National Park Service
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Natural Resource Program Center

Water Quality in the Northern Colorado Plateau Network, 2006–2009

Natural Resource Technical Report NPS/NCPN/NRTR—2010/358

ON THE COVER

Water quality sites monitored during the period covered in this report. From upper left: Halls Creek Narrows. Capitol Reef National Park; Sheep Creek drainage, Bryce Canyon National Park; Pleasant Creek, Capitol Reef National Park; La Verkin Creek, Zion National Park. NPS photos.

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Abstract

Water quality monitoring in National Park Service units of the Northern Colorado Plateau Network (NCPN) is made possible through partnerships between the National Park Service Inventory & Monitoring Program, individual park units, the U.S. Geological Survey, and the State of Utah's Division of Water Quality. This report evaluates data from 1,267 site visits made at 76 different locations on NCPN streams and rivers in or near 12 NCPN park units between January 1, 2006 and December 31, 2009. Evaluation of water quality parameters relative to state water quality standards indicated that 24,878 (97.7%) of the 25,462 total designated beneficial-use evaluations completed for the period covered in this report did not exceed state water quality standards (Figure A).

While some exceedances were reoccurring and may have been caused by human activities in the watersheds, many were due to naturally occurring conditions characteristic of the geographic setting. The most common exceedances or indications of impairment, in order of abundance, were due to elevated nutrients, elevated trace metals, elevated bacteria (*E. coli*), low dissolved oxygen, elevated pH, elevated total dissolved solids, and elevated temperature (Figure B).

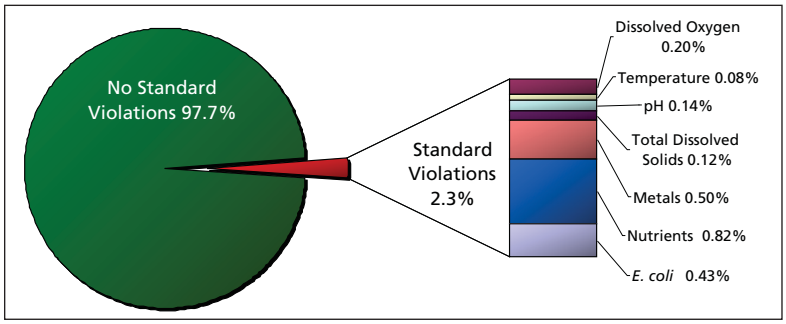

Figure A. Percentage of use evaluations that exceeded standards, and the causes of exceedances at selected sites sampled in NCPN park units, 2006–2009.

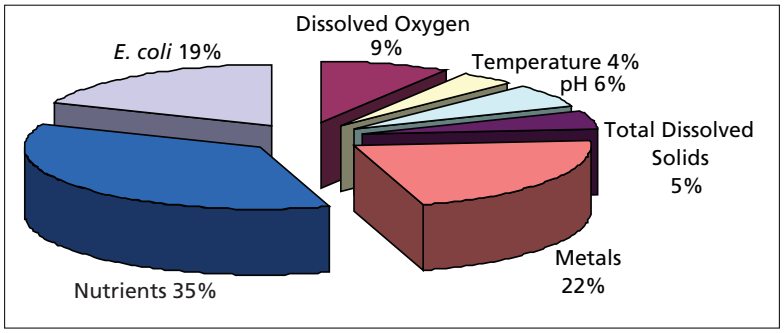

Figure B. Most commonly exceeded water quality standards in NCPN park units, 2006–2009.

Milestones

Also during 2006–2009:

- NCPN water quality data was transitioned from an internal Microsoft Access database to the National Park Service-hosted NPSTORET database.
- The National Park Service entered into a Memorandum of Understanding (MOU) for implementation of the Nonpoint Source Water Quality Program in the State of Utah (see Appendix B).
- The Utah Division of Water Quality placed the North Fork Virgin River on the 303(d) list of impaired water bodies as a result of persistent summertime *E. coli* contamination (see Appendix E).
- The Utah Division of Water Quality re-designated the beneficial-use classification of the North Fork Virgin River from secondary-contact recreation (2B) to primary-contact recreation (2A).

Acronyms, Abbreviations, and Codes

General acronyms and abbreviations

303(d)	Section 303(d) of Clean Water Act, requiring a reporting of waters not meeting criteria
AB	above
BL	below
BLCA	Black Canyon of the Gunnison National Park
BLM-WSA	Bureau of Land Management Wilderness Study Area
BNDRY	boundary
CARE	Capitol Reef National Park
cfs	cubic feet per second
cfu	
ck	creek
CNFL	confluence
CNTY	county
CO	Colorado
CR	county road
CURE	Curecanti National Recreation Area
CWA	Clean Water Act
DO	dissolved oxygen
E. coli	*Escherichia coli* bacteria
EPA	U.S. Environmental Protection Agency
fk	fork
GPRA	Government Performance and Results Act
HWY	highway
mg/L	milligrams per liter
MPN	most probable number
NFVR	North Fork Virgin River
NHS	national historic site
NPS	National Park Service
NCPN	Northern Colorado Plateau Network
NDVI	Normalized Difference Vegetation Index
NM	national monument
NP	national park
NR	near
NRA	national recreation area
NWQL	National Water Quality Laboratory
ONRW	Outstanding Natural Resource Waters
OHV	off-highway vehicle
SEUG	Southeast Utah Group (includes ARCH, CANY, HOVE, and NABR)
SOP	standard operating procedure
TDS	total dissolved solids
TICA	Timpanogos Cave National Monument
TMDL	total maximum daily loading
TP	total phosphorus
µg/L	micrograms per liter
U12	Utah Highway 12
U24	Utah Highway 24
UT	Utah
UDWQ	Utah Division of Water Quality
UDEQ	Utah Department of Environmental Quality
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WRD	National Park Service Water Resources Division
XING	crossing

Designated Use Codes

AC	Acute
CH	Chronic

Colorado Water Quality Use Codes

DWS	Drinking water
RECE	Existing primary-contact recreation
RECU	Undetermined use recreation
ALC1	Aquatic Life Cold Water Class 1
ALC2	Aquatic Life Cold Water Class 2
ALW1	Aquatic Life Warm Water Class 1
ALW2	Aquatic Life Warm Water Class 2
AG	Agriculture

Utah Water Quality Use Codes

1C	Drinking water
2A	Primary-contact recreation
2B	Secondary-contact recreation
3A	Cold water game fish
3B	Warm water game fish
3C	Non-game fish

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1 Introduction

1.1 Background

The National Park Service's Natural Resource Inventory & Monitoring Program is designed to provide park managers with information they need to perform science-based management of natural resources. Under the program, 32 networks of parks in geographic proximity and with similar ecological processes were organized to support the development of integrated park natural resource inventory and monitoring programs. The program is structured around the inventory and monitoring of park "vital signs"—chemical, biological, and physical factors that determine the health of park ecosystems.

Servicewide goals for vital-signs monitoring include the following:

1. Determine status and trends in selected indicators of the condition of park ecosystems, in order to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources;
2. Provide early warning of abnormal conditions of selected resources to help managers develop effective mitigation measures and reduce costs of management;
3. Provide data that will help managers to better understand the dynamic nature and condition of park ecosystems, and provide reference points for comparisons with other altered environments;
4. Provide data that will help managers to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment; and
5. Provide a means of measuring progress toward performance goals.

The Northern Colorado Plateau Network (NCPN) consists of 16 park units in Utah, Colorado, Arizona, and Wyoming (Figure 1-1). Through comprehensive scoping processes, water quality and quantity were identified as vital signs that should be monitored (O'Dell et al. 2005). The water-dependent ecosystems in these unique landscapes are protected by the National Park Service (NPS) Organic Act, *NPS Management Policies*, and the Clean Water Act (CWA).

Under authority of the U.S. Environmental Protection Agency (EPA), U.S. states have developed a regulatory system under the CWA that provides for specific concentrations or measures for water quality constituents that protect a class of uses. The protected uses vary by state, but generally include irrigated agriculture, domestic water supply, cold-water aquatic life, warm-water aquatic life, water-based recreation, and livestock watering.

1.2 Program justification

In order to mitigate past and future threats to park water resources, managers need objective information on status and trends in surface-water quality and quantity.

Section 4.3.6 of *NPS Management Policies* sets forth expectations for park managers regarding water resources (NPS 2006):

> The pollution of surface waters and groundwaters by both point and nonpoint sources can impair the natural functioning of aquatic and terrestrial ecosystems and diminish the utility of park waters for visitor use and enjoyment. The Service will determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside the parks. The Service will
>
> a) work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for the protection for park waters;
>
> b) take all necessary actions to maintain or restore the quality of surface waters and groundwaters within the parks consistent with the Clean Water Act and all other applicable Federal, State, and local laws and regulations; and
>
> c) enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

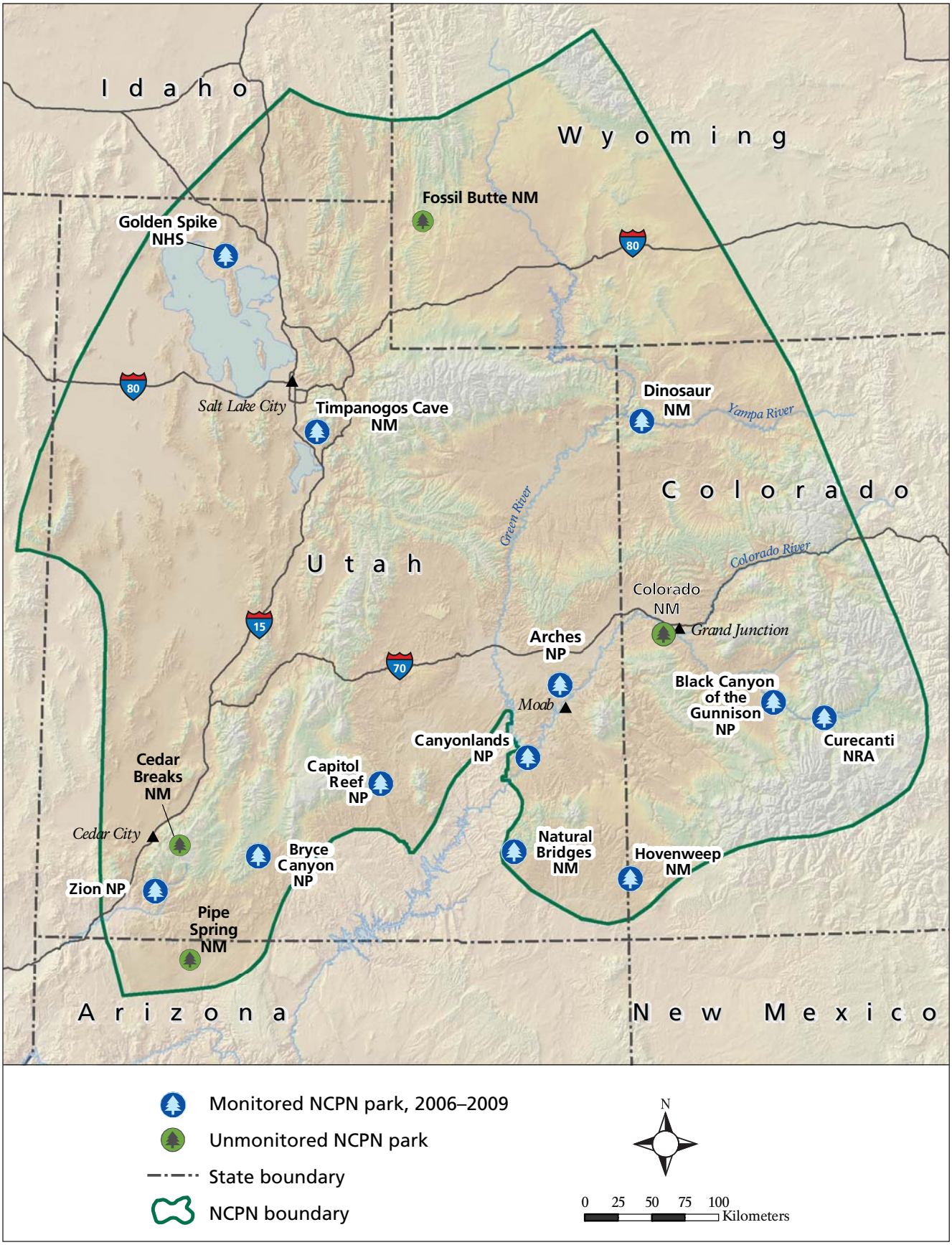


Figure 1-1. Northern Colorado Plateau Network parks and park units monitored, 2006–2009.

1.3 Long-term monitoring objectives

Measurable objectives of this long-term monitoring program focus on status and trends in water quality parameters, and include the following:

a) Establish range and variability of water quality parameters under base flow conditions as they vary with seasonal and climatic conditions using descriptive statistics.

b) Determine status and trends in selected water quality parameters as a function of flow, season, and climatic conditions, using trend-analysis techniques.

c) Compare water quality data against state criteria for acute and chronic exceedance on a monthly basis.

d) Analyze long-term data for designation as Outstanding Natural Resource Waters (ONRW).

e) Determine point and nonpoint sources of pollution within watersheds via association with ancillary data or knowledge of land-management practices or activities in the watersheds.

1.4 Management outcomes

The knowledge gained by achieving the measurable objectives of this monitoring will be used to evaluate and report on the condition of water bodies in NCPN park units. Additionally, it can be used to inform park managers about water resources in order to:

a) Maintain waters that vary within their natural chemical and biological ranges and meet applicable federal and state water quality criteria.

   Justification: Waters that vary within their natural ranges can typically support healthy aquatic ecosystems and most beneficial uses.

b) Improve water quality of impaired waters.

   Justification: The NPS GPRA goal is that 99.3% of streams and rivers managed by the NPS will meet state and federal water quality standards.

c) Demonstrate and maintain high water quality where it exists.

   Justification: The antidegradation provision of the Clean Water Act specifies that high-quality waters will be maintained (USEPA 2006; Section 303).

1.5 Report scope and objectives

This is the second report on activities and results of the NCPN water quality monitoring program. It focuses on sites monitored by NCPN staff and by cooperating hydrologists and agencies working in and near NCPN parks. Although long-term data records exist for some of these sites, the period considered in this report is from January 1, 2006 through the most current available record for each site in the NCPN water quality database as of December 31, 2009.

Not all site data collected during the period covered in this report were available for analysis. Certain monitoring sites, initiated by the NCPN and its partners since 2008, were not available for analysis as of December 31, 2009. For other sites, historic data are available but current data have not been updated into a national data repository, such as EPA STORET, since 2008. Therefore, even though a site may be currently monitored by the NCPN, or was monitored more recently than is indicated in this report, monitoring results may not have been available at the time of writing. Those data will be included in the next annual report.

The objectives of this report are to:

a) evaluate exceedances of water quality standards,

b) provide descriptive statistics for water quality data,

c) identify and characterize potential sources of water quality contamination, and

d) provide resource managers with pertinent information about these data.

2 Methods

2.1 Target population

The target population for NCPN water quality monitoring is a subset of potential daytime water quality measurements in perennial streams and rivers, selected through a judgmental or targeted process involving the participation of park resource managers, NCPN staff, U.S. Geological Survey (USGS) staff, and other water quality specialists (O'Dell et al. 2005; Thoma et al. 2007).

Specific water sources were selected based on the following hierarchy:

a) **303(d)-listed waters,** where previous sampling indicated that one or more parameters regularly approached or exceeded criteria or recommended levels.

b) **Waters with demonstrated threat levels,** where an analysis of available data indicated that measured conditions regularly approached or exceeded criteria or recommended levels, but where the frequency of exceedance or the quality of the data did not support a 303(d) listing.

c) **Data gaps:** Waters identified as important, but where little or no water quality information existed.

d) **Waters of management concern,** where past sampling may not have indicated constituent values of concern, but where anthropogenic activities indicated that contamination was a significant threat.

e) **Other perennial waters** with no specific threat.

Perennial waters were preferentially selected over ephemeral or seasonal water sources because they support year-round ecological process and function and have established criteria that allow monitoring for CWA compliance. Seventy-six sites in or near 12 NCPN units were sampled between January 1, 2006 and December 31, 2009 (see Appendix A).

