituent concentrations did not meet applicable standards

Site	Parameter	Year	Standard*	Units	Exceedance/ # of visits	Range of values
Shoshone River near Lovell	*E. coli*	2007	126/100 mL	Geometric mean of five samples: cfu/100 mL	4/4	299.6–633.3
		2008			1/4	4–157

* See references, appendix A.
cfu = colony forming unit
mL = milliliter

3.1.2 Spring monitoring

Arid land seeps and springs in Bighorn Canyon were identified as a vital sign for the GRYN. Seeps and spring ecosystems have an ecological importance disproportionate to their spatial extent in this desert environment. Protecting seep and spring resources requires in-depth understanding of their ecological character, controlling factors, and natural variability over space and time.

A monitoring protocol was developed to track the ecological condition of the 34 confirmed springs in Bighorn Canyon. To date, only protocols for the physical parameters have been developed. Four springs were used during protocol development and have been sampled for water quality seasonally since fall 2004.

Water quality samples from Bighorn Canyon springs were collected at seven sites in 2007 and eight sites in 2008 (table 1). All springs were sampled in May and December of 2008, while Layout Spring was sampled additionally in March and September. Samples collected from seeps and springs in Bighorn Canyon during calendar years 2007 and 2008 met applicable standards.

3.2 Grand Teton National Park

During the 2007 and 2008 calendar years, the quality of Grand Teton’s Outstanding Natural Resource Waters was monitored. Outstanding Natural Resource Waters receive special protection against degradation and typically exhibit exceptional recreational function and/or

ecological significance. Basic water quality parameters were collected *in situ* at each site, including water temperature, dissolved oxygen, pH, specific conductivity, and raw conductivity.

Sampling in Grand Teton occurs June through October. In 2007, water samples were collected once at two sites (each) on the Gros Ventre River and Sheffield Creek; three times at two sites (each) on Pilgrim Creek and Spread Creek; and four times at two sites on the Snake River. In 2008, samples were collected once at two sites (each) on Lake Creek, Spread Creek, Pilgrim Creek and Cottonwood Creek; four times at two sites (each) on Ditch Creek and the Snake River; five times at two sites on Pacific Creek (table 1).

Water samples from each of these sites were collected and shipped overnight on ice for analysis by ETC. The following list of analyses was conducted:

- Dissolved anions (chloride, sulfate, and total alkalinity)
- Dissolved cations (calcium, magnesium, potassium, and sodium)
- Nutrients (nitrate, nitrite, and ortho-phosphate)
- Dissolved metals (arsenic, copper, iron and selenium)
- Total metals (arsenic, copper, iron, selenium and carbonate hardness)

In 2007, water samples were collected twice at alpine lakes Amphitheatre and Surprise and once at Delta Lake. In 2008 water samples were collected twice at all three alpine lakes (Surprise, Amphitheatre, and Delta). Water chemistry was analyzed by the USDA-FS/USGS Water Chemistry and Passive Ozone Laboratory in Fort Collins, Colorado for the following parameters: pH, acid neutralizing capacity, conductivity, sodium, ammonium, potassium, magnesium, calcium, fluoride, chloride, nitrate, phosphate, and sulfate.

The water quality sampling effort in Grand Teton during 2007 comprised a total of 29 site visits and 1,156 results. In 2008, 39 visits yielded approximately 1,230 results. Results include field observations, multi-probe measurements, and laboratory analysis results. A summary of sampling locations (by drainage) that did not meet applicable water quality standards follows.

3.2.1 Snake River Drainage
The Snake River and its tributaries were sampled in 2007 and 2008. Review of laboratory analyses results identified six locations that did not meet state and/or federal standards (appendix A): Sheffield Creek at Forest Service Boundary (dissolved copper), both sites at Spread Creek (total iron), and Amphitheatre, Surprise and Delta lakes (pH). All waters within Grand Teton are Outstanding Natural Resource Waters.

The source of high metals concentrations (table 4) at Sheffield Creek at Forest Service boundary, Upper Ditch Creek, Spread Creek at Forest Service above dam, and Spread Creek at Hwy 89 bridge may be related to the geology of their respective sites. Metals contamination identified in samples collected at these locations is not commonly associated with recreational or automobile use, suggesting that the source of the metals is not anthropogenic in nature. The chemical

composition of these water bodies is likely to be more closely related to geology of the site or surrounding (upstream) areas.

In addition, a review of 2006 data from Sheffield Creek shows that neither total nor dissolved copper has been identified above laboratory detection limits in water samples collected at this site. The lack of a definable trend suggests that elevated copper concentrations are not a chronic problem at this location and may be related to natural fluctuations in chemical composition of the water due to the area's geology.

The source of total iron at Spread Creek at Forest Service above dam and Spread Creek at Hwy°89 bridge may be related to the geology and geomorphology of the sites (table 4). A review of 2007 and 2008 data from both sites shows identification of total iron below standards but above laboratory detection limits is common at both sites, although in all data reviewed (four cases: three from 2007 and one from 2008) concentrations tend to decrease from Spread Creek Forest Service above dam (upstream) to Spread Creek at Hwy 89 bridge (downstream) for samples collected on the same day. These decreasing concentrations may be a result of additional water input to Spread Creek prior to sampling at Spread Creek at Hwy 89 bridge, or may be related a geologic source of iron at Spread Creek at Forest Service above dam that is not available at Spread Creek at Hwy 89 bridge. Although iron is routinely identified at these locations, the concentrations identified here (greater than applicable standards) are the first recorded via sampling in Grand Teton and are likely related to natural fluctuations in chemical composition of the water due to the area's geology.

Field pH at Amphitheatre, Delta and Surprise Lakes was identified below the acceptable range (excessively acidic) for naturally occurring waters in Wyoming. Overall, acid neutralizing capacity for Grand Teton's high alpine lakes fall within the range for sensitive lakes and pH values.