2.2 Laboratory and field methods

Approximately 30 parameters were measured for each site visit. The core parameters, or those measured in the field, included dissolved oxygen, pH, temperature, conductivity, and flow. Other parameters measured in the laboratory from samples collected in the field fell into general categories, including metals, nutrients, total dissolved solids, and bacteria.

Field methods used to collect data for this report are outlined in the NCPN Standard Operating Procedures (SOPs) for Water Quality (Thoma et al. 2007). Specifically, SOPs 3–11 outline the techniques for measurement of core parameters and sample collection and handling in the field.

Laboratory analytical methods are discussed in detail in SOPs 11–13 (Thoma et al. 2007). The NCPN ensures comparability of the laboratory data created by this monitoring program by using the USGS National Water Quality Laboratory (NWQL) methods for Colorado parks (SOP 12), and the EPA standard methods, or methods outlined in Standard Methods for Analysis of Water and Wastewater, for Utah parks (APHA, 1998; SOP 13). Details of the quality-control process for NWQL and the Utah Public Health Laboratory are provided in SOP 7, Appendices A and B (Thoma et al. 2007).

2.3 Partnerships

The NCPN water quality monitoring program is a collaborative venture between the NCPN, Black Canyon of the Gunnison National Park (BLCA), Curecanti National Recreation Area (CURE), the Southeast Utah Group (SEUG), Timpanogos Cave National Monument (TICA), the USGS, and the Utah Division of Water Quality (UDWQ). NCPN, TICA, and SEUG staff conducts field work and delivers samples to the Utah Public Health Laboratory according to a partnership agreement between the NPS and the UDWQ. BLCA and CURE conduct field work and have laboratory analysis conducted at the NWQL, in Lakewood, Colorado, via agreements with the USGS. Dinosaur National Monument sites are visited by USGS staff, who deliver samples to the NWQL for laboratory analysis. Other nearby sites (outside park boundaries) that are routinely monitored by the states of Colorado and Utah are also considered. Regardless of which entity performed the field work or laboratory analysis, the data were stewarded through the NPSTORET database, which was used for this analysis.

2.4 Understanding water quality data and standards

The sampling methodology used in the NCPN water quality monitoring program has implications in data interpretation for management. Monthly grab samples represent conditions at the point and time of sampling; they do not represent the condition of the entire water body, spatially or temporally. Samples are routinely collected several times per year in order to build a database that represents the range of conditions that occur, with a focus on base flow conditions. Thus, rare and short-term events are often not captured.

This report contains terminology that may not be readily understood by non-specialists. For clarification purposes, various terms and concepts that may cause confusion will be defined here. A water quality standard refers to an individual parameter and its associated beneficial-use designation, in conjunction with a criterion, which is the numeric component against which a result is compared. For example, the standard for chronic selenium (parameter) for cold-water game fish (beneficial-use designation) is 4.6 µg/L (numeric criterion).

One site visit yields approximately 30 water quality parameter measurements or results. Each result is then evaluated against a water quality standard; this is referred to as a use evaluation in this report. Each beneficial-use designation may contain distinct criteria for one parameter, and each site may contain up to four distinct beneficial-use designations. Therefore, one parameter measurement from one site visit may result in multiple use evaluations.

Over the course of the study period, one site may have a different number of results for each parameter. For example, the NCPN may have visited one monitoring site 24 times during the period covered in this report; however, not all parameters may have been measured during each site visit. This is especially true for metals results. Laboratory analysis for metal concentrations is typically performed quarterly, whereas other parameters, such as nutrients and dissolved oxygen, are determined for each site visit.

2.4.1 Chronic and acute standards

For a single parameter, numeric criteria for water quality standards address potential effects of both chronic exposure over an extended period of time (months) and acute exposure over a short period of time (hours or days). Permitted levels are much lower for chronic exposure than for acute exposure. Criteria for chronic exposure are not directly comparable to the results obtained from a one-time monthly grab sample. From a compliance standpoint, the acute instantaneous criteria afford the only direct comparison for such data. However, from a resource-conservation standpoint, instantaneous grab-sample data, when compared against more stringent chronic criteria, can provide a means of early warning and an indication of a problem that may require more attention.

For these reasons, parameter results were compared against the chronic standards to create the graphical and tabular data included in this report. Each exceedance was then re-evaluated against the less-stringent acute criteria. If a chronic exceedance also exceeded the acute standard, then documentation was provided in the results section for that individual site.

2.4.2 Phosphorus as an indication of impairment

The State of Utah does not have a water quality standard for total phosphorus (Tom Toole, pers. comm. 12/20/07). Rather, the value of 0.05 mg/L is used as an indication of impairment meant to be considered with other parameters, such as dissolved oxygen. If low dissolved oxygen concentrations were observed commensurate with elevated total phosphorus concentrations (above 0.05 mg/L), the collective results might then indicate an impairment due to eutrophication. Corroborating evidence may include other chemical parameters associated with eutrophication—such as elevated nutrient concentrations or low dissolved oxygen concentrations—and bioassessments.

2.4.3 Rules for applying standards

When criteria for a parameter differ by designated beneficial use, or within a use class by aquatic-life stage, the more stringent standard is used as the basis for comparison in this report. Results that exceeded the more stringent standard (chronic standard) were then compared against the less stringent standard (acute standard). The goal is to provide advance warning of an impending problem before it becomes severe.

2.4.4 Frequency of exceedances for reporting

This report presents beneficial-use evaluation exceedances only if they occur for more than 10% of results. This approach minimizes reporting of short-duration changes in water chemistry that may result from natural variability associated with weather events and may not be of management concern. It also follows the assessment guidelines used by the UDWQ in preparing the list of impaired water bodies.

Summary statistics displayed at the beginning of each results section refer to the number of use evaluations performed for all sites in or near that NPS unit. The term "evaluation" is used throughout this report in connection with exceedance analyses. Thus, tables and results sections for individual sites refer to "evaluations" instead of "site visits." The total number of evaluations is synonymous with the total number of site visits when an individual parameter is compared against an individual beneficial-use designation at one monitoring site.

2.4.5 Regulatory authority

The National Park Service does not have regulatory authority over waters in U.S., or even the authority to make assessments for designated beneficial use. For that reason, this report compares water quality data to designated beneficial-use criteria without stating whether a designated beneficial use was attained. Those designations are left to the states, in their triennial 305(b) reports to Congress. However, the NPS participates with states in collecting data used in the protection of water bodies under state jurisdiction. The roles and responsibilities of different government entities in nonpoint source pollution monitoring are described in the MOU between the NPS and the UDWQ in Appendix B. Definitions of water quality standards according to the states of Utah and Colorado are found in Appendices C and D, respectively.

2.5 Site-specific standards and triennial reviews

A triennial review process allows stakeholders to provide feedback about water quality standards, criteria, and designated beneficial uses. Through this process, the regulatory agencies may re-classify a water body's designated use or set standards appropriate for the use. This process is especially relevant where uses were not assigned, due either to a lack of use data or a situation in which natural conditions preclude a water body from meeting its designated beneficial use. For instance, a use-attainability analysis may indicate that a water body cannot achieve its beneficial designated use due to naturally elevated parameter concentrations that have been observed in that stream or stream segment. If the historical data record is not long enough or reasonable supporting evidence does not exist, then the state may choose not to change a water quality standard, or reclassify a designated use during the triennial review, but may provide guidance on how to further investigate the particular issue.

Some NCPN water quality monitoring sites may be suitable candidates for a use-attainability analysis and site-specific criteria, due to naturally elevated total phosphorus or total dissolved solids concentrations that may be derived from soil and bedrock weathering. If commensurate measurements, such as dissolved oxygen or nitrogen concentrations at a site, do not indicate that elevated total phosphorus concentrations are causing eutrophication of the water body, then the water body may be considered for a different use classification or a water-body specific standard.

Results displayed in this report highlight and characterize such scenarios, but do not necessarily contain the breadth of supporting documentation required for submission to the triennial review process. Completion of a long-term trend-analysis report will significantly improve the NCPN's ability to determine which candidate sites and associated water quality standards merit inclusion in a use-attainment assessment.

3 Results, Discussion, and Management Implications

3.1 Arches National Park

3.1.1 Water quality summary

A total of 2,627 designated beneficial-use evaluations were completed for water quality results obtained between January 18, 2006 and November 17, 2009, at eight sites in or near Arches National Park (NP). Of those 2,627 evaluations, 49 (1.9%) exceeded water quality standards or indications of impairment (Figure 3-1). Standards were exceeded for six constituent categories, most commonly total dissolved solids, nutrients, and dissolved oxygen (Figure 3-2).

3.1.2 Reportable exceedances

The Colorado River near Cisco, Utah, was the only one of eight sites monitored in or near Arches NP that did not exceed water quality standards or indications of impairment, based upon 486 total evaluations. Seven of eight sites sampled had exceedances of water quality standards for the states of Utah or Colorado (Table 3-1, Figure 3-3). The following discussion focuses only on sites that had exceedances.

1. ***Colorado River near Colorado–Utah State Line.*** This site is located in the state of Colorado, and is thus subject to Colorado state water quality standards. Selenium concentrations exceeded the chronic cold-water biota (class 1) standard for 14% of evaluations.

2. ***Freshwater Spring.*** Dissolved oxygen concentrations at Freshwater Spring were below the warm-water game fish standard for 67% of evaluations.

3. ***Salt Wash at Wolfe Ranch.*** This site had exceedances for dissolved oxygen, total dissolved solids, and selenium for 11%, 95%,

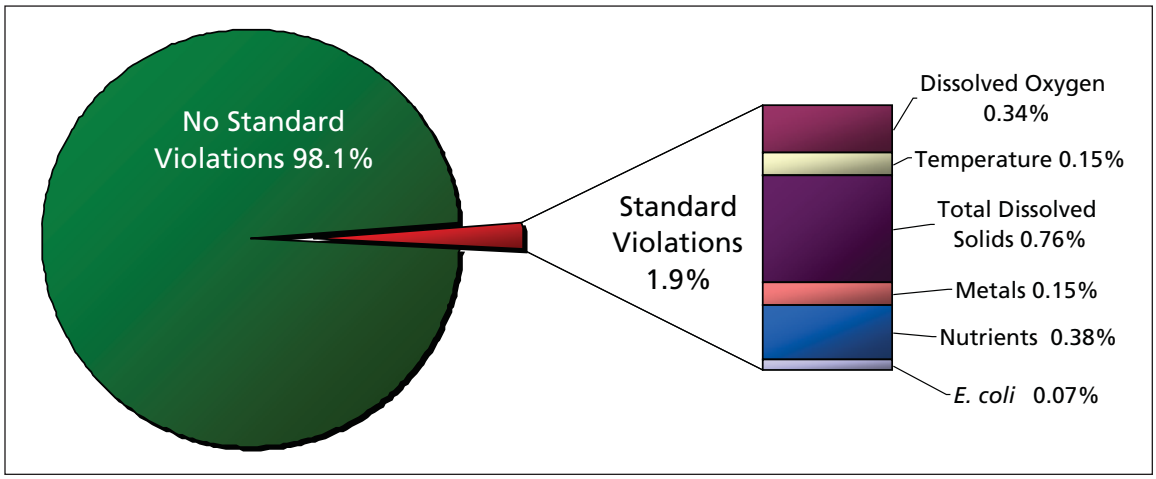


Figure 3-1. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Arches NP, 2006–2009.

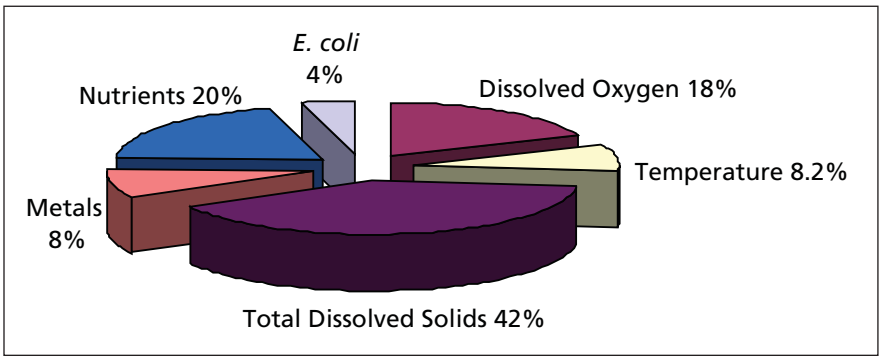


Figure 3-2. Most commonly exceeded water quality standards at Arches NP, 2006–2009.

Table 3-1. Exceedances of surface water quality standards for sites sampled in or near Arches NP, 2006–2009.

Site		Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
1	Colorado River near Colorado–Utah State Line	ALC1	Selenium, Dissolved	4.6	µg/L	22	14
2	Freshwater Spring	3B	Dissolved oxygen	5.5	mg/L	3	67
3	Salt Wash at Wolfe Ranch	3B	Dissolved oxygen	5.5	mg/L	19	11
		3B	Selenium, Dissolved	4.6	µg/L	8	13
		4	Total dissolved solids	1,200	mg/L	20	95
4	Lower Courthouse Wash	2B, 3B	Phosphorus, Total	0.05	mg/L	21	19
5	Sleepy Hollow Spring	3B	Dissolved oxygen	5.5	mg/L	2	100
6	Willow Spring	3B	Dissolved oxygen	5.5	mg/L	3	100
7	Dolores River near Cisco, UT	4	Total dissolved solids	1,200	mg/L	6	17

Use codes: ALC1 = aquatic life cold-water class 1 (CO standard); 2B = secondary-contact recreation; 3B = warm-water game fish; 4 = agricultural uses

and 13% of evaluations, respectively. Dissolved oxygen and selenium exceeded the chronic standards for warm-water game fish, and total dissolved solids exceeded the standard for agricultural uses.

4. ***Lower Courthouse Wash.*** Near its confluence with the Colorado River, Courthouse Wash had exceedances for total phosphorus for 19% of evaluations. Total phosphorus exceeded the indication of impairment criteria for secondary-contact recreation and early life stages of warm-water game fish.

5. ***Sleepy Hollow Spring.*** Only two samples from Sleepy Hollow Spring were available for analysis during the monitoring period. Dissolved oxygen concentrations failed to meet the standard for warm-water game fish in both of those samples.

6. ***Willow Spring.*** Only three samples from Willow Spring were available for analysis during the monitoring period. Dissolved oxygen concentrations were below the standard for warm-water game fish in all of those samples.

7. ***Dolores River near Cisco, Utah.*** This site exceeded total dissolved solids standards for 17% of evaluations. The total dissolved solids exceeded the standard for agricultural uses.

3.1.3 Discussion

3.1.3.1 Total dissolved solids

The total dissolved solids (TDS) concentrations at Salt Wash at Wolfe Ranch likely have a geologic origin, as there are few human activities near Salt Wash that could contribute to such high TDS levels. Elevated TDS concentrations in surface water and groundwater are not uncommon in the Moab area, and result from the underground weathering of the near sub-surface salt dome (Baars and Doelling 1987; Chaffin 2002). Mineral-rich clay and shale deposits of the Morrison and Mancos formations exposed near the sample site may also contribute TDS to Salt Wash during overland flow events. These results are consistent with 10 years of sampling in Arches NP, as described by Schelz and Moran (2004). Sources of elevated TDS concentrations in the Dolores River near Cisco, Utah, may be derived from the weathering of the Mancos Shale deposit or possibly from agricultural return flow. TDS levels from the Dolores River were not great enough to cause TDS exceedances at the Colorado River near Cisco, Utah, site, which is downstream from the confluence.

3.1.3.2 Dissolved oxygen

Low dissolved oxygen concentrations that exceed the warm-water game fish standard are likely

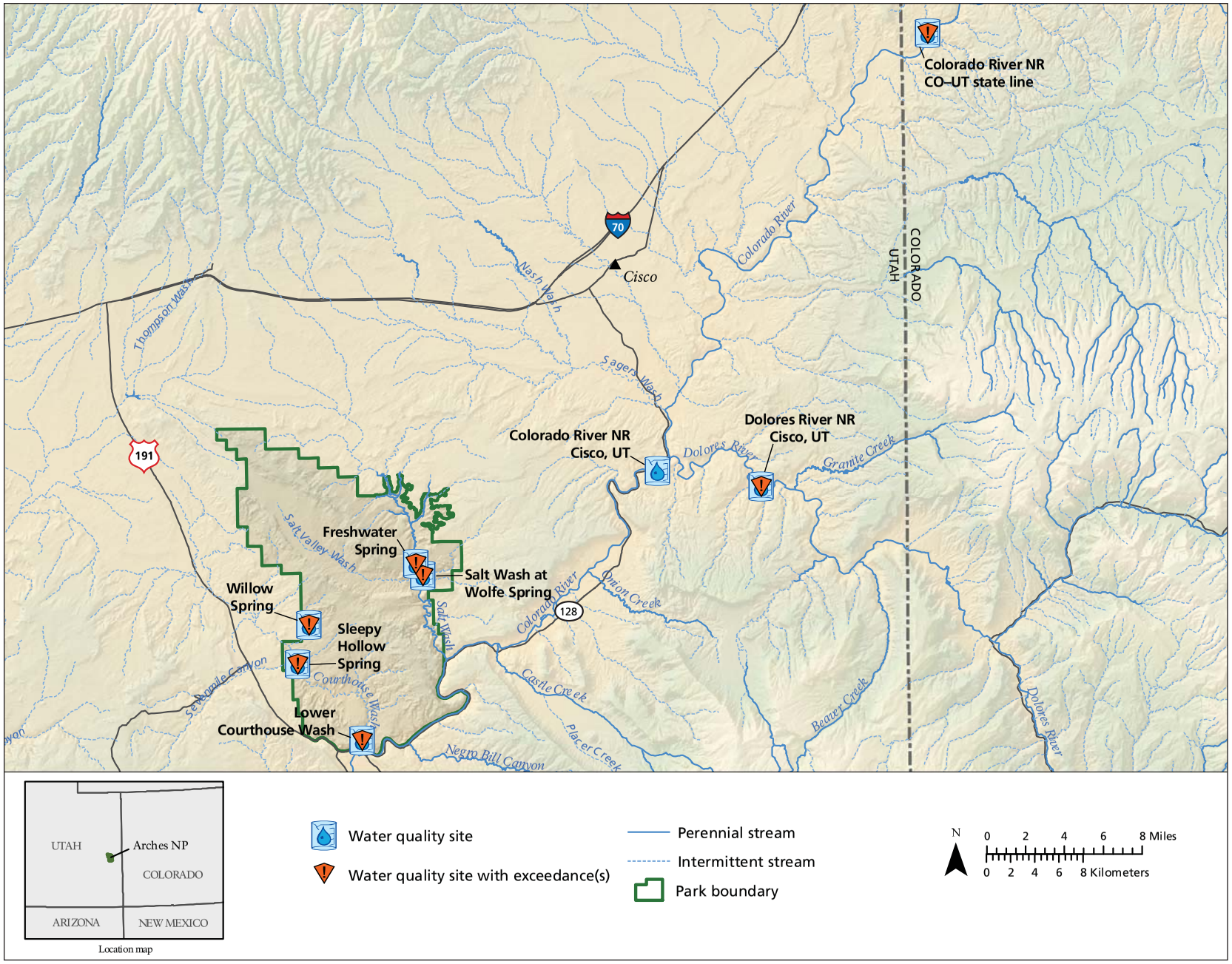


Figure 3-3. Water quality sites sampled in or near Arches NP, 2006–2009.

the result of two factors: hydrologic setting and summertime low-flow conditions. Exceedances at Freshwater Spring, Sleepy Hollow Spring, and Willow Spring were likely hydrologic in origin. At these sites, discharge of oxygen-depleted groundwater is a natural phenomenon, and indicates that the water has been underground long enough for complete or significant biological consumption of dissolved oxygen to have occurred. At Salt Wash at Wolfe Ranch and Willow Spring, the potential existence of stagnant or semi-stagnant pools caused by summer low-flow conditions can cause depleted oxygen concentrations. In these pools, a lack of shade may increase temperature, decreasing oxygen solubility. In concert with high temperatures, the decomposition of organic matter, which is an oxygen-consuming biological activity, can further deplete oxygen concentrations.

3.1.3.3 Nutrients

In Lower Courthouse Wash, total phosphorus levels above the indication of impairment do not appear to be causing eutrophication and, therefore, do not warrant concern. Commensurate dissolved oxygen concentrations were consistently within water quality standards during the daytime sampling events evaluated in this report. Also, observations of elevated total phosphorus levels occurred primarily during turbid conditions, indicating that their source is likely derived from overland flow.

Natural sources of phosphorus likely occur within the Courthouse Wash watershed. However, accelerated weathering from grazing and off-highway vehicle (OHV) use upstream from the park boundary may contribute to the observed total phosphorus levels. Occasional cattle and OHV trespass have occurred within the park boundary; however, these trespass instances occurred at the Upper Courthouse Wash boundary, approximately 10–15 miles upstream from the Lower Courthouse Wash site.

Because commensurate measurements did not indicate impairment, and the elevated concentrations were associated with periodic runoff events, total phosphorus concentrations do not appear to be degrading overall water quality. However, elevated total phosphorus concentrations have been routinely observed in the past, and cattle grazing and OHV recreation are known to occur within the watershed and occasionally within the park boundary.

3.1.3.4 Metals

The source of elevated selenium concentrations in the Upper Colorado River basin has been well documented (Tuttle 2009; BLM-USGS 2010). Spatially extensive deposits of Mancos Shale exist in the Book Cliffs range of eastern Utah and western Colorado, directly adjacent to the Colorado River near the Utah–Colorado state line site (Figure 3-4). This layer was deposited in a shallow sea environment during the Cretaceous period, and contains an abundance of salt (NaCl), as well as evaporite (gypsum, $CaSO_4$) and iron sulfide (pyrite) minerals. The pyrite found in this deposit contains an unusually large selenium component in the form of lead selenide (PbSe). Once exposed to the atmosphere, oxidative processes readily convert the reduced form of selenium to selenate. Additionally, dissolution processes produce sulfate salts ($NaSO_4$) when the sodium from the salt is exchanged with the calcium from gypsum. Once formed, the selenate quickly associates with the $NaSO_4$, and is carried into the Colorado River through surface water recharge. Although the source and process of selenium erosion is natural, these conditions can become anthropogenically accelerated due to land management practices, such as OHV recreation, grazing, and irrigation (USGS-BLM 2010).

One of eight samples collected from Salt Wash at Wolfe Ranch exceeded the selenium standard for warm-water game fish. Mancos Shale is exposed in Salt Valley near the sample site in Arches NP (Baars and Doelling 1987), and is also exposed in the upper reaches of Salt Wash approximately 15 miles upstream from the sample site. Mineral-rich clays found in the Morrison Formation near the sample site may contribute selenium to Salt Wash during overland flow events. However, selenium concentrations in the Morrison Formation are not well documented. It is likely that the observed selenium levels in Salt Wash are natural in origin, and do not warrant much concern, because observations of elevated levels were infrequent.

3.1.4 Management implications

Many of the water quality exceedances in Arches NP were likely due to naturally occurring conditions, and resulted from the application of use designations that were intended to protect the Colorado River and its tributaries. Because all monitoring sites in Arches NP are low-flow, inter-

mittent, or ephemeral tributaries to the Colorado River, the applicable use designations, specifically 3B (warm-water game fish), do not necessarily account for their biogeochemical nature.

Additionally, the presence of salt-bearing geologic layers near the surface results in conditions that may be cause for exemption or re-classification of the total dissolved solids standard for Salt Wash. In fact, the UDWQ is reviewing water bodies across the state that may need to be re-classified as a result of natural conditions, such as salt-bearing geologic layers, that cause elevated TDS concentrations.

Most of the monitoring sites in Arches NP are candidates for use-attainability assessments because of their geologic setting. The geologic conditions of small springs with large groundwater components, and predominantly intermittent streams that may episodically contribute naturally elevated constituent loads, distinguish them from other perennial tributaries to the Colorado River.

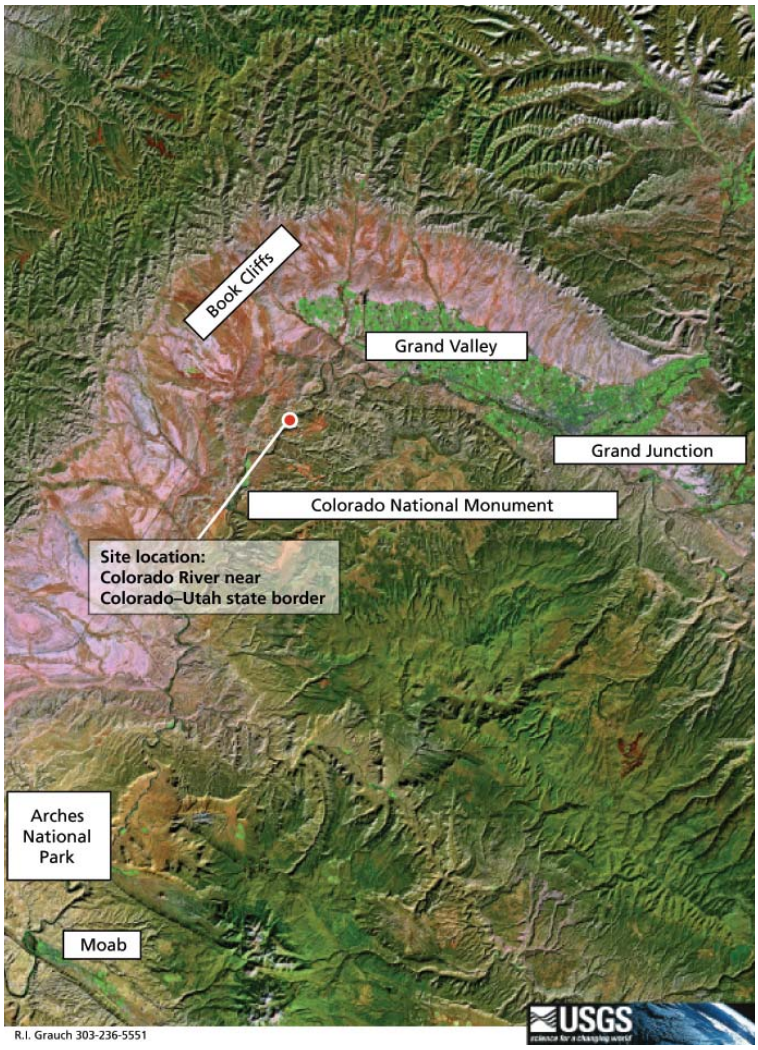


Figure 3-4. Geographic extent of Mancos Shale deposit (light pink) in western Colorado and eastern Utah (http://www.blm.gov/nstc/USGS%20BLM/manc3.html).

3.2 Black Canyon of the Gunnison National Park

3.2.1 Water quality summary

A total of 1,058 designated beneficial-use evaluations were completed for water quality results obtained between January 18, 2006 and August 21, 2008, at three sites in Black Canyon of the Gunnison National Park (BLCA). Of those 1,058 evaluations, 73 (4.6%) exceeded water quality standards or criteria (Figure 3-5). Water quality standards were exceeded for two constituent categories, metals and *E. coli*.

3.2.2 Reportable exceedances

The Gunnison River below the Gunnison Tunnel had no water quality exceedances or indications of impairment, based upon 588 total evaluations. Two of the three sites sampled had exceedances of surface water quality standards for the State of Colorado (Table 3-2, Figure 3-6). The following discussion focuses only on sites that had exceedances.

1. ***Red Rock Canyon at mouth near Montrose, Colorado.*** This site exceeded standards for aquatic life warm-water class 2, agricultural uses, and drinking-water selenium, as well as the existing primary-contact recreation standard for *E. coli*. Both the acute (18.6 µg/L) and chronic (4.6 µg/L) aquatic life warm-water class 2 standards, as well as the agricultural-uses standard, were exceeded for 100% of evaluations. Selenium concentrations exceeded the drinking-water standard for 50% of evaluations. *E. coli* levels exceeded the existing primary-contact recreation standard for 20% of evaluations.

2. ***Red Rock Canyon near the NPS boundary near Montrose, Colorado.*** This site had exceedances for manganese, selenium, and *E. coli*. Two designated beneficial-use standards, drinking water and aquatic life warm-water class 2, had selenium exceedances. Selenium concentrations exceeded the acute (18.6 µg/L) and chronic (4.6 µg/L) standards for aquatic life warm-water class 2, and agricultural-uses standards, for 50%, 100%, and 50% of evaluations, respectively. Manganese concentrations were greater than the drinking-water standard for 39% of evaluations. *E. coli* levels exceeded the existing primary-contact recreation standard for 38% of evaluations.

3.2.3 Discussion and management implications

3.2.2.1 Metals

Although selenium and manganese weather naturally from bedrock and soils in the Red Rock Creek drainage, statewide debate exists about the impact of irrigation on this weathering. The majority of Red Rock Creek's discharge is return flow from an upstream irrigation headgate. The concentration of manganese in these water bodies does not exceed the criterion for aquatic life, and the secondary drinking-water standard is for odor, color, and staining—not human health. Because there are no drinking-water intakes and the manganese concentrations do not exceed the human-health criterion, these concentrations are not problematic.

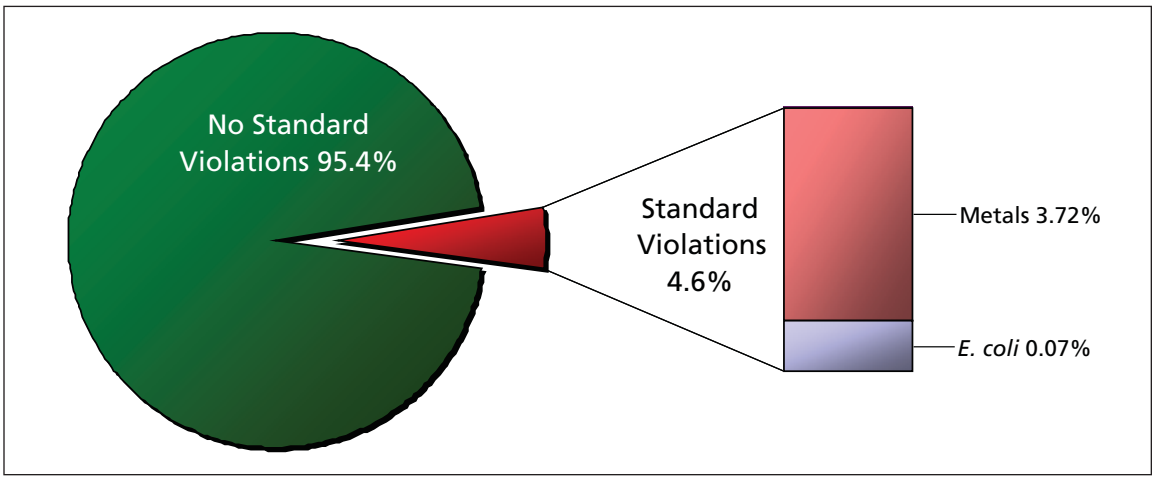


Figure 3-5. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Black Canyon of the Gunnison NP, 2006–2008.

Table 3-2. Exceedances of surface water quality standards for sites sampled in or near Black Canyon of the Gunnison NP, 2006–2008.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standard
1 Red Rock Canyon at mouth near Montrose, CO	ALW2	Selenium, Dissolved	4.6	µg/L	11	100
	AG	Selenium, Dissolved	20	µg/L	11	100
	DWS	Selenium, Dissolved	50	µg/L	11	18
	RECE	*E. coli*	126	cfu/100 ml	10	20
2 Red Rock Canyon near NPS boundary near Montrose, CO	DWS	Manganese, Dissolved	50	µg/L	18	39
	ALW2	Selenium, Dissolved	4.6	µg/L	18	100
	AG	Selenium, Dissolved	20	µg/L	18	50
	RECE	*E. coli*	126	cfu/100 ml	26	38

Use codes: ALW2 = aquatic life warm-water class 2 (similar to class 1 but recognized as impaired); AG = agricultural usage; DWS = drinking-water supply; RECE= existing primary-contact recreation.