Table 4. 2007–2008 water quality sampling locations in Grand Teton where constituent concentrations did not meet applicable standards

Site	Parameter	Year	Standard*	Units	Exceedance/ # of visits	Range of values
Sheffield Creek at Forest Service boundary (SHC01)	Dissolved copper	2007	13	µg/L	1/1	17
Spread Creek Forest Service above dam (SPC01)	Total iron	2008	300**	µg/L	1/1	1,770
Spread Creek at Hwy 89 bridge (SPC02)	Total iron	2008	300**	µg/L	1/1	1,620
Surprise Lake (SUR01)	pH	2008	6.5–9	—	2/2	6.33–6.38
Amphitheatre Lake (AMP01)	pH	2008	6.5–9	—	2/2	5.76–6.33
Delta Lake (DEL01)	pH	2008	6.5–9	—	1/2	6.20–6.68

* See references, appendix A.
** Human health standard
µg/L = micrograms per liter

3.2.2 Snake River gaging station at Moose, Wyoming
Data collected at the Snake River gage at Moose, Wyoming (drainage area 1,677 square miles), was reviewed as part of the water quality analysis of Grand Teton. The Moose gage, operated by the USGS and funded by the GRYN, Grand Teton, and the Teton Conservation District, is

located on the Snake River adjacent to park headquarters in Moose, Wyoming. Discharge data has been collected at this location since 1995, and real-time temperature, pH, dissolved oxygen, and specific conductivity data have been collected since 2002 (table 5). Average, minimum and maximum data for temperature, dissolved oxygen, specific conductance, and discharge were collected for the years specified in table 5; only minimum and maximum pH values were reported. With the exception of pH (in which case both maximum and minimum trends are shown), the figures and tables provided in this section are calculated using average data for the parameter of interest for water years 2002–2008 (October 2002 through September 2009) and include approximately nine months of provisional data from 2009. Field parameter data are not presented for December, January, and February due to freezing conditions.

Table 5. Snake River at Moose, Wyoming field parameter and discharge descriptive statistics

Parameter	Units	Years	n	Min	Max	Mean	Median	SD
pH	standard units	2002–2008	1,580	7.3	9.5	*	*	*
Temperature	°C	2002–2008	1,739	0	19.6	10.5	10.4	4.65
Dissolved oxygen	mg/L	2002–2008	1,182	6.1	13.4	9.1	9	1.34
Specific conductance	µS/cm	2002–2008	1,735	84	235	160.9	160.0	31.9
Discharge	cfs	1995–2008	5,205	600	24,500	2,977.5	1,460	3,062.4

* Only maximum and minimum values of pH for the period of record were reported. Therefore, calculation of a mean, median or standard deviation is not appropriate. Statistics for the remaining parameters (temperature, dissolved oxygen, specific conductance, and discharge) were based on reported mean values.
Min = minimum
Max = maximum
mg/L = milligrams per liter
µS/cm = microsiemens/centimeter
cfs = cubic feet per second
SD = standard deviation

Table 5 indicates similar mean and median values for the temperature, dissolved oxygen, and specific conductance, suggesting skewing agents such as extreme outliers are not present within these datasets. In contrast, due to large natural variability over an annual cycle, it is not unexpected to see a large discrepancy between the mean and median of recorded discharge data.

3.2.2.1. Seasonal Variation: Field ParametersData for each of the field parameters collected at the Moose gage have been plotted by month using box plots to illustrate parameter values and variability during the year and occurrence of potential extreme values. All of the parameters are observed to change seasonally, although the causes of the volatility vary (figs. 3–7).

Temperature data exhibit a strong seasonal trend, which closely tracks air temperature (fig. 3). Water temperatures in May and June tended to be lower than air temperatures would suggest due in part to the influence of snowmelt. Based on the box plots, most of the data (with the exception of September) appear to be normally distributed or slightly left-skewed. Median water temperatures are observed to increase steadily from March until July and then stabilize before decreasing again as winter approaches. The warmest months (July and August) exhibit remarkably similar temperature profiles, including nearly identical maximum and median values.

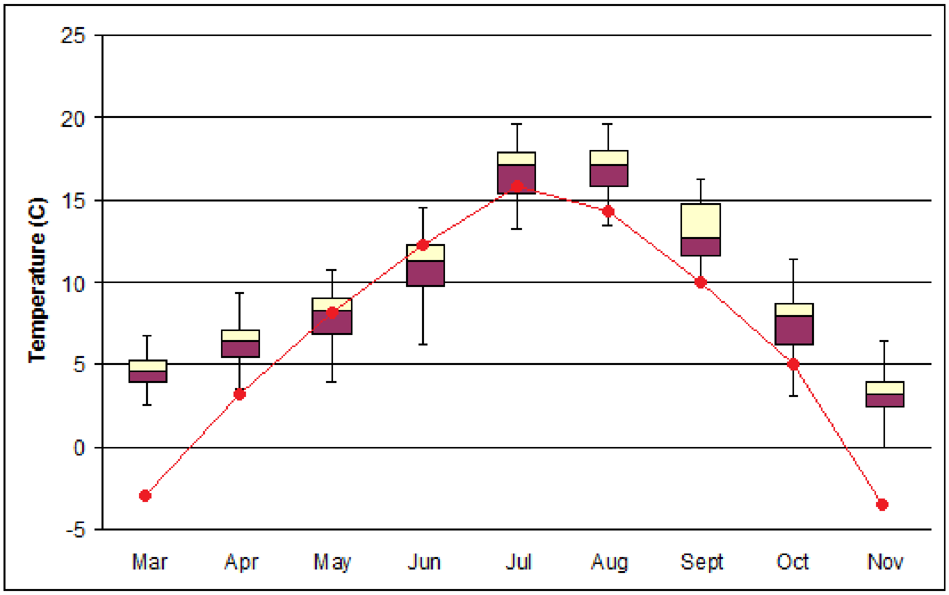


Figure 3. Box plots of monthly average water temperature and air temperature (red line) for the Snake River at Moose, Wyoming, for the period of record (2002–2008).

Dissolved oxygen content is a measure of the ability of surface waters to support aquatic life. Oxygen saturation concentration is dependent on three primary parameters: temperature, atmospheric pressure and dissolved solids (Maidment 1993). Dissolved oxygen values exhibit a weak seasonal trend, decreasing in summer months due to warmer temperatures (fig. 4). July and August box plots are similar in terms of median, although August dissolved oxygen values exhibit the greatest range. Based on water quality standards presented in appendix A, dissolved oxygen values appear to be consistently high enough to meet aquatic life needs.