Manganese occasionally exceeded the secondary drinking-water standard for drinking-water supply, which at 50 µg/L, is set for odor, color, and staining. The EPA's 300-µg/L human-health advisory level was not exceeded. No drinking water intakes occur within the park.

As long as no drinking-water intakes exist on the water bodies, it may be possible to request exemptions or site-specific manganese standards if sufficient evidence exists to make a strong case for naturally occurring manganese concentrations that exceed standards. Such a change would not improve water quality, but would make accounting for exceedances more straightforward.

Selenium exceedances in Red Rock Canyon have been documented, and the tributary is included on the 303(d) list of impaired waters in Colorado. Selenium exceedances are ubiquitous throughout the Grand Valley, and Red Rock Creek is no exception.

A brief discussion about elevated selenium concentrations found throughout western Colorado and eastern Utah can be found in Section 3.1.3.4. The Mancos Shale deposit, found in the Book Cliffs range and discussed in that section, is also present in the Red Rock Canyon watershed (Figure 3-7). Natural weathering of the Mancos Shale deposit generates elevated selenium and TDS levels in surface water bodies. However, accelerated erosion of the Mancos Shale deposit from land-use practices, such as grazing and OHV recreation, are known to exacerbate selenium and TDS levels (http://www.blm.gov/nstc/USGS%20BLM/manc3.html).

3.2.2.2 E. coli

The existing primary-contact recreation standard for *E. coli* was exceeded at Red Rock Canyon near the NPS boundary near Montrose, Colorado. The unknown source of *E. coli* contamination could be from wildlife, domestic animals, humans, or a combination thereof.

During high-discharge events, runoff from the watershed contributes large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli*, are carried into steams, along with the silts and sands being eroded during overland flow events. *E. coli* readily binds to benthic and suspended sediment in surface water bodies, and is able to survive for prolonged periods of time when attached to sediments (Sampson et al. 2006). In addition, *E. coli* concentrations have been shown to be positively correlated with turbidity levels (Smith et al. 2008). Therefore, elevated *E. coli* concentrations are more likely to occur during high-turbidity discharge events. However, if elevated concentrations occur in clear water conditions, then a persistent source may exist.

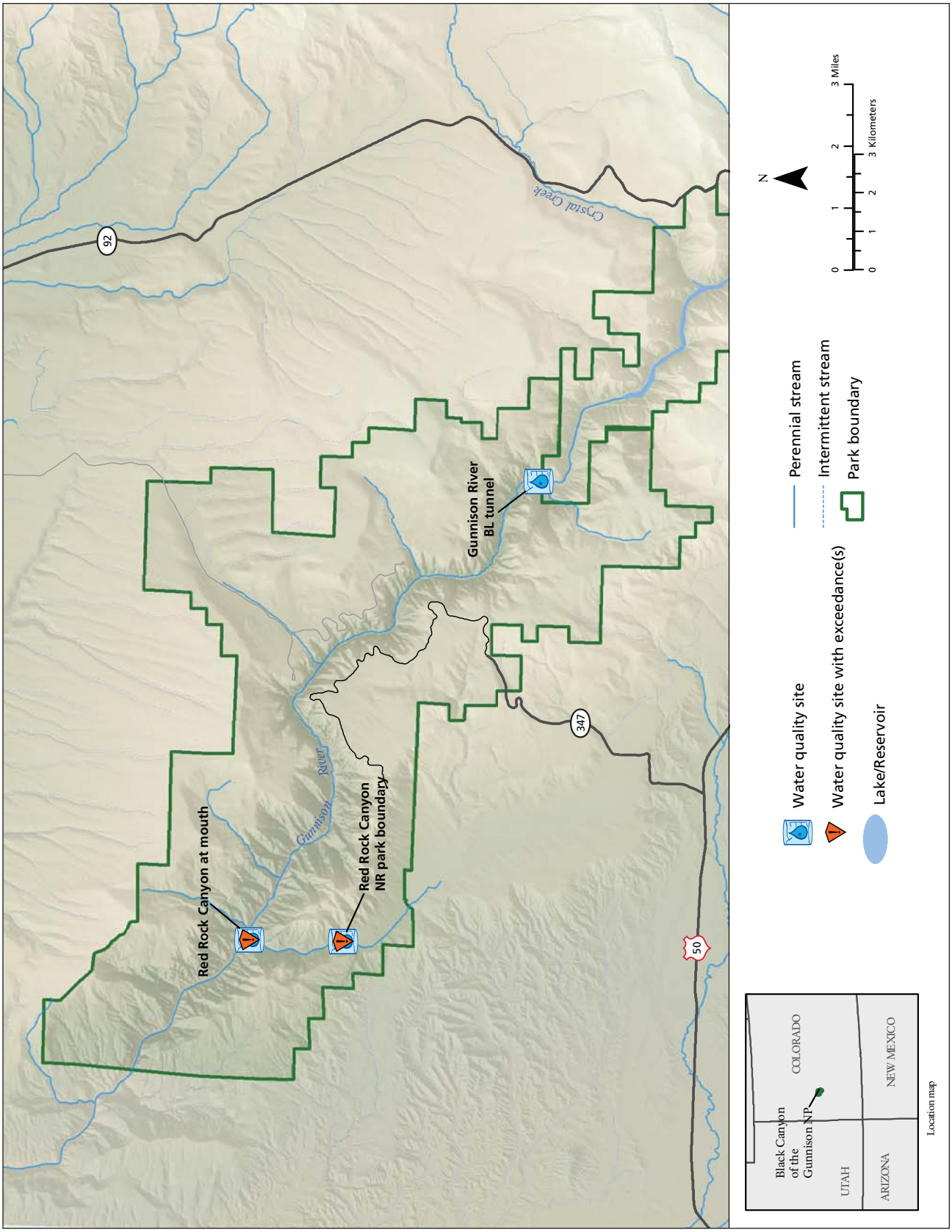


Figure 3-6. Water quality sites sampled in Black Canyon of the Gunnison NP, 2006–2008.

The majority of *E. coli* exceedances in BLCA occurred during average flow and clear water conditions. In some cases, there were insufficient data available to correlate some of the *E. coli* exceedances with flow and turbidity.

Because episodic storm events were not related to the observed *E. coli* exceedances, a continuous source may exist upstream. Additionally, the majority of *E. coli* exceedances occurred during the summer months, when recreational activity in Red Rock Canyon is at its peak. It is recommended that an increased rate of sample collection be initiated at this site if an exceedance is observed in the future, and that turbidity measurements be collected in conjunction with bacteria samples.

3.2.4 Water rights issue

On December 31, 2008, the Colorado water court (District 4, Gunnison Basin) approved the federal government's claim for water pursuant to a March 2, 1933 reserved water right for Black Canyon, as affirmed in 1978. Unusually, this claim process revolved around the competing interests of two agencies of the Department of Interior: the National Park Service, responsible for preserving water resources in Black Canyon of the Gunnison NP, and the Bureau of Reclamation (BOR), which generates electricity and regulates water flow into BLCA by controlling upstream dam operations at Blue Mesa, Morrow Point, and Crystal reservoirs (known as the Aspinall Unit).

Under the decree governing its dam operations, the BOR previously was not authorized to conduct water releases specifically for the purpose of benefitting water resources in Black Canyon. Through the Black Canyon decree, however, the NPS successfully secured the necessary water for "preservation of the spectacular gorges and additional features of scenic, scientific and educational interest" of the Black Canyon of the Gunnison River, and the U.S. received a decree legally allowing the BOR to pass inflows from the Aspinall Unit downstream to BLCA for resource purposes. Approval of the decree constitutes finalization of the adjudication process, which makes the water right complete.

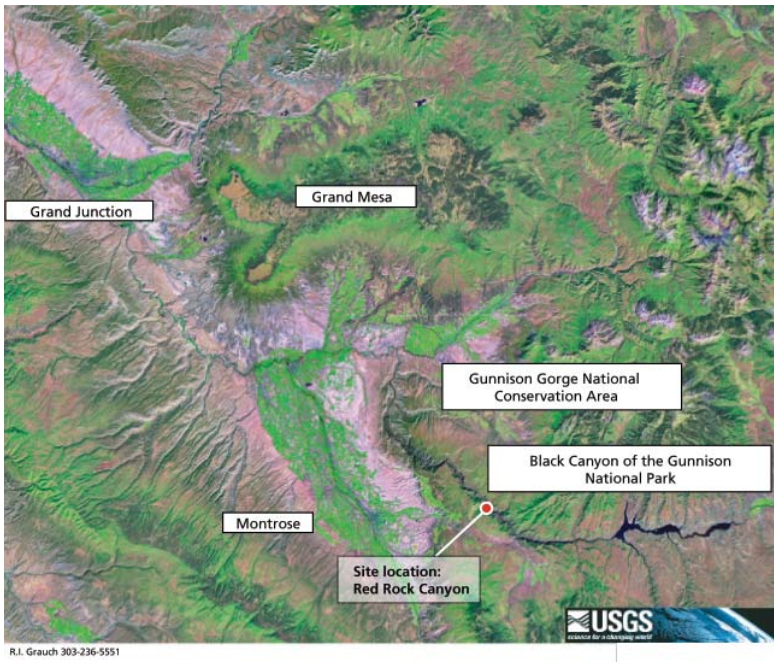


Figure 3-7. Geographic extent of Mancos Shale deposit (light pink) in western Colorado. (http://www.blm.gov/nstc/USGS%20BLM/manc3.html).

3.3 Bryce Canyon National Park

3.3.1 Water quality summary

A total of 1,122 designated beneficial-use evaluations were completed for water quality results obtained between January 13, 2006 and January 29, 2008, at four sites in Bryce Canyon NP. Of those 1,122 evaluations, four (0.6%) exceeded water quality standards or criteria (Figure 3-8). Water quality standards were exceeded for one constituent category, *E. coli* (Figure 3-8).

3.3.2 Reportable exceedances

The chronic *E. coli* standard for the State of Utah was exceeded at all four sites (Figure 3-9), but on less than 10% of site visits. The acute *E. coli* standard was not exceeded.

3.3.1 Discussion and management implications

In part, Sheep and Yellow creeks were included in the NCPN monitoring plan because they contribute flow to segments of the Paria River, which is on the State of Utah's 303(d) list of impaired water bodies for total dissolved solids. Although TDS exceedances are common on these streams below the park boundary (Judd and Adams 2006), there were no exceedances observed at the park boundary during the sampling period covered in this report.

The infrequent *E. coli* exceedances that occurred during the study period do not warrant concern from a human-health perspective. Possible sources of contamination include wildlife, human use, and trespass cattle, which have been an infrequent but reoccurring issue in Bryce Canyon NP. During monthly monitoring visits, cattle were occasionally observed in the park along the riparian corridors of Sheep and Yellow creeks during this sampling period. Some were herded out of the park at the time of sampling, and both resource-management and law-enforcement personnel were alerted to their presence. Potential physical and biological damage to the riparian corridor and degradation of water quality from cattle trespass is not being measured, but may be a resource management concern. Re-construction of the boundary fence on Sheep Creek—destroyed by flood in 2007, repaired in 2008, and undergoing maintenance in 2009—should eliminate any potential impacts caused by trespass cattle in the biologically rich riparian area along the stream.

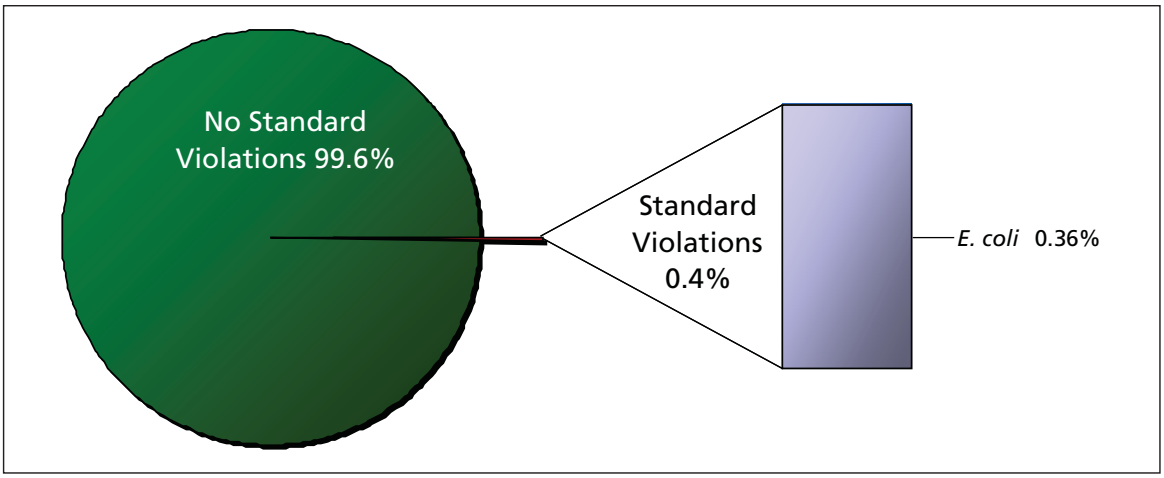


Figure 3-8. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Bryce Canyon NP, 2006–2008.

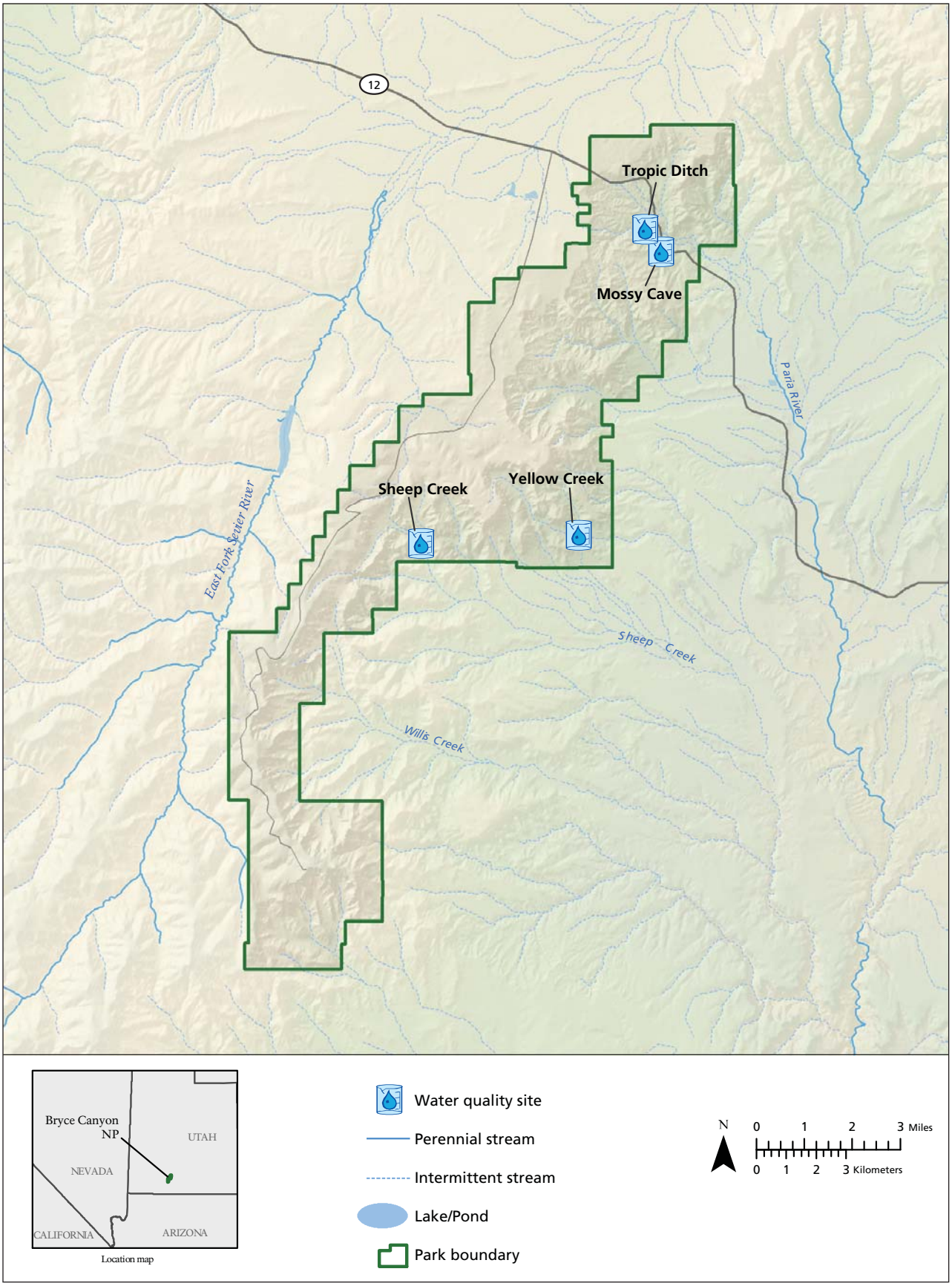


Figure 3-9. Water quality sites sampled in Bryce Canyon NP, 2006–2008.

3.4 Canyonlands National Park

3.4.1 Water quality summary

A total of 2,225 designated beneficial-use evaluations were completed for water quality results obtained between January 20, 2006 and December 1, 2009, at 15 sites in or near Canyonlands NP. Of those 2,225 evaluations, 97 (3.7%) exceeded water quality standards or criteria (Figure 3-10). Water quality standards were exceeded for five constituent categories, most commonly nutrients, dissolved oxygen, and *E. coli* (Figure 3-11).

3.4.2 Reportable exceedances

Five of the 15 sites monitored in or near Canyonlands NP did not have exceedances or indications of impairment, based upon 668 total evaluations: Chocolate Drops Spring (55 total evaluations), 2.4-mile Loop Spring (76 total evaluations), Salt Creek near Peekaboo Spring (76 total evaluations), Green River at Green River, Utah (401 total evaluations), and Green River at Ouray, Utah (60 total evaluations). Ten of 15 sites had exceedances of water quality standards for the State of Utah (Table 3-3, Figure 3-12). The following discussion focuses only on sites that had exceedances.

1. ***Cave Spring.*** Cave Spring exceeded the indication of impairment for total phosphorus for 50% of evaluations, and the dissolved oxygen standard for 17% of evaluations. Total phosphorus concentrations were greater than the indication of impairment for warm-water game fish and primary-contact recreation. Dissolved oxygen concentrations were less than the chronic (30-day average, 5.5-mg/L) and acute (5.0 mg/L) early life stage present standard for warm-water game fish. However, no evaluations resulted in a dissolved oxygen concentration below the acute (3.0 mg/L) early life stage absent standard for warm-water game fish.

2. ***Colorado River above the confluence with the Green River.*** This site exceeded the indication of impairment for total phosphorus, the standard for selenium, and the standard for temperature. Total phosphorus concentrations were greater than the indication of impairment for the warm-water game fish

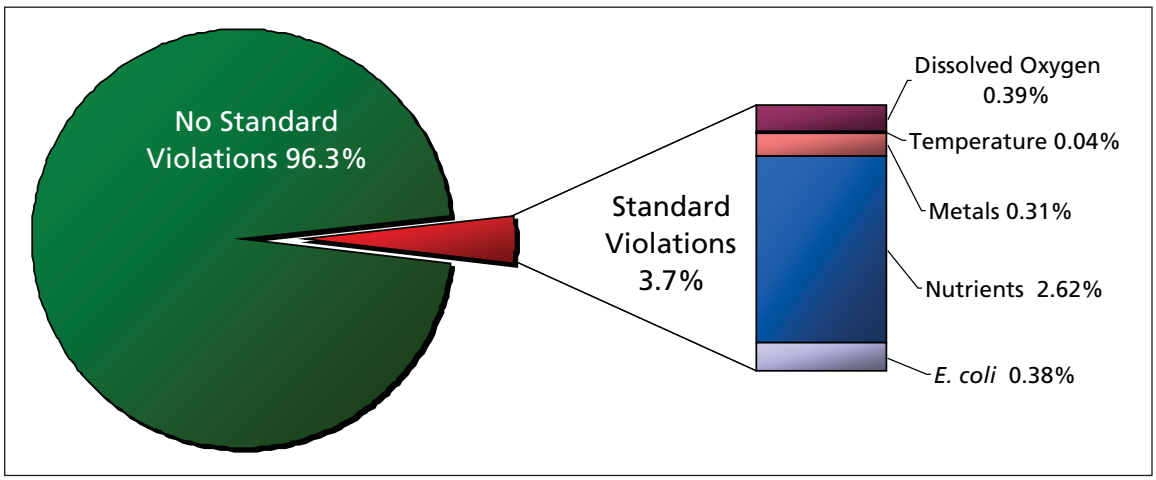


Figure 3-10. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Canyonlands NP, 2006–2009.

Figure 3-11. Most commonly exceeded water quality standards at Canyonlands NP, 2006–2009.

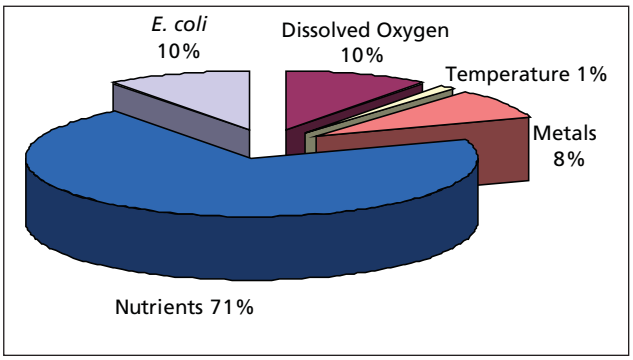


Table 3-3. Exceedances of surface water quality standards for sites sampled in or near Canyonlands NP, 2006–2009.

	Site	Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
1	Cave Spring	3B	Dissolved oxygen	5.5	mg/L	6	17
		2A, 3B	Phosphorus, Total	0.05	mg/L	6	50
2	Colorado River above confluence with Green River	2A, 3B	Phosphorus, Total	0.05	mg/L	8	88
		3B	Selenium, Dissolved	4.6	µg/L	8	13
		3B	Temperature, Water	27	°C	8	13
3	Colorado River at Potash boat ramp	2A, 3B	Phosphorus, Total	0.05	mg/L	4	75
		3B	Selenium, Dissolved	4.6	µg/L	4	25
4	Colorado River below Big Drop #3	3B	Copper, Dissolved	HD	µg/L	8	13
		2A, 3B	Phosphorus, Total	0.05	mg/L	8	100
5	Green River above confluence with Colorado River	2A, 3B	Phosphorus, Total	0.05	mg/L	8	100
6	Green River at Mineral Bottom	2A, 3B	Phosphorus, Total	0.05	mg/L	3	100
7	Horseshoe Canyon Spring (0.3 mi above confluence with Water Canyon)	3B	Dissolved oxygen	5.5	mg/L	3	67
		2A, 3B	Phosphorus, Total	0.05	mg/L	4	25
		2A	*E. coli*	126	MPN	8	13
		1C	*E. coli*	206	MPN	8	13
8	Little Spring Canyon Creek	3B	Selenium, Dissolved	4.6	µg/L	2	100
9	Maze Overlook Spring (0.25 mi SE of Maze Overlook)	3B	Dissolved oxygen	5.5	mg/L	4	25
10	Salt Creek near Crescent Arch	3B	Dissolved oxygen	5.5	mg/L	18	33
		2A	*E. coli*	126	MPN	17	12
		1C	*E. coli*	206	MPN	17	12

Use codes: 3B = warm-water game fish; 2A = primary-contact recreation; 3B = warm-water game fish; 1C = drinking water; HD = hardness-dependent

standard and the primary-contact recreation standard for 88% of evaluations. Selenium concentrations exceeded the chronic standard for warm-water game fish for 13% of evaluations, but did not exceed the acute selenium standard (18.6 µg/L). Temperatures exceeded the standard for warm-water game fish for 11% of evaluations.

3. ***Colorado River at Potash boat ramp.*** This site exceeded the indication for impairment for total phosphorus, and the selenium standard, for 75% and 25% of evaluations, respectively. The total-phosphorus exceedances were greater than the indication for impairment for primary-contact recreation and warm-water game fish. The selenium concentrations exceeded the chronic standard for warm-water game fish, but did not exceed the acute standard (18.6 µg/L).

4. ***Colorado River below Big Drop #3.*** This site exceeded the indication of impairment for total phosphorus concentration for primary-contact recreation and warm-water game fish for 100% of evaluations. Dissolved copper concentrations exceeded the acute (hardness-dependent) and chronic standards for warm-water game fish for 13% of evaluations.

5. ***Green River above confluence with Colorado River.*** This site exceeded the indication of impairment for total phosphorus for 100% of evaluations. The total phosphorus concentrations exceeded the indication of impairment for primary-contact recreation and warm-water game fish.

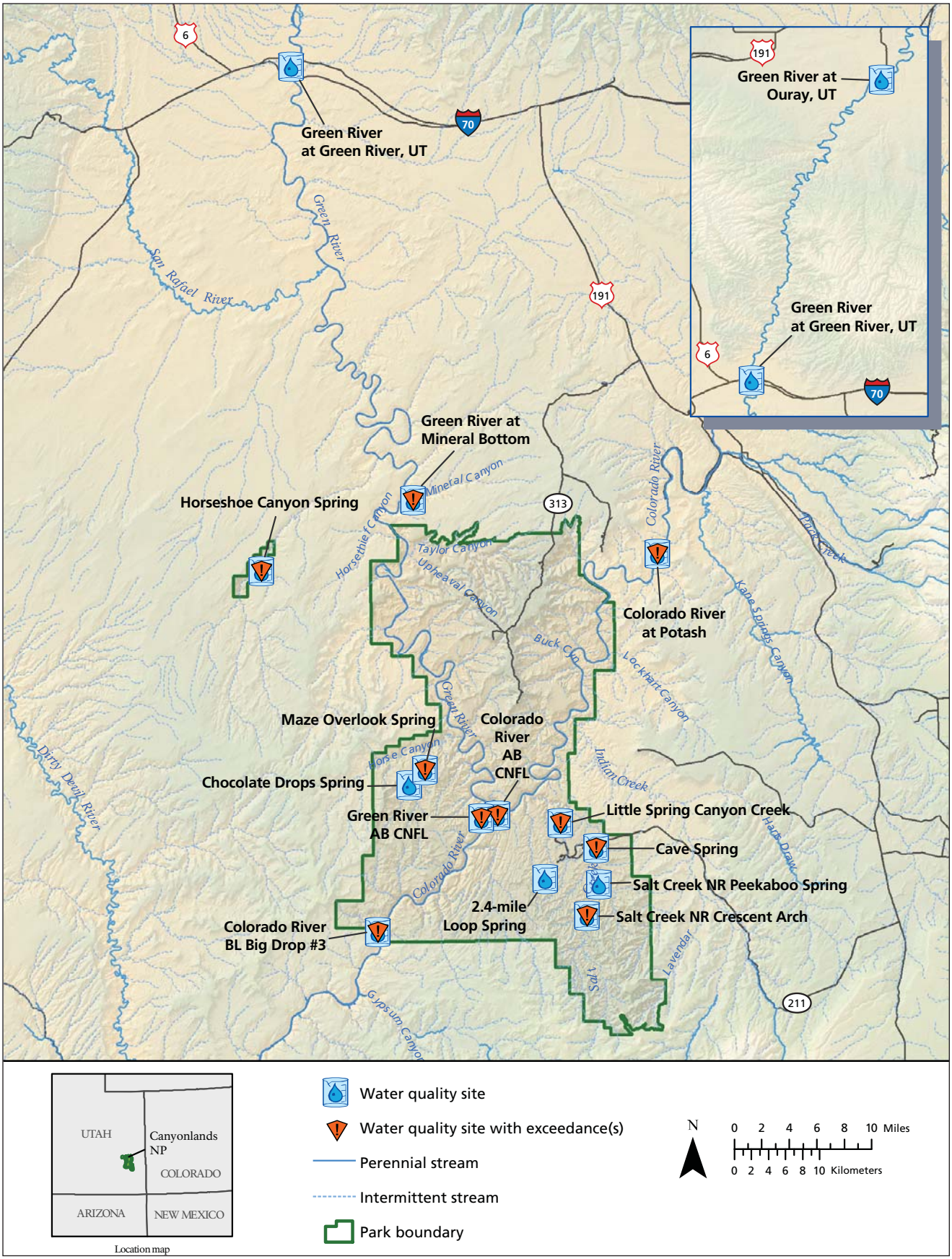


Figure 3-12. Water quality sites sampled in or near Canyonlands NP, 2006–2009.

6. ***Green River at Mineral Bottom.*** This site exceeded the indication of impairment for total phosphorus for 100% of evaluations. The total phosphorus concentrations exceeded the indication of impairment for primary-contact recreation and warm-water game fish.

7. ***Horseshoe Canyon.*** Horseshoe Canyon exceeded the dissolved oxygen and *E. coli* standards, as well as the indication of impairment due to total phosphorus, for 67%, 13%, and 25% of evaluations, respectively. DO concentrations failed to meet the standard for warm-water game fish. One of eight evaluations resulted in an *E. coli* exceedance for the chronic and acute standards for both drinking water (acute, 668 MPN) and primary-contact recreation (acute, 409 MPN) standards. One of four total phosphorus evaluations was greater than the indication of impairment for primary-contact recreation.

8. ***Little Spring Canyon Creek.*** Little Spring Canyon Creek exceeded the chronic selenium standard for warm-water game fish for 100% of evaluations. There were only two results available for analysis from Little Spring Canyon Creek during the period covered in this report, neither of which exceeded the acute standard for selenium.

9. ***Maze Overlook Spring (0.25 miles SE of Maze Overlook).*** Maze Overlook Spring exceeded the chronic and acute (5.0 mg/L) warm-water game fish (early life stage present) dissolved oxygen standard for 25% of site visits. Dissolved oxygen concentrations were never below the acute (early life stage absent) standard. There were only four results available for analysis from Maze Overlook Spring during the period covered in this report.

10. ***Salt Creek near Crescent Arch.*** Salt Creek near Crescent Arch exceeded dissolved oxygen and *E. coli* standards. The DO concentrations were below the chronic and acute (5.0 mg/L) standard for warm-water game fish (early life stage present) for 33% and 28% of evaluations respectively, and below the acute standard (4.0 mg/L) for warm-water game fish (early life stage absent) for 22% of evaluations. The acute (409 MPN) and chronic *E. coli* standard for primary-contact recreation and the chronic *E. coli* drinking-water standard were each exceeded for 12% of evaluations.

3.4.3 Discussion

3.4.3.1 Dissolved oxygen

The results from this monitoring period are consistent with the results from 10 years of sampling in Canyonlands NP described by Schelz and Moran (2005). Both the hydrologic setting and low-flow conditions typically found in intermittent streams contribute to low dissolved-oxygen concentrations. During low-flow conditions, when water temperatures are high and surface flow is low, stagnant pools form. The combination of elevated temperatures and organic matter decomposition in stagnant or low-flow conditions causes the reduction and depletion of dissolved oxygen. In addition, these intermittent streams often have un-shaded reaches in which water temperatures are elevated, even in free-flowing environments. Groundwater-fed springs, such as Cave Spring and Maze Overlook Spring, also have low dissolved-oxygen concentrations. Spring sites, which are predominantly recharged by groundwater, tend to have low dissolved-oxygen concentrations because of underground biological activity that reduces the amount of oxygen present in emergent groundwater.

3.4.3.2 Nutrients

Total phosphorus exceedances in perennial and intermittent streams may result from rock weathering, airborne deposition, or soil erosion. Phosphorus comes in several forms, including a form sorbed to soil particles that may be transported to water bodies where dissolution can occur, resulting in bioavailable phosphorus. In the headwaters areas of Canyonlands NP stream basins, soil erosion on uplands may have been accelerated due to grazing, and may continue at an accelerated pace if soil-surface crusts have not stabilized despite the absence of grazing for many years (Reynolds et al. 2005). Although speculative, this scenario may have important management implications. It is also possible that the phosphorus has a geologic origin and is naturally occurring at high levels due to weathering (Reynolds et al. 2001). A better understanding of phosphorus source, transport, and biological effect in these watersheds would help determine potential management actions for restoration, including the possibility of reclassifying or providing site-specific classifications for water bodies based on natural conditions.