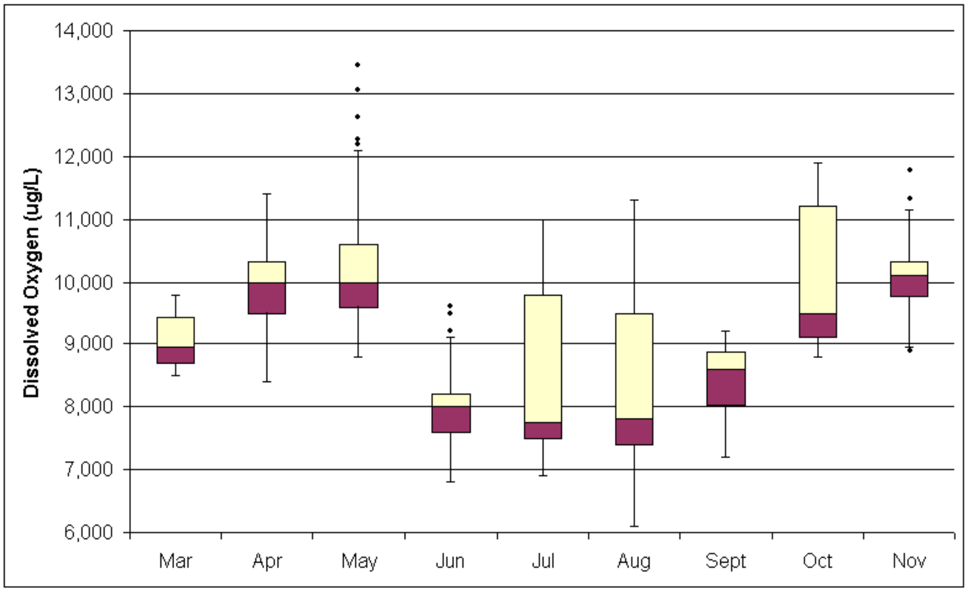


Figure 4. Box plots of monthly dissolved oxygen concentrations for the Snake River at Moose, Wyoming for the period of record (2002–2008).

Conductivity declined markedly during the high flow months of May and June, reflecting the dilution effect of snowmelt (fig. 5). However, the box plots for May and June also indicate a wide variation in potential conductivity values, reflecting the additional dissolved solids load (and therefore potential *increase* in conductivity) carried by the river during the spring months. In general the data appear to be normally distributed to slightly left-skewed.

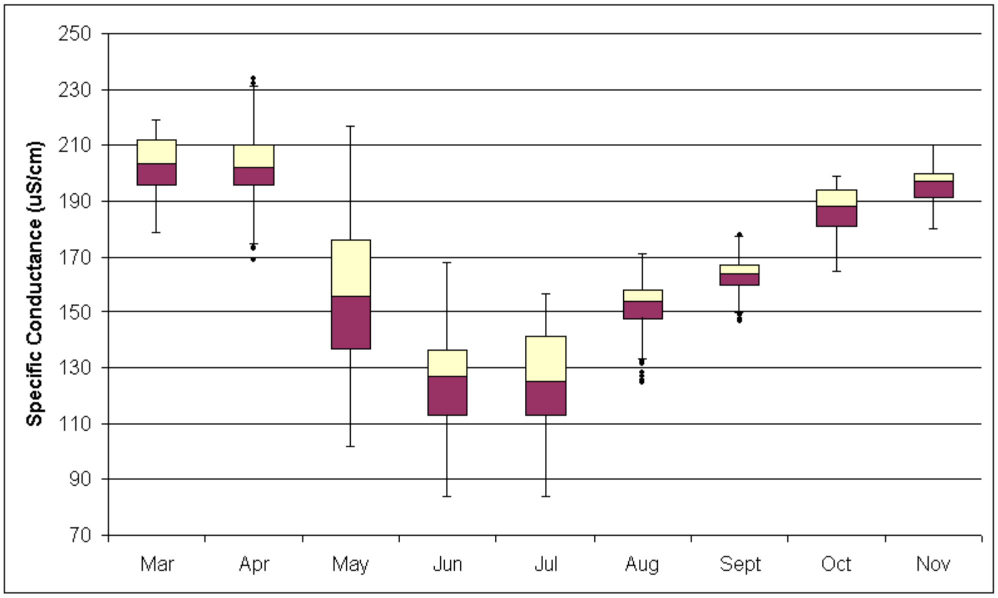
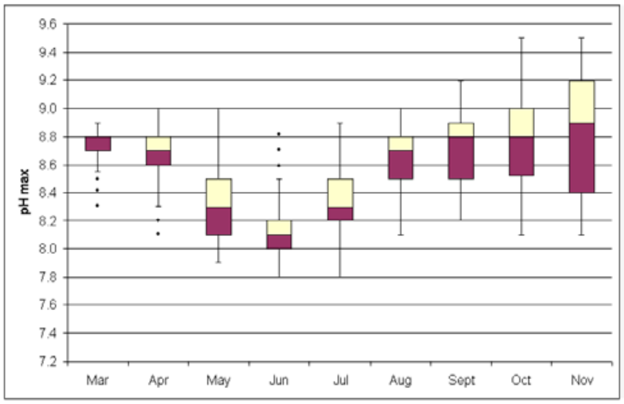
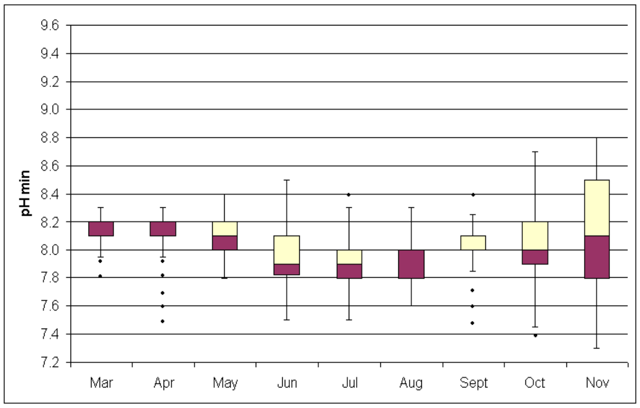


Figure 5. Box plots of monthly specific conductance for the Snake River at Moose, Wyoming for the period of record (2002–2008).

Although mean pH values were not reported, assessment of maximum and minimum pH values suggests fairly constant pH throughout the year, especially in terms of minimum values (fig. 6). Slight decreases in both maximum and minimum values were observed during June and July, which may be related to the increase in water temperature (pH and temperature are inversely correlated). October and November data appear to exhibit the greatest variability, with significant overlap between maximum and minimum observations. As reported in appendix A, a pH of 6.5 to 9 is considered "normal" for waters such as the Snake; pH values ranging from 7.3 to 9.5 were observed at the Moose gage (table 5).





a **b**

Figure 6. Box plots of monthly maximum (a) and minimum (b) pH values for the Snake River at Moose, Wyoming, for the period of record (2002–2008).

3.2.2.2. Seasonal Variation: Discharge

Discharge passing the gage at Moose is influenced by releases from the impoundment on the Snake River at Jackson Lake. Flows are managed to maintain aquatic life standards while retaining sufficient water storage for the high demand periods in mid-summer. The box plots shown in figure 7 indicate winter flows generally below 1,300 cubic feet per second (cfs) (October through March), and an order of magnitude increase in flow during the period of spring runoff (May and especially June). A significant number of high outliers (i.e., outside the range of the box plots) were observed in the dataset. Many of these outliers were linked to flows in 1997, the year in which flows were the highest in the period of record. Figure 8 illustrates how flows in each of the years of the period of record compare to the mean flow for the period of record. Figure 8 also indicates a long-term, below-average trend in flows at the Moose gage (1999–2007).