3.4.3.3 Metals

Erosion of the Mancos Shale formation causes naturally elevated selenium concentrations in surface water bodies throughout the Northern Colorado Plateau, as discussed in Section 3.1.3.4. Water quality monitoring sites located on the Colorado River are no exception, as a large contributing area of the watershed includes a Mancos Shale component.

Little Spring Canyon Creek's selenium exceedances may result from naturally derived sources; a geochemical investigation of the Cedar Mesa Sandstone and Elephant Canyon Formation could verify the likelihood of a naturally derived selenium source. Because the watershed lies entirely within Canyonlands NP, and open-range grazing near the Little Spring Canyon Creek headwaters ceased a few years after the park's 1964 designation, erosion from the Little Spring Canyon Creek watershed has likely been mitigated with time. In addition, the majority of surface water present at the Little Spring Canyon Creek site is derived from groundwater seepage, and the available results were collected during low-flow, clear water conditions, indicating that the selenium source is likely derived from groundwater and not overland flow.

3.4.3.4 Temperature

Temperature in the Colorado River above the confluence with the Green River exceeded the warm-water game fish standard of 27 ºC by 0.2 ºC in August 2007. Temperature exceedances are not historically common at this site, and were infrequent during the study period covered in this report. This exceedance also occurred during a low-flow period, and thus does not warrant immediate concern. However, continued monitoring is recommended to detect and assess the frequency of long-term temperature exceedances at this site.

3.4.3.5 E. coli

During high-discharge events, runoff from the watershed and re-suspension of bedrock material contribute large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli*, are carried into nearby steams, along with the silts and sands being eroded and re-suspended during these events. *E. coli* readily binds to benthic and suspended sediment, and is able to survive for prolonged periods when so attached (Sampson et al. 2006). In addition, *E. coli* concentrations have been shown to be positively correlated with turbidity levels (Smith et al. 2008). Therefore, elevated *E. coli* concentrations are more likely to occur during turbid, high-discharge events. However, if elevated concentrations occur in clear water conditions, a persistent source may exist.

All exceedances in Horseshoe Canyon Spring and Salt Creek near Crescent Arch occurred during above-average discharge events. Unfortunately, no turbidity data were available from these sites at the time of collection. Because exceedances were infrequent and episodically correlated with high-discharge events, it is unlikely that a persistent source exists in the watershed. While the exact cause of these exceedances is unknown, preventive measures, such as ensuring that fences are properly maintained, can at least help eliminate cattle trespass as a potential source of future *E. coli* contamination. When exceedances occur, the field technician processing the samples immediately alerts resource managers and park staff. If concern is warranted, five samples should then be collected in a 30-day period in order to properly assess the issue and warn visitors of the impaired quality of the water.

3.4.4 Management implications

The sources of phosphorus and selenium could be further investigated through evaluation of geologic formations and current and past human land-use practices in the watersheds. If a likely source or sources cannot be identified in the current literature or via additional internal investigation, the NPS could advance a regional study by partnering with academic institutions or the USGS. When park managers understand the source and mechanisms of pollutant transport to water bodies—and their potential biological impact—then management actions can be developed in cases where the pollutant source is anthropogenic. If the source is outside the park, then managers can advocate for the resource when opportunities arise. Additionally, when investigations of the source and cause determine that the pollutants are naturally occurring, the NPS can work with the state to reclassify water bodies or develop site-specific standards to better reflect natural conditions.

Bacterial water quality in small intermittent and spring sites can episodically degrade after large discharge events. This was likely the scenario observed at Salt Creek and Horseshoe Canyon Spring during the period covered in this report,

and is likely to be true of all wadeable surface water bodies in Canyonlands NP. Microorganisms present in fecal matter can survive for at least several days—and up to a few weeks once exposed to the environment (Sampson et al. 2006). Surface water located in rain-catchment pools, stagnant sections of intermittent streams, and free-flowing streams can potentially contain elevated concentrations of *E. coli* following a precipitation event that causes overland flow. It is always recommended that visitors properly filter or treat surface water prior to consumption, but added caution should be taken if the pool is turbid or if an overland flow event recently occurred. Even groundwater can potentially be contaminated with *E. coli*.

3.5 Capitol Reef National Park

3.5.1 Water quality summary

A total of 1,798 designated beneficial-use evaluations were completed for water quality results obtained between January 12, 2006 and November 19, 2009, at nine sites in or near Capitol Reef NP. Of those 1,798 evaluations, 77 (4.3%) exceeded water quality standards or criteria (Figure 3-13). Water quality standards were exceeded for six constituent categories, most commonly for nutrients, *E. coli*, and temperature (Figure 3-14).

3.5.2 Reportable exceedances

Halls Creek below the Narrows, and the Fremont River near Caineville, Utah, did not have exceedances or indications of impairment, based upon 372 and 19 total evaluations, respectively. The other seven sites sampled had water quality exceedances for the State of Utah (Table 3-4, Figure 3-15). The following discussion focuses only on sites that had exceedances.

1. ***Fremont River at U12 crossing.*** Total phosphorus concentrations at this site exceeded the standards for secondary-contact recreation and cold-water game fish for 21% of evaluations. *E. coli* concentrations were greater than the chronic secondary-contact recreation (2B) and drinking-water supply (1C) standard for 33% of evaluations.
2. ***Fremont River near Bicknell, Utah.*** Total phosphorus concentrations in the Fremont River at this site exceeded the standards for secondary-contact recreation and cold-water game fish for 14% of evaluations.
3. ***Fremont River at old U24 crossing.*** This site exceeded the total phosphorus, total dissolved solids, and temperature standards for 93%, 13%, and 18% of evaluations, respectively. Total phosphorus exceeded the standards for secondary-contact recreation and non-game fish. Total dissolved solids exceeded the agricultural-uses standard, and temperature exceeded the non-game fish standard.

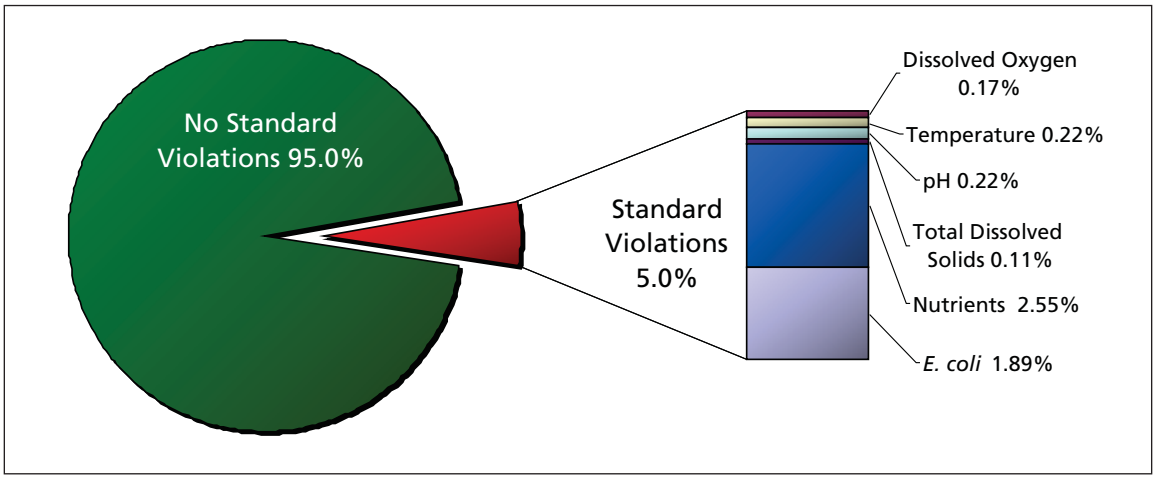


Figure 3-13. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Capitol Reef NP, 2006–2009.

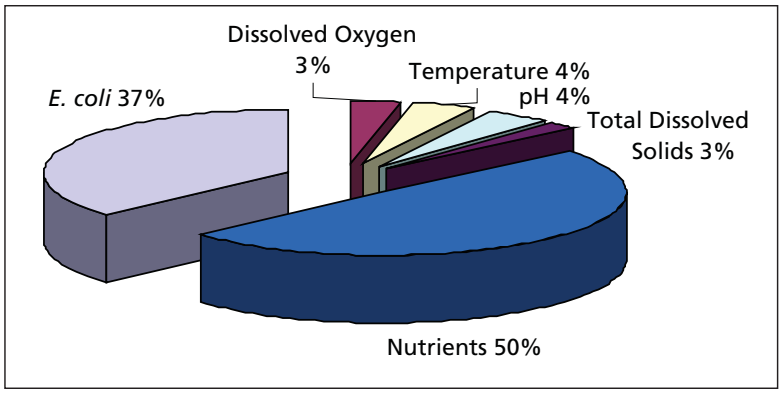


Figure 3-14. Most commonly exceeded water quality standards at Capitol Reef NP, 2006–2009.

Table 3-4. Exceedances of surface water quality standards for sites sampled in or near Capitol Reef NP, 2006–2009.

	Site	Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
1	Fremont River at U12 crossing*	2B, 3A	Phosphorus, Total	0.05	mg/L	14	21
		1C, 2B	*E. coli*	206	MPN	24	33
2	Fremont River near Bicknell, UT	2A, 3B	Phosphorus, Total	0.05	mg/L	21	14
3	Fremont River at old U24 crossing	2B, 3C	Phosphorus, Total	0.05	mg/L	15	93
		4	Total Dissolved Solids	1,200	mg/L	15	13
		3C	Temperature, Water	27	°C	17	18
4	Fremont River above Mill Meadow Reservoir	2B, 3A	Phosphorus, Total	0.05	mg/L	4	50
5	Fremont River at Fruita Campground*	1C, 2B	*E. coli*	206	MPN	7	86
6	Fremont River at CARE waterfall*	1C, 2B	*E. coli*	206	MPN	25	24
7	Pleasant Creek S of Sleeping Rainbow Ranch	1C, 2B	*E. coli*	206	MPN	17	12
8	Sulphur Creek below road to Goosenecks Overlook	1C, 2B	*E. coli*	206	MPN	17	12
9	Sulphur Creek above confluence with Fremont River	1C, 2B	*E. coli*	206	MPN	17	12

Use codes: 2A = primary-contact recreation; 2B = secondary-contact recreation; 3A = cold-water game fish; 3B = warm-water game fish; 1C = domestic use; 3C = non-game fish; 4 = agricultural uses

*Sites contain 2010 data

4. ***Fremont River above Mill Meadow Reservoir.*** Total phosphorus concentrations at this site exceeded the standards for secondary-contact recreation and cold-water game fish for 50% of evaluations.

5. ***Fremont River at Fruita Campground.*** *E. coli* concentrations exceeded the chronic secondary-contact recreation (2B) and drinking-water supply (1C) standards for 86% of evaluations at this site.

6. ***Fremont River at CARE waterfall.*** *E. coli* concentrations exceeded the chronic secondary-contact recreation (2B) and drinking-water supply (1C) standards for 24% of evaluations at this site.

7. ***Pleasant Creek South of Sleeping Rainbow Ranch.*** Pleasant Creek exceeded the chronic drinking water and secondary-contact recreation standards for *E. coli* for 12% of evaluations.

8. ***Sulphur Creek below road to Goosenecks Overlook.*** This site exceeded the chronic drinking water and secondary-contact recreation standards for *E. coli* for 12% of evaluations.

9. ***Sulphur Creek above confluence with Fremont River.*** This site exceeded the chronic drinking water and secondary-contact recreation standards for *E. coli* for 12% of evaluations.

3.5.3 Discussion and management implications

3.5.3.1 Fremont River

The State of Utah has documented elevated temperatures, total phosphorus levels, and TDS concentrations in the Fremont River due to agricultural activities upstream from Capitol Reef NP, and the UDWQ has an EPA-approved total maximum daily load (TMDL) plan for the Fremont River watershed upstream from the park (UDWQ 2002). The plan identifies the most likely sources of pollution, as well as potential solutions. At time of writing, approximately three miles of streambank stabilization had been completed between Bicknell and Grover, Utah, immediately upstream from the park. Feeding operations have been moved further from the river and grazing improvements have been made. All management actions on private land are voluntary, with

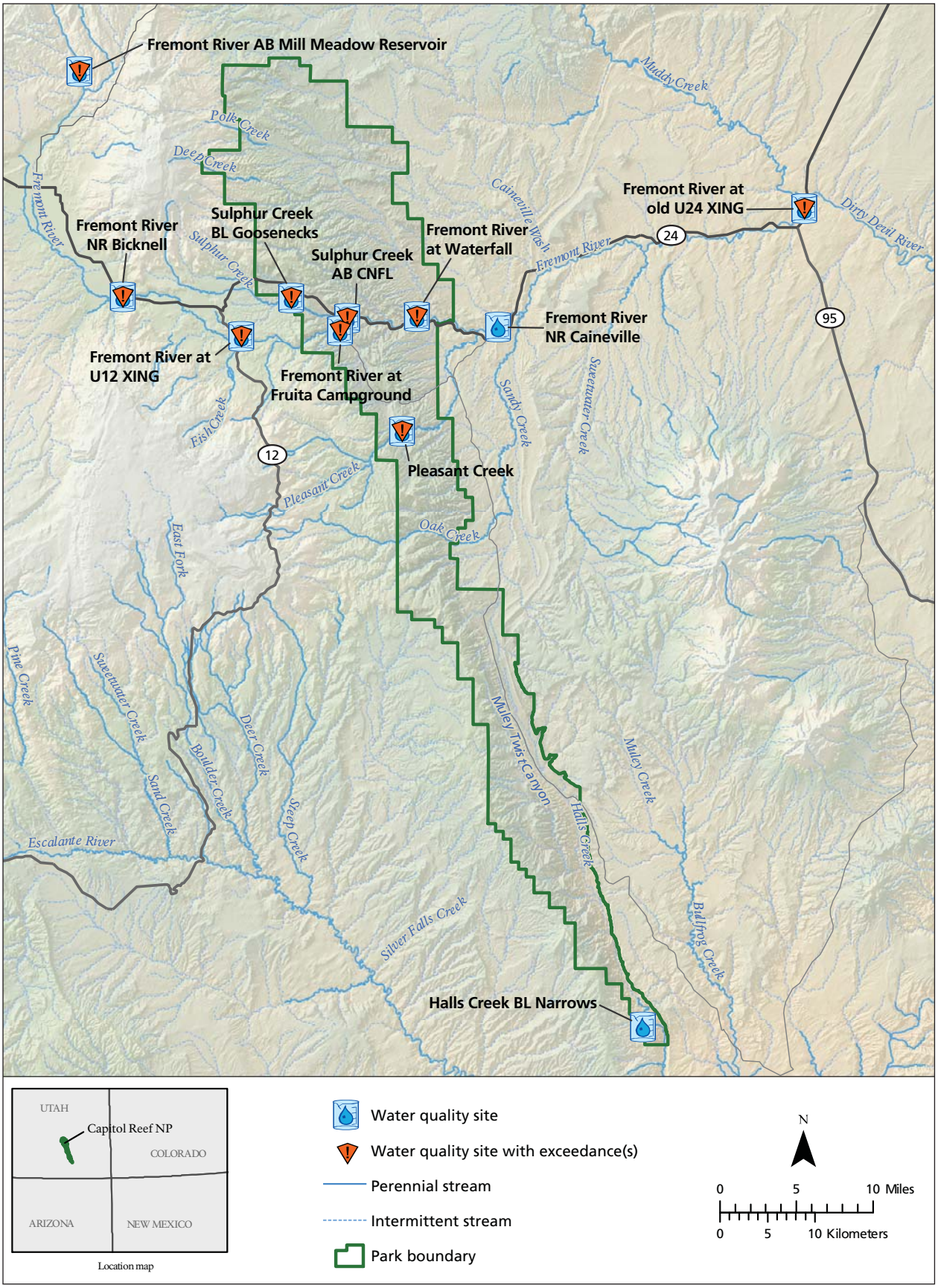


Figure 3-15. Water quality sites sampled in or near Capitol Reef NP, 2006–2009.

an opportunity for cost-sharing with the state. Additional opportunities for implementing best management practices in the watershed, which could improve water quality in Capitol Reef NP, are extant.