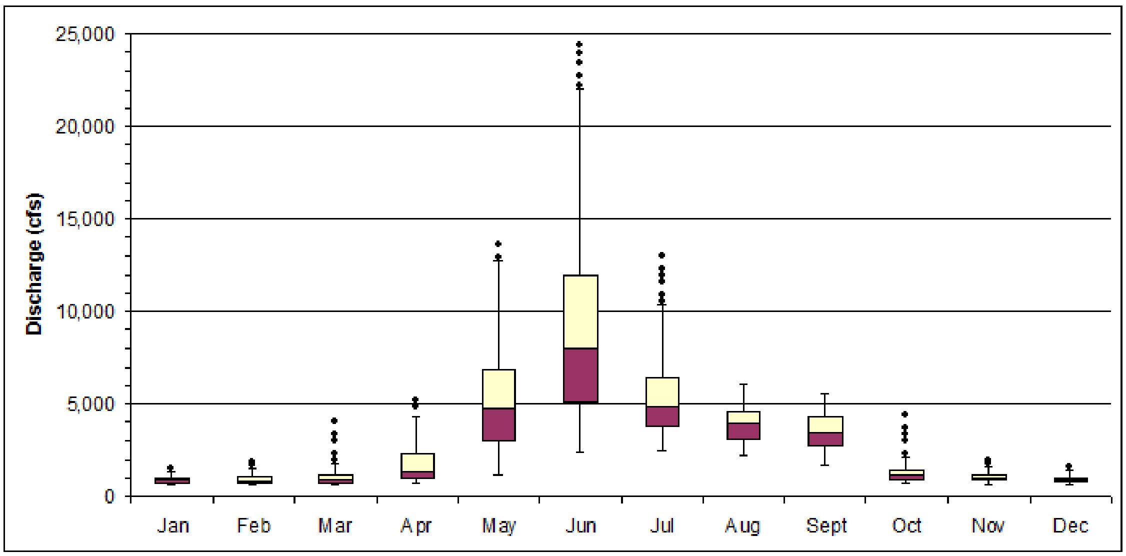


Figure 7. Boxplots of monthly discharge for the Snake River at Moose, WY for the period of record (1995–2008).

Figure 9 illustrates the variation in total (cumulative annual) flow at the Moose gage for the period of record. Total annual discharge varied from almost 60,000 cfs (14.1 trillion gallons per year) to approximately 20,000 cfs (4.7 trillion gallons per year). A marked change in total flow was noted to occur between 1998 and 1999, when total discharge was reduced by almost one-half from peak (58,499 cfs in 1996 compared to 32,229 cfs in 2007). Because major tributaries to the Snake, including the Buffalo Fork and Pacific Creek enter the system below the dam, the effects shown in figure 9 are attributable to a combination of natural and anthropogenic causes.

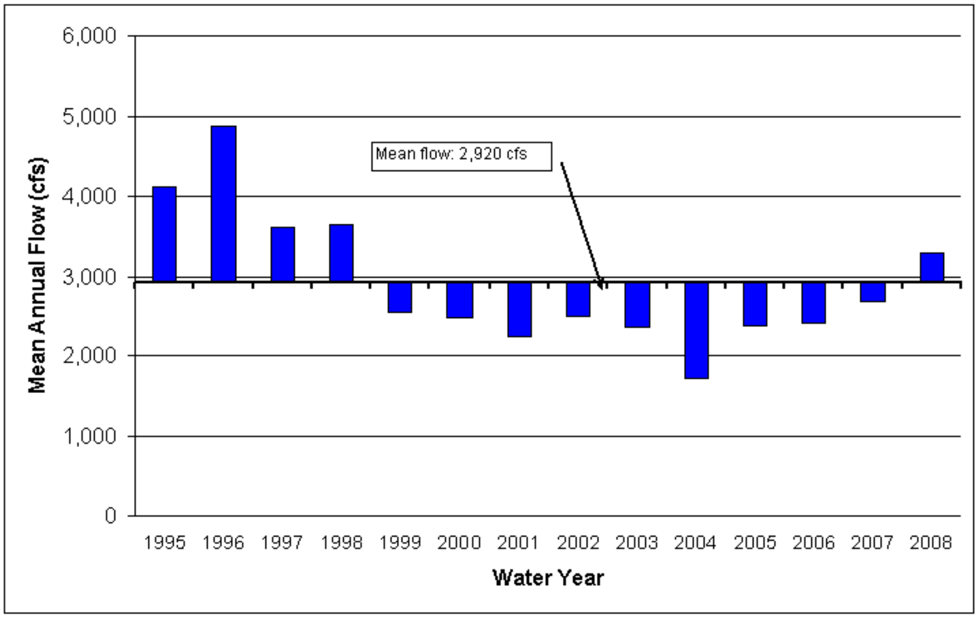


Figure 8. Variation of mean annual flow around mean flow for the period of record (1995–2008).

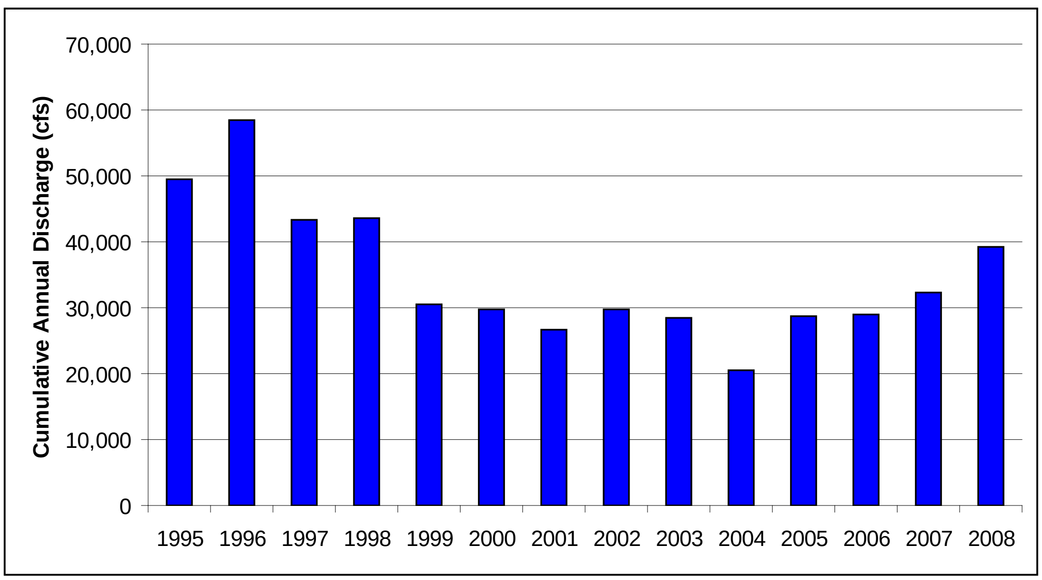


Figure 9. Annual cumulative discharge volume, calculated by water year.

3.3 Yellowstone National Park

The water quality at Yellowstone was monitored at a mix of regulatory (two sites) and Outstanding Natural Resource Waters (10 sites) monitoring locations. During the 2007 and 2008 calendar years, water samples were collected monthly from the 12 established stream water-quality sites and seasonally (summer months only) from an additional seven established lake water-quality sites. Basic water quality parameters were measured *in situ* at each site visit and included water temperature, dissolved oxygen, pH, specific conductivity, and turbidity.

Water samples were collected for total suspended solids, volatile suspended solids, and fixed suspended solids and taken to the field laboratory of the Yellowstone Fisheries and Aquatics Sciences section for analysis. Water samples were collected from the ten Outstanding Natural Resource Waters water quality sites and shipped overnight to Environmental Testing and Consulting, Inc., of Memphis, Tennessee. Chemical analysis of these samples included:

- Dissolved anions (chloride, sulfate, and total alkalinity)
- Dissolved cations (calcium, magnesium, potassium, and sodium)
- Nutrients (nitrate, nitrite, ammonia, total phosphorus, and ortho-phosphate)
- Dissolved and total metals (arsenic, copper, iron, selenium) Soda Butte Creek near Silver Gate, MT only

All water bodies in Yellowstone are classified as Outstanding Natural Resource Waters by the states of Montana and Wyoming, although two stream segments on the border of Yellowstone were listed (at the time of this report) as quality impaired by the State of Montana and are monitored as regulatory streams: Upper Soda Butte Creek near Cooke City, Montana (metals), and Reese Creek at the park’s northern boundary near Gardiner, Montana (discharge). Sampling at Soda Butte and discharge measurements at Reese Creek is required to meet monitoring requirements under the Clean Water Act.

Soda Butte Creek is located in the northeast corner of Yellowstone. A section of this water body, outside of park boundaries, is listed as impaired by the State of Montana. To assess the health of this stream, water and sediment samples were analyzed for metals (i.e., arsenic, copper, iron, and selenium) during both high- and low-flow conditions, which occur in June and September, respectively, in addition to the standard field and chemical water quality parameters. In-stream metals contamination in Soda Butte Creek is the result of historic mining in the vicinity of Cooke City, Montana, which is approximately eight kilometers from the Yellowstone boundary. Mine tailings still persist within the floodplain of Soda Butte Creek, and contribute to the listing of the portion of this stream as impaired and only partially supporting of aquatic life and coldwater fisheries. The upper Soda Butte Creek regulatory water quality site is co-located with the park’s long-term water quality site, which is sampled monthly.

The lower portion of Reese Creek is included in Montana’s quality impaired 303(d)/305(b) report due to irrigation practices from adjacent land owners, who often leave too little water in the stream to sustain healthy resident fish populations during the critical summer months of July and August.

In addition to water chemistry, aquatic invertebrates were sampled at five stream locations at long-term water quality monitoring sites to supplement physical and chemical data. Within the Yellowstone River Drainage, aquatic invertebrate monitoring locations included: Soda Butte Creek near Silver Gate, Montana, Soda Butte Creek at Buffalo Ranch, Gardner River, and Reese Creek. Within the Madison River Drainage, aquatic invertebrate monitoring locations included: Gibbon River at Madison Junction.

The water quality sampling effort in Yellowstone during 2007 comprised a total of 188 site visits and 4,805 results. The 2008 sampling effort yielded a total of 168 site visits and 5,309 results. Results include field observations, multi-probe measurements, and laboratory analysis.

Review of field and laboratory analyses results from 2007 and 2008 identified seven locations where constituent concentrations did not meet state and/or federal standards: Reese Creek (discharge); Soda Butte Creek at Silver Gate, MT (total and dissolved iron); Soda Butte Creek at Buffalo Ranch, Yellowstone River at Canyon, Pelican Creek at Lake, and Gibbon River near Madison Junction (pH); and Firehole River near Madison Junction (pH and water temperature). A summary of water quality results by drainage follows.

3.3.1 Yellowstone River Drainage

Discharge measurements on Reese Creek in 2007 were collected during 17 site visits between 22 May and 20 September 2007 and 18 site visits between 28 May and 25 September 2008 by Yellowstone's resource management staff (fig. 10). Discharge measurements were collected from two locations: (1) just above the uppermost flume and (2) stream water flowing through the upper diversion ditch. The difference between these two readings equals the amount of water entering the main channel of Reese Creek from the uppermost flume. Adjudicated water rights stipulate that Reese Creek is to have a minimum flow of 1.306 cubic feet per second between April 15 and October 15 during any given year to maintain healthy fish and aquatic invertebrate populations. During 2007, instream flow below the diversion on Reese Creek ranged from 0.53 to 4.94 cfs; during 2008, instream flow below the diversion ranged from 5.57 to 18.88 cfs (fig.°10). Water use and water rights issues surrounding Reese Creek continue to be a concern to park resource managers. Continued monitoring of discharge during the summer months is important to conserve the stream's native fish populations and biological integrity.

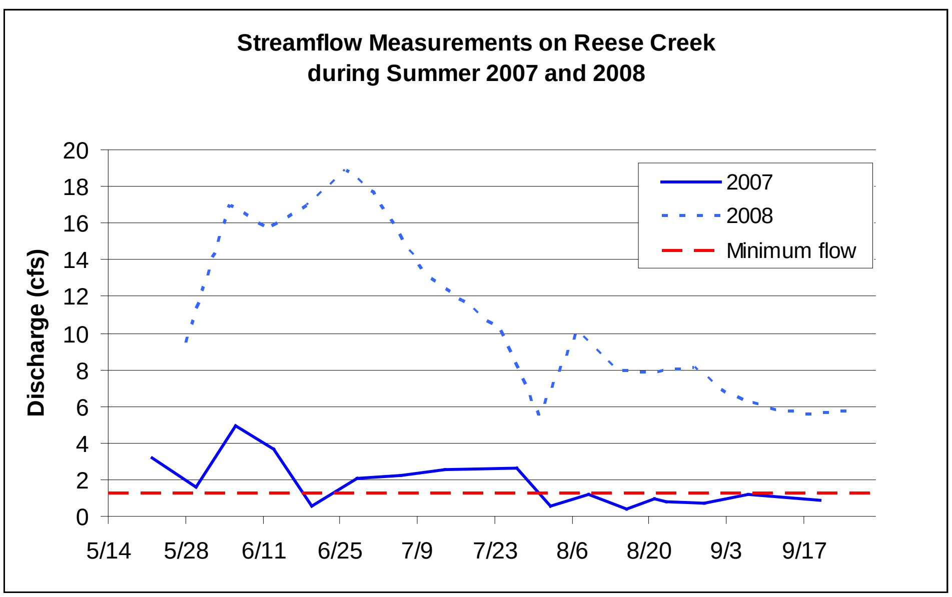


Figure 10. Streamflow measurements on Reese Creek during summer 2007 and 2008. Adjucated water rights (1.306 cfs) are shown as "minimum flow."