In June 2007, the non-profit Wild Utah Project conducted a riparian-area assessment workshop upstream from Loa, Utah, and on two sections of the Fremont River in Capitol Reef NP. Participants included Wayne County commissioners, NPS staff, and local landowners. Bringing together entities with a common interest in shared water resources had a positive outcome. Using an objective set of criteria, participants evaluated the riparian areas and observed the state of the resource (Stacey et al. 2007). It is hoped that the riparian-area assessment will be a starting point for continued cooperation and interaction between landowners, the state, and the NPS in the Fremont River watershed.

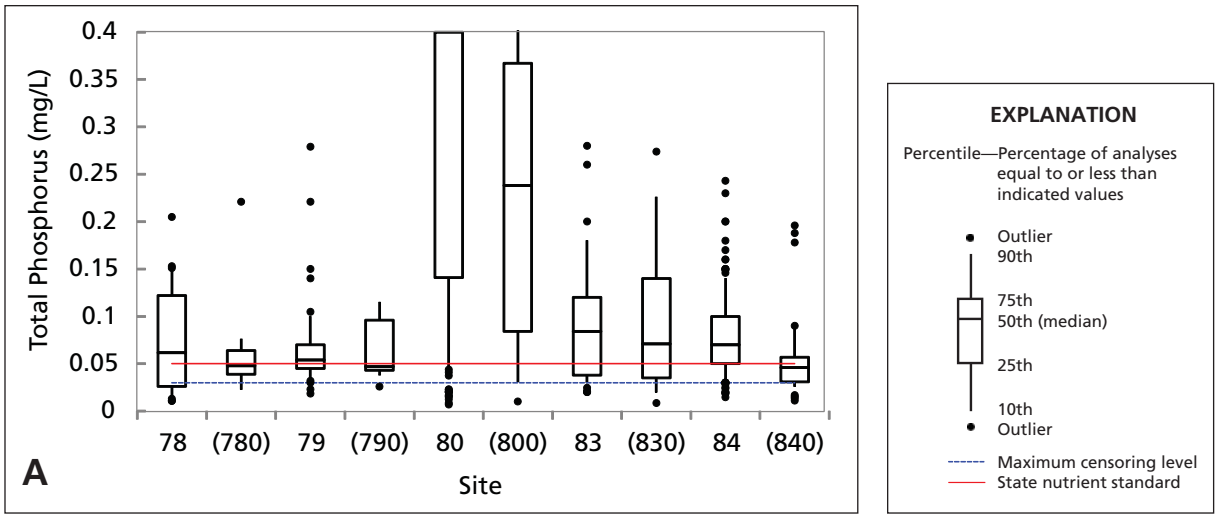
In July 2008, the UDWQ hosted a follow-up tour so that participants could view and discuss nonpoint source management practices implemented in the watershed. Attendees included representatives from the UDWQ, NPS, Conservation Districts, Grand Canyon Trust, and Bureau of Land Management.

As best management practices are encouraged and implemented, water quality may improve as fewer exceedances are detected and concentrations decrease seasonally (Figure 3-16). A weak positive relationship between total phosphorus concentration and flow ($r^2 = 0.09$) indicates generally higher pollutant loads with higher flows, which may indicate that seasonal inputs and mechanisms from diffuse overland flow and redistribution in channels are potential sources of phosphorus (Figure 3-17). Total phosphorus concentrations are lowest during the seasons when eutrophication may be most problematic, thus further reducing the impacts of total phosphorus (TP) on aquatic organisms.

3.5.3.2 E. coli

The majority of the *E. coli* exceedances in Pleasant Creek and Sulphur Creek were associated with elevated turbidity and flow, and most did not exceed the acute standards for secondary-contact recreation and drinking water. In July 2008, one result each from Lower Sulphur Creek and Pleasant Creek did exceed the acute standards for secondary-contact recreation and drinking water (668 MPN). A precipitation event likely caused these exceedances, as they occurred within 12 hours of one another. Elevated flow and turbidity conditions were present at the time of sampling in Pleasant Creek. However, average flow and turbidity conditions were present in Lower Sulphur Creek at the time of sampling. In the event that a bacteria result exceeds the acute standards for recreation or drinking water, NCPN staff notifies park natural resource staff. Capitol Reef NP staff can then decide whether an increased sampling effort is necessary to determine if a persistent source may exist.

Elevated summertime *E. coli* concentrations on the Fremont River in or near Capitol Reef NP were observed during 2009 (Figure 3-18). In addition to the 2009 results, concern about potential bacteria sources within the park and the Fremont River watershed upstream initiated a more frequent sampling effort during 2010. Consistently elevated concentrations were observed both upstream at the U12 crossing and at two sites within the park during 2010 (Figure 3-18). The geometric means calculated from samples collected at all three sites between July 15 and August 13, 2010 were greater than the chronic secondary-contact recreation standard. More intensive sampling efforts will most likely be implemented during 2011 to better understand the potential bacteria sources within the watershed.



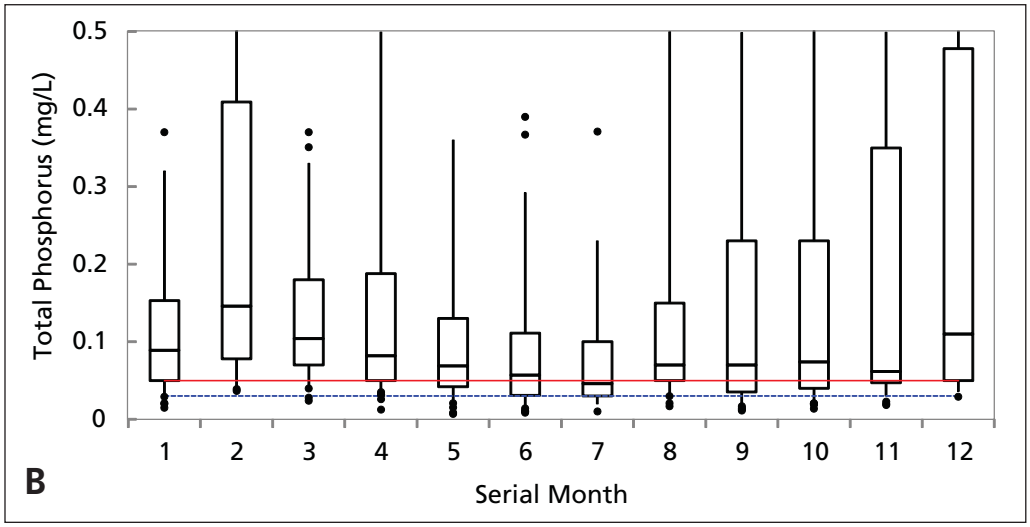


Figure 3-16a. Total phosphorus (TP) concentrations at six monitoring sites on the Fremont River, before and after year 2000. In all cases, TP concentrations were lower after year 2000 than previously. Post-2000 results are labeled as site number with trailing zero in parentheses.

Figure 3-16b. Seasonality of total phosphorus concentrations from six monitoring sites on the Fremont River.

Water quality sites displayed in Figure 3-16.

Site no.	Site name	TP median conc. (mg/L)	
		pre-2000	post-2000
78	Fremont River at Hwy 12 NR Grover, UT	0.06	0.05
79	Fremont River at inflow to Mill Meadow Reservoir	0.05	0.05
80	Fremont River at old U24 XING	0.40	0.24
83	Fremont R. at Hickman Bridge Trailhead	0.08	0.07
84	Fremont River NR Bicknell, UT	0.07	0.05

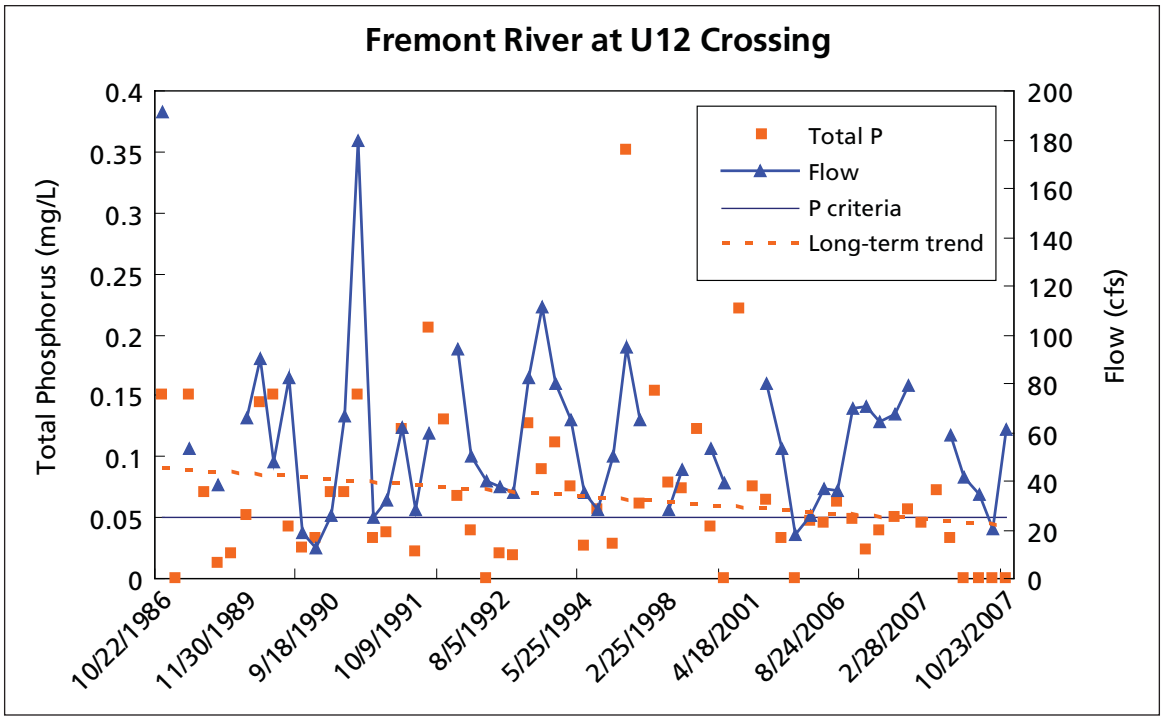


Figure 3-17. Total phosphorus concentration versus flow, Fremont River at U12 crossing sample site, October 1986–October 2007. Values above the horizontal blue line exceed the State of Utah indication of impairment for secondary-contact recreation and cold-water game fish species.

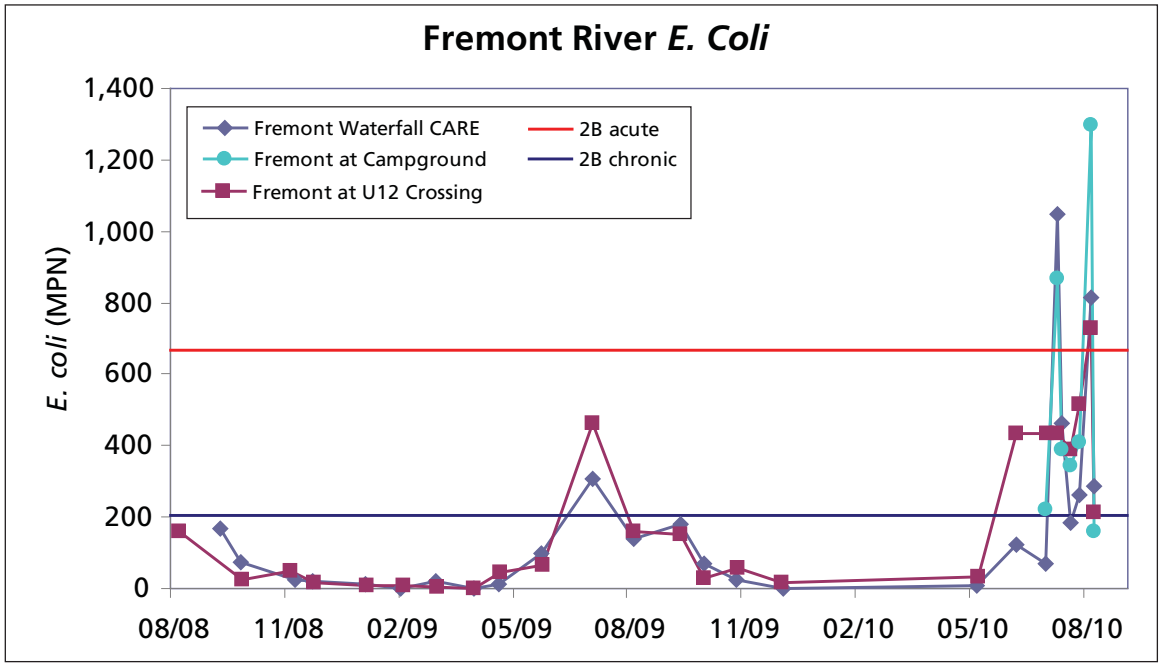


Figure 3-18. *E. coli* concentrations at three locations along the Fremont River in or near Capitol Reef NP.

3.6 Curecanti National Recreation Area

3.6.1 Water quality summary

A total of 8,096 designated beneficial-use evaluations were completed for water quality results obtained between January 18, 2006 and September 25, 2008, at 13 sites in and near Curecanti National Recreation Area (NRA). Of those 8,096 evaluations, 81 (1.0%) exceeded water quality standards or indications of impairment for the State of Colorado (Figure 3-19). Water quality standards were exceeded for four constituent categories, most commonly metals, *E. coli*, and dissolved oxygen (Figure 3-20).

3.6.2 Reportable exceedances

Six of 13 sites sampled in Curecanti NRA did not have water quality exceedances for the State of Colorado, based upon 3,592 total evaluations: Cebolla Creek at Powderhorn (659 total evaluations), Gunnison River at County Rd 32 (582 total evaluations), Soap Creek above Chance Creek (545 total evaluations), Steuben Creek near mouth (628 total evaluations), West Elk Creek below USFS boundary (476 total evaluations), and Lake Fork Gunnison River (702 evaluations). The other seven monitored sites had exceedances (Table 3-5, Figure 3-21). The following discussion focuses only on sites that had exceedances.

1. ***Beaver Creek at Hwy 50 near Gunnison, Colorado.*** This site exceeded the chronic manganese standard for drinking-water supply for 22% of evaluations. There are no drinking-water supplies drawn from Beaver Creek within or outside Curecanti NRA.

2. ***Blue Creek at Hwy 50 (near Sapinero).*** This site exceeded copper and *E. coli* standards for 29% and 21% of evaluations, respectively. The copper concentrations exceeded the chronic standard for aquatic life cold-water class 1. However, it is suspected that occasional contamination within the sampling process may have led to these exceedances (Matt Malick, CURE hydrologist, pers. comm. April 2010). Dissolved oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning

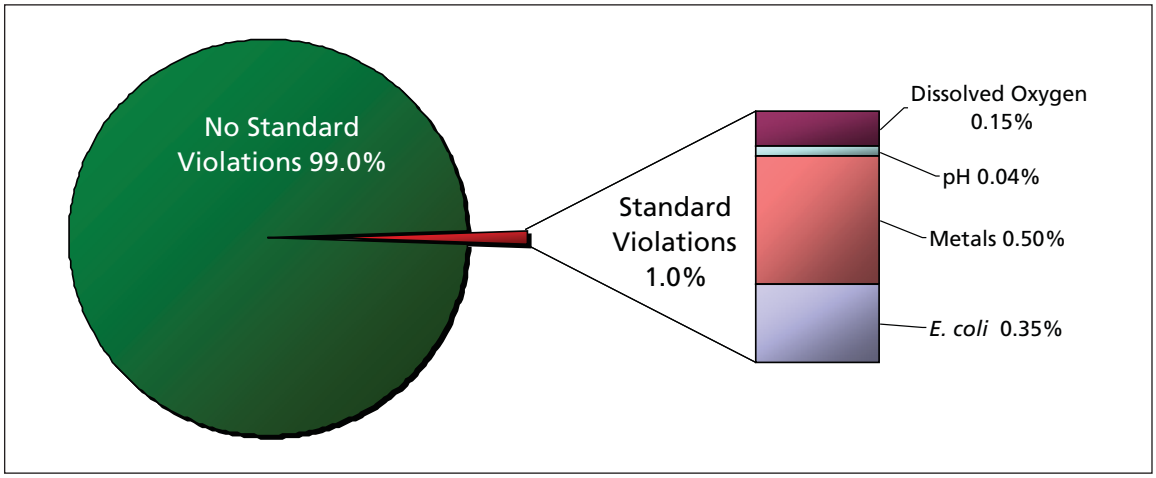


Figure 3-19. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Curecanti NRA, 2006–2008.