All basic physical and chemical parameters at Soda Butte at Silver Gate, MT were within ranges expected of high-elevation, coldwater streams with the exception of iron (total/dissolved;

table°6), which is most likely being transported from the mine tailings downstream to the sample site. Water chemistry and aquatic biota analysis results from the water quality site on Soda Butte Creek near Silver Gate, MT indicate that Soda Butte Creek, as it enters Yellowstone, fully supports aquatic life. However, proposed plans for the removal of the McLaren mine tailings from the floodplain could potentially re-suspend heavy metals in upstream reaches of Soda Butte Creek. These metals could have a tremendous negative impact to water quality and stream biota in downstream reaches of Soda Butte Creek inside the park's boundaries. Continued water quality monitoring at this site is imperative to ascertain future impacts from activities associated with the McLaren mine tailings.

The low pH values recorded in 2007 and 2008 at Soda Butte Creek at Buffalo Ranch near the confluence with Lamar River are most likely due to naturally occurring conditions (seasonal variation) in this portion of the Yellowstone River Drainage (table 6). As a result, there will likely be no long-term, negative effect to water-quality, aquatic biota, or recreation use within this portion of the park. The low pH values observed in 2008 at Yellowstone River at Canyon and Pelican Creek at Lake (table 6) are most likely attributed to natural seasonal variation within the watersheds. Additionally, both the Yellowstone River and Pelican Creek receive a large upstream thermal input, which is likely to contribute greatly to the overall acidity of the streams and affect the pH, particularly during low flow periods.

Table 6. 2007–2008 water quality sampling locations in the Yellowstone River Drainage of Yellowstone where constituent concentrations did not meet applicable standards

Site	Parameter	Year	Standard*	Units	Exceedance/ # of visits	Range of values
Reese Creek	Minimum flow	2007	1.306	cfs	8/16	0.52–4.94
Soda Butte Creek at Silver Gate, MT	Total iron	2007	300**	µg/L	4/4	393–550
	Dissolved iron	2008	300**	µg/L	1/4	ND–545
Soda Butte Creek at Buffalo Ranch	pH (low)	2007	6.5–9	—	1/12	6.2–7.8
		2008			1/12	6.4–7.7
Yellowstone River at Canyon	pH (low)	2008	6.5–9	—	4/9	5.5–7.5
Pelican Creek at Lake	pH (low)	2008	6.5–9	—	1/9	5.9–8.0

* See references, appendix A.
** Secondary standard for iron (water supply)
ND = not detected
Cfs = cubic feet per second
µg/L = micrograms per liter

Aquatic invertebrate sampling was conducted during at one location in 2006 and four locations in 2007 in the Yellowstone River Drainage. The sites included: Soda Butte Creek near Silver Gate, MT, Soda Butte Creek at Buffalo Ranch, Gardner River at Rescue Creek trail crossing, and Reese Creek.

Benthic macroinvertebrates samples were collected to evaluate the overall health of selected streams. Although results for the 2008 invertebrate samples are still being processed, results for the 2006 and 2007 samples have been analyzed and compared to the State of Montana

impairment score. State of Montana impairment scores for streams are expressed as a range from 0 to 1 (0=most impaired, 1=least impaired).

One site, Soda Butte Creek near Silver Gate, MT, was monitored for macroinvertebrates in 2006. Metric scoring for Soda Butte Creek was determined to be 0.85. When these data are compared with the suggested State of Montana impairment score, the site rates as a stream that is fully supportive of aquatic life, with no evidence of impairment.

The metric scoring for 2007 ranged from 0.52 at Reese Creek to 0.95 at Lower Soda Butte. The score for the regulatory location at Soda Butte Creek near Silver Gate, MT was 0.86. Impairment scores for the sites on Gardner River and Reese Creek indicate that the current water quality is only partially supporting of aquatic life with moderate impairment. The invertebrate sampling site on the Gardner River is located approximately 3 kilometers below the Boiling River, a thermal area that discharges approximately 25 cfs daily to the Gardner River. Flow within Reese Creek is often altered during summer months for irrigating adjacent lands outside Yellowstone. Both the thermal contribution to Gardner River and low stream flows on Reese Creek could increase water temperatures and affect aquatic communities living within the stream. Closer monitoring of the invertebrate communities on these two stream sections are needed to establish a baseline for future evaluation of stream water quality.

3.3.2 Madison River Drainage

Two locations within the Madison River Drainage did not meet state or federal standards: Firehole River near Madison Junction and Gibbon River near Madison Junction (table 7).

The Madison River Drainage in the western portion of Yellowstone is dominated by geothermal activity. As a result, water entering this drainage varies considerably in acidity and temperature. The temperature and pH values that did not meet state/federal standards observed in the Firehole River and Gibbon River, respectively, are mostly likely a result of local geology and thermal activity in this region of the park. As a result, aquatic life has evolved with these conditions and should be minimally impacted by seasonal temperature changes and subtle changes in pH. Since these conditions are naturally occurring, there will likely be no long-term, negative effect to water quality, aquatic biota, or recreational use within this portion of the park.

Table 7. 2007–2008 water quality sampling locations in the Madison River Drainage of Yellowstone where constituent concentrations did not meet applicable standards

Site	Parameter	Year	Standard*	Units	Exceedance/ # of visits	Range of values
Firehole River near Madison Junction	Water Temperature	2008	22.7	°C	1/12	5.2–24.3
Gibbon River near Madison Junction	pH (low)	2007	6.5–9	—	1/12	5.7–7.9
		2008			3/12	6.3–7.1

* See references, appendix A.

Aquatic invertebrate sampling was conducted in August of 2007 and 2008 at one location in the Madison River Drainage: Gibbon River at Madison Junction.

Benthic macroinvertebrates samples were collected to evaluate the overall health of selected streams. Although results for the 2008 invertebrate samples are still being processed, results for

the 2006 and 2007 samples have been analyzed and compared to the State of Montana impairment score (MTDEQ 2004). State of Montana impairment scores for streams are expressed as a range from 0 to 1 (0=most impaired, 1=least impaired).

Using the metric scoring criteria for Montana streams, the site on the Gibbon River scored very low in 2007 (0.17). Water quality at this site is heavily influenced by thermal areas along the lower 21 kilometers of the stream. These thermal features contribute greatly to increased water temperatures and chemical component of stream water. Additionally, the site selected on the Gibbon River is not an ideal invertebrate collection site due unstable substrate which is composed primarily of sand and fine gravel. Because of the stream's thermal areas, the Montana scoring criteria is not an appropriate use for this stream and a more appropriate index is needed.

4 Summary

Overall, waters within the GRYN are of high quality and do not indicate significant degradation, as would be expected for water bodies in national parks and preserved lands. Water quality sampling is slated to continue at the current frequency pending budgetary constraints. Members of the GRYN water quality oversight committee are working with statisticians to develop trend analyses for parameters of concern within the parks. Trend analysis is slated to be complete by 2011.

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Appendix A: Water Quality Standards

	EPA National Recommended Water Quality Criteria (2006)[a]	EPA Gold Book (1987)[b]	EPA Ambient Water Quality Criteria (2000)[c]	Montana Circular DEQ-7 (February 2008)[d]	Wyoming Department of Environmental Quality Water Quality Rules and Regulations (2007)[e]
Arsenic	Freshwater (Acute) = 340 µg/L Freshwater (Chronic) = 150 µg/L Human Health consumption of water plus organism = 0.018 µg/L Human health for consumption of organism only = 0.14 µg/L	Freshwater aquatic organisms and their uses should not be affected unacceptably if the 4-day average concentration of arsenic does not exceed 190 µg/L more than once every 3 years on the average and if the 1-hour average concentration does not exceed 360 µg/L more than once every 3 years on the average. For the maximum protection of human health from the potential carcinogenic effects due to exposure of arsenic through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at and the corresponding criteria are 0.022 µg/L, 0.0022 µg/L, and 0.00022 µg/L, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 0.175 µg/L, 0.0175 µg/L, and 0.00175 µg/L, respectively.	—	Aquatic Life Standard/Acute = 340 µg/L; Aquatic Life Standard/Chronic = 150 µg/L; Human Health surface water = 10 µg/L	Aquatic Life/Acute = 340 µg/L; Aquatic Life/Chronic = 150 µg/L; Human Health value fish and drinking water = 10 µg/L; Human Health value fish only = 10 µg/L
Alkalinity	Freshwater (Chronic) = not less than 20,000 µg/L	Freshwater aquatic life = not less than 20,000 µg/L as $CaCO_3$ except where natural concentrations are less	—	not found in any MT guidance documents	not found in any WY guidance documents

	EPA National Recommended Water Quality Criteria (2006)[a]	EPA Gold Book (1987)[b]	EPA Ambient Water Quality Criteria (2000)[c]	Montana Circular DEQ-7 (February 2008)[d]	Wyoming Department of Environmental Quality Water Quality Rules and Regulations (2007)[e]
Ammonia	Acute criteria/pH and temperature dependent; from pH 6.5–9.0, acute values for NH_3-N plus NH_4-N ranges from 885 to 32,600 µg/L for coldwater/ salmonids present and from 1,320 to 48,800 µg/L salmonids absent.	Acute criteria/pH and temperature dependent; from pH 6.5–9.0, acute values for NH_3-N plus NH_4-N ranges from 885 to 32,600 µg/L for coldwater/ salmonids present and from 1,320 to 48,800 µg/L salmonids absent.	—	Acute criteria/pH and temperature dependent; from pH 6.5–9.0, acute values for NH_3-N plus NH_4-N ranges from 885 to 32,600 µg/L for coldwater/ salmonids present and from 1,320 to 48,800 µg/L salmonids absent.	Acute criteria/pH and temperature dependent; from pH 6.5–9.0, acute values for NH_3-N plus NH_4-N ranges from 885 to 32,600 µg/L for coldwater/ salmonids present and from 1,320 to 48,800 µg/L salmonids absent.
Chloride	Freshwater (Acute) = 860,000 µg/L Freshwater (Chronic) = 230,000 µg/L	Domestic water supplies = 250,000 µg/L	—	not found in any MT guidance documents	Aquatic Life/Acute = 860,000 µg/L; Aquatic Life/Chronic = 230,000 µg/L
Copper	Freshwater (Acute) = 13 µg/L Freshwater (Chronic) = 9.0 µg/L at a $CaCO_3$ hardness of 100,000 µg/L Human health for consumption of water + organism = 1,300 µg/L	Freshwater aquatic organisms = at a hardness of 100,000 µg/L as $CaCO_3$, the 4-day average concentration is 12 µg/L and the 1-hour average concentration is 18,000 µg/L Human health = for controlling undesirable taste and odor quality of ambient water, the estimated level is 1,000 µg/L.	—	Aquatic Life Standard/Acute = 3.79 µg/L; Aquatic Life Standard/Chronic = 2.85 µg/L; at a $CaCO_3$ hardness of 25 mg/L; Human Health surface water = 1,300 µg/L	Aquatic Life/Acute = 13.4 µg/L; Aquatic Life/Chronic = 9.0 µg/L at a $CaCO_3$ hardness of 100,000 µg/L; Human Health value fish and drinking water = 1,000 µg/L

	EPA National Recommended Water Quality Criteria (2006)[a]	EPA Gold Book (1987)[b]	EPA Ambient Water Quality Criteria (2000)[c]	Montana Circular DEQ-7 (February 2008)[d]	Wyoming Department of Environmental Quality Water Quality Rules and Regulations (2007)[e]
Dissolved Oxygen	For early life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/ 1-day minimum = 8,000 µg/L; 5,000 µg/L for early life stages exposed directly to the water column For other life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/1-day minimum = 4,000 µg/L	For early life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/1-day minimum = 8,000 µg/L; 5,000 µg/L for early life stages exposed directly to the water column. For other life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/1-day minimum = 4,000 µg/L.	—	For early life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/ 1-day minimum = 8,000 µg/L; 5,000 µg/L for early life stages exposed directly to the water column; For other life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/ 1-day minimum = 4,000 µg/L	For early life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/ 1-day minimum = 8,000 µg/L; 5,000 µg/L for early life stages exposed directly to the water column; For other life stages, coldwater criteria, the water column concentration recommended to achieve inter-gravel DO concentration/ 1-day minimum = 4,000 µg/L
E. coli	Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the indicated bacterial densities should not exceed one or the other of the following:(') *E. coli* 126 per 100 mL	Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the indicated bacterial densities should not exceed one or the other of the following:(') *E. coli* 126 per 100mL	—	not applicable	In all waters designated for primary contact recreation, during the summer recreation season (May 1 through September 30), concentrations of E. coli bacteria shall not exceed a geometric mean of 126 organisms per 100 milliliters based on a minimum of not less than 5 samples obtained during separate 24-hour periods for any 30-day period

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Iron	Freshwater (Chronic) = 1000 µg/L Human health for consumption of water + organism = 300 µg/L	Freshwater aquatic life = 1,000 µg/L Domestic water supplies (welfare) = 300 µg/L	—	Aquatic Life Standard/Chronic = 1000µg/L; Human Health standard = The concentration of iron must not reach values that interfere with the uses specified in the surface and groundwater standards (17.30.601 et seq. and 17.30.1001 et seq.) The Secondary Maximum Contaminant Level of 300 micrograms per liter which is based on aesthetic properties such as taste, odor, and staining may be considered as guidance to determine the levels that will interfere with the specified uses.	Aquatic Life/Chronic = 1,000 µg/L; Human Health value fish plus drinking water = 300 µg/L
Nitrate as N	Human health consumption of water + organism = 10,000 µg/L	Domestic water supplies = 10,000 µg/L	—	Human health standard/Surface water = 10,000 µg/L	Human health value/fish and drinking water = 10,000 µg/L
Nitrite as N	not found	not found	—	Human health standard/Surface water = 1,000 µg/L	human health value/fish and drinking water = 1,000 µg/L
Nitrite + Nitrate	not found	Domestic water supplies = 10,000 µg/L	60 µg/L*	Human health standard/Surface water = 10,000 µg/L	Human health value/fish and drinking water = 10,000 µg/L
pH	Freshwater = 6.5–9.0	Freshwater Aquatic Life = 6.5–9.0	—	Induced variation of hydrogen ion concentration (pH) within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH maintained without change. Natural pH above 7.0 must be maintained above 7.0 (from 17-30-6 MTDEQ)	Aquatic Life Chronic value = 6.5 - 9.0
Phosphorus	no standard	no standard	10,000 µg/L[f]	not found in any MT guidance documents	not found in any WY guidance documents
Ortho-phosphate	no standard	no standard	—	not found in any MT guidance documents	not found in any WY guidance documents
Selenium	Freshwater (Chronic) = 5.0 µg/L	Freshwater Aquatic life/acute = 260 µg/L	—	Aquatic Life standard/Acute = 20 µg/L; Aquatic Life Standard/Chronic = 5 µg/L	Aquatic Life/Acute = 20 µg/L; Aquatic Life/Chronic = 5 µg/L
Specific Conductance	no standard	no standard	—	not found in any MT guidance documents	not found in any WY guidance documents

	EPA National Recommended Water Quality Criteria (2006)[a]	EPA Gold Book (1987)[b]	EPA Ambient Water Quality Criteria (2000)[c]	Montana Circular DEQ-7 (February 2008)[d]	Wyoming Department of Environmental Quality Water Quality Rules and Regulations (2007)[e]
Sulfate	no standard	no standard	—	not found in any MT guidance documents	not found in any WY guidance documents
Total Suspended Solids	—	Freshwater fish and other aquatic life: settle-able and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life	—	No increases are allowed above naturally occurring concentrations of sediment or suspended sediment which will or are likely to create a nuisance or render the waters harmful, detrimental or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish or other wildlife	In all Wyoming surface waters, floating and suspended solids attributable to or influenced by the activities of man shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife.
Turbidity	—	Freshwater fish and other aquatic life: settle-able and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life	0.5 NTU (based on less than 4 streams to calculate 25th percentile)*	No increase above naturally occurring turbidity or suspended sediment is allowed (A-1); no increase above naturally occurring greater than 5 NTUs (B-1)	In all cold water fisheries and drinking water supplies (classes 1, 2AB, 2A, and 2B) the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than ten (10) NTUs

	EPA National Recommended Water Quality Criteria (2006)[a]	EPA Gold Book (1987)[b]	EPA Ambient Water Quality Criteria (2000)[c]	Montana Circular DEQ-7 (February 2008)[d]	Wyoming Department of Environmental Quality Water Quality Rules and Regulations (2007)[e]
Water Temperature	species specific	species specific	—	A-1: A 1ºF maximum increase above naturally occurring water temperature is allowed within the range of 32ºF to 66ºF; within the naturally occurring range of 66ºF to 66.5ºF, no discharge is allowed which will cause the water temperature to exceed 67ºF; and where the naturally occurring water temperature is 66.5ºF or greater, the maximum allowable increase in water temperature is 0.5ºF. A 2ºF-per-hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55ºF. A 2ºF maximum decrease below naturally occurring water temperature is allowed within the range of 55ºF to 32ºF; B-1: A 1ºF maximum increase above naturally occurring water temperature is allowed within the range of 32ºF to 66ºF; within the naturally occurring range of 66ºF to 66.5ºF, no discharge is allowed which will cause the water temperature to exceed 67ºF; and where the naturally occurring water temperature is 66.5ºF or greater, the maximum allowable increase in water temperature is 0.5ºF. A 2ºF per-hour maximum decrease below naturally occurring water temperature is allowed when the water temperature is above 55ºF. A 2ºF maximum decrease below naturally occurring water temperature is allowed within the range of 55ºF to 32ºF	the maximum allowable stream temperature will be the maximum natural daily stream temperature plus the allowable change, provided that this temperature is not lethal to existing fish life and under no circumstance shall this maximum temperature exceed 68ºF (20ºC) in the case of cold water fisheries and 86ºF (30ºC) in the case of warm water fisheries

Note: DO = dissolved oxygen

[a]*Source*: U.S. Environmental Protection Agency (EPA). 2006. National recommended water quality criteria. U.S. EPA, Office of Water, Washington, D.C.

[b]*Source*: U.S. Environmental Protection Agency. 1987. Quality criteria for water 1986 [The Gold Book]. Report nr EPA 440/5-86-001. U.S. EPA, Office of Water Regulations and Standards, Washington, D.C.

[c]*Source*: U.S. EPA. 2000. Ambient water quality criteria recommendations: Information supporting the development of state and tribal nutrient criteria for rivers and streams in nutrient ecoregion III. EPA 822-B-00-015. U.S. EPA, Office of Water, Washington, D.C.

[d]*Source*: Montana Department of Environmental Quality (DEQ). 2008. Montana numeric water quality standards. Circular DEQ-7. Montana DEQ, Planning, Prevention, and Assistance Division, Helena, Montana.

[e]*Source*: Wyoming Department of Environmental Quality. 2007. Water quality rules and regulations. Chapter 1 *in* Water Quality Division rules and regulations. Online. (http://deq.state.wy.us/wqd/wqdrules/). April 25, 2007, (variously paged). Accessed 12 March 12 2009.

*Reference conditions for level III ecoregion 17; 25th Percentiles based on all seasons data for the Decade