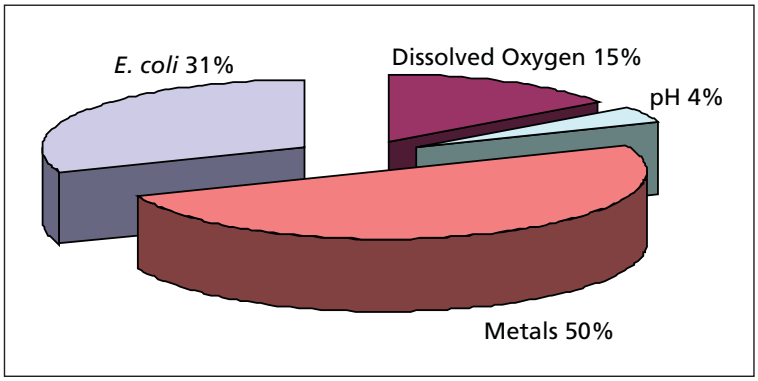


Figure 3-20. Most commonly exceeded water quality standards at Curecanti NRA, 2006–2008.

Table 3-5. Exceedances of surface water quality standards for sites sampled in or near Curecanti NRA, 2006–2008.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
Beaver Creek at Hwy 50 near Gunnison, CO	DWS	Manganese, Dissolved	50	µg/L	18	22
Blue Creek at Hwy 50 near Sapinero, CO	ALC1	Dissolved oxygen	7	mg/L	21	10
	ALC1	Copper, Dissolved	HD	µg/L	21	19
	RECE	*E. coli*	126	cfu/100 ml	34	20
Pine Creek at Hwy 50 near Sapinero, CO	ALC1	Dissolved oxygen	7	mg/L	19	11
Red Creek near mouth near Sapinero, CO	ALC1	Dissolved oxygen	7	mg/L	19	21
	DWS	Manganese, Dissolved	50	µg/L	19	74
East Elk Creek near mouth near Sapinero, CO	ALC1	Dissolved oxygen	7	mg/L	18	11
	DWS	Manganese, Dissolved	50	µg/L	18	61
Curecanti Creek near Sapinero, CO	RECE	*E. coli*	126	cfu/100 ml	17	18
Cimarron River below Squaw Creek near Cimarron, CO	RECE	*E. coli*	126	cfu/100 ml	35	26

Use code: DWS = drinking-water supply; ALC1 = aquatic life cold water class 1 (spawning present); RECE = existing primary-contact recreation; HD = hardness-dependent

present) for 10% of evaluations, but never exceeded the standard for aquatic life cold-water class 1 (spawning absent). *E. coli* exceeded the existing primary-contact recreation standard for 20% of evaluations.

3. ***Pine Creek at Hwy 50 near Sapinero, Colorado.*** This site exceeded the dissolved oxygen standard for aquatic life cold-water class 1 (spawning present) for 15% of evaluations. However, DO concentrations never exceeded the standard for aquatic life cold-water class 1 (spawning absent).

4. ***Red Creek near mouth (Sapinero, CO).*** At this site, exceedances were observed for dissolved oxygen and dissolved manganese for 33% and 67% of site visits, respectively. Dissolved oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning present), but never exceeded the standard for aquatic life cold-water class 1 (spawning absent). Dissolved manganese concentrations exceeded the chronic standard for drinking-water supply. There are no drinking-water supplies drawn from Red Creek within or outside Curecanti NRA.

5. ***East Elk Creek near mouth near Sapinero, Colorado.*** This site exceeded the dissolved oxygen and dissolved manganese standards for 18% and 64% of evaluations, respectively. Dissolved oxygen concentrations failed to meet the standard for aquatic life cold-water class 1 (spawning present), but never exceeded the standard for aquatic life cold-water class 1 (spawning absent, 6.0 mg/L). Dissolved manganese measurements exceeded the drinking-water standard. There are no drinking-water supplies drawn from East Elk Creek within or outside Curecanti NRA.

6. ***Curecanti Creek near Sapinero, Colorado.*** This site exceeded the existing primary-contact recreation standard for *E. coli* for 25% of evaluations.

7. ***Cimarron River below Squaw Creek near Cimarron, Colorado.*** This site exceeded the existing primary-contact recreation standard for *E. coli* for 26% of evaluations.

3.6.3 Discussion

3.6.3.1 Metals

The chronic manganese standard for drinking-water supply was exceeded at East Elk, Red, and Beaver creeks. These exceedances did not raise significant concerns because there are no drinking-water intakes on these streams. These tributaries drain areas of public land (includ-

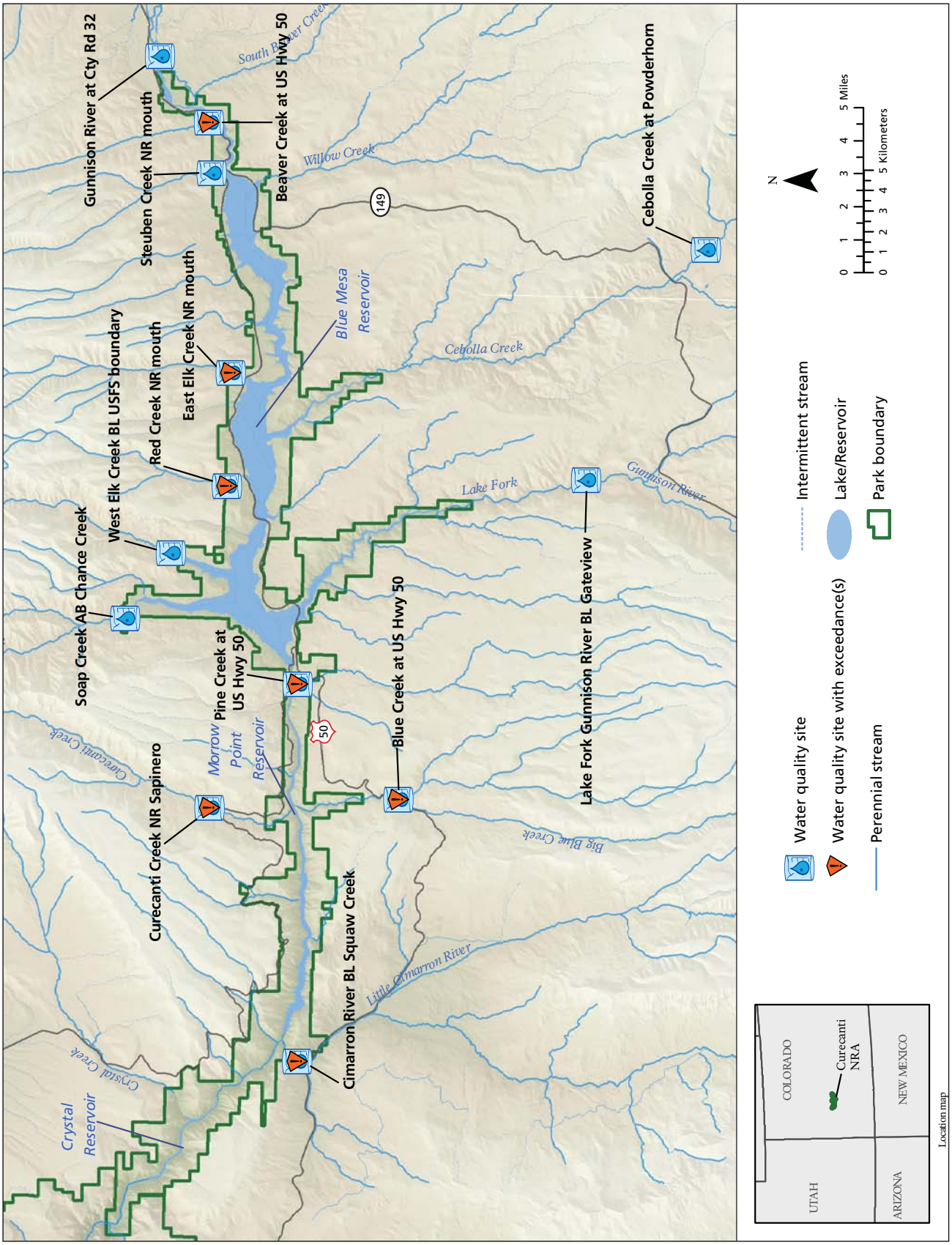


Figure 3-21. Water quality sites sampled in Curecanti NRA, 2006–2008.

ing the West Elk Wilderness) that are minimally impacted by human activities, and it is likely that the source of manganese is natural weathering. It should also be noted that the concentration of manganese in these and other water bodies did not exceed criteria for aquatic life, and that the drinking-water standard of 50 μg/L is for odor, color, and staining, not human health.

It may be possible to request exemptions or site-specific manganese criteria if sufficient evidence exists to make a strong case for naturally occurring conditions that exceed criteria, and no drinking-water source exists on the water bodies. Such a change would not improve water quality, but would make accounting for exceedances more straightforward, especially if these conditions are already recognized by the Colorado State Water Quality Control Commission.

The copper exceedances in Blue Creek occurred during a period sampled by an outside (non-NPS) source. These exceedances were not previously present, nor were they recorded after the NPS resumed monitoring Blue Creek. Therefore, it seems likely that the copper exceedances observed on Blue Creek resulted from poor sample handling procedures, contaminated sampling equipment, or laboratory error.

Only one of nine samples collected on West Elk Creek resulted in a silver exceedance for the drinking-water standard. It is important to note that the reporting limit of the analytical procedure used to measure this result was greater than the drinking-water standard for silver. Thus, the accuracy of this result is questionable, and does not warrant concern.

3.6.3.2 E. coli

The primary-contact recreation standard for *E. coli* was exceeded on Blue Creek, the Cimmaron River below Squaw Creek, and Curecanti Creek near Sapinero. The unknown source of *E. coli* contamination could be from wildlife, domestic animals, humans, or a combination thereof.

During high-discharge events, runoff from the watershed and re-suspension of bedrock material contribute large amounts of sediment and organic material to streams. Fecal matter and its microbial components, such as *E. coli,* are carried into nearby steams, along with the silts and sands being eroded and re-suspended during these events. *E. coli* readily binds to benthic and suspended sediment, and is able to survive for prolonged periods when so attached (Sampson et al. 2006). In addition, *E. coli* concentrations have been shown to be positively correlated with turbidity levels (Smith et al. 2008). Therefore, elevated *E. coli* concentrations are more likely to occur during turbid, high-discharge events. However, if elevated concentrations occur in clear water conditions, a persistent source may exist. The majority of *E. coli* exceedances in Curecanti NRA occurred during average flow and clear water conditions. In some cases, there were insufficient data available to correlate some of the *E. coli* exceedances with flow and turbidity.

Because episodic storm events were not related to the observed *E. coli* exceedances, a persistent, seasonal bacterial source may exist upstream. Additionally, the majority of *E. coli* exceedances occurred during the late summer months, when recreational activity in the park is at its peak. Because the risk of primary contact is greatest at the same time when the *E. coli* exceedances tend to occur, it is recommended that park resource staff warn visitors of potential bacterial contamination and increase the rate of sample collection if an exceedance is observed in the future.

3.6.3.3 Dissolved oxygen

All dissolved oxygen exceedances in Curecanti NRA failed to meet the standard for cold-water aquatic life class 1 (spawning present, 7.0 mg/L), but did not exceed the standard for cold-water aquatic life class 1 (spawning absent, 6.0 mg/L). Seasonal fluctuations in DO concentrations occur in all surface water bodies. During the summer, low-flow conditions and elevated water temperatures work in concert to reduce the amount of oxygen dissolved in surface water. Because no results exceeded the aquatic life cold-water (spawning absent) standard, and all results that exceeded the aquatic life cold-water (spawning present) standard occurred during late summer, when there is presumably no spawning activity occurring, DO exceedances warrant little concern in the park.

3.6.4 Management implications

Generally, water quality of all streams in Curecanti NRA is excellent, with occasional exceedances due to naturally occurring conditions in the watersheds. A monitoring record of more than 10 years supports the findings in this report. Furthermore, overall water quality is sufficient to warrant consideration for all or a subset of park streams as Outstanding Natural Resource Waters

(ONRW), which would result in the establishment of source-specific criteria more stringent than typical water quality criteria, and would prevent any future point source pollutant inputs.

3.7 Dinosaur National Monument

3.7.1 Water quality summary

A total of 2,258 designated beneficial-use evaluations were completed for water quality results obtained between January 4, 2006 and December 2, 2009, at eight sites in or near Dinosaur NM. Of those 2,258 evaluations, 30 (1.3%) exceeded water quality standards or indications of impairment (Figure 3-22). Water quality standards were exceeded for four constituent categories, most commonly nutrients, metals, and dissolved oxygen (Figure 3-23).

3.7.2 Reportable exceedances

Based upon 1,259 total evaluations, four of eight sites monitored in or near Dinosaur NM did not have any water quality exceedances for the states of Utah or Colorado: Green River above Gates of Lodore (399 total evaluations), Green River near Jensen, Utah (180 evaluations), Yampa River near Craig, Colorado (404 total evaluations), and Yampa River near Maybell, Colorado (276 total evaluations). The other four monitored sites had exceedances (Table 3-6, Figure 3-24). The following discussion focuses only on sites that had exceedances.

1. ***Brush Creek at U149 Crossing.*** Selenium concentrations were measured at Brush Creek only twice during the period covered in this report. Of those two visits, this site exceeded the selenium standard for cold-water game fish for 50% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for secondary-contact recreation and cold-water game fish for 44% of evaluations.
2. ***Pot Creek above Calder Reservoir.*** This site exceeded the chronic and acute (5.0 mg/L)

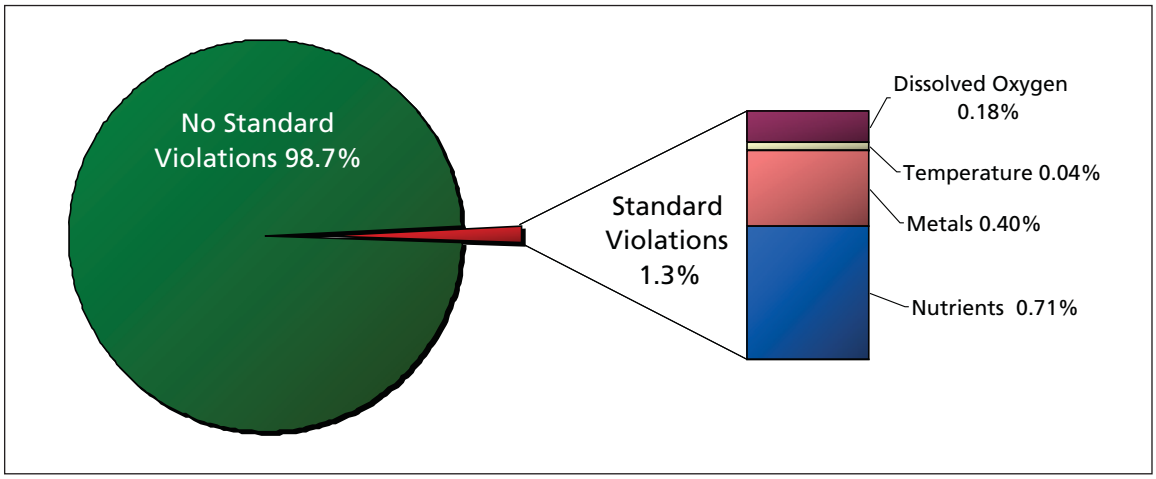


Figure 3-22. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Dinosaur NM, 2006–2009.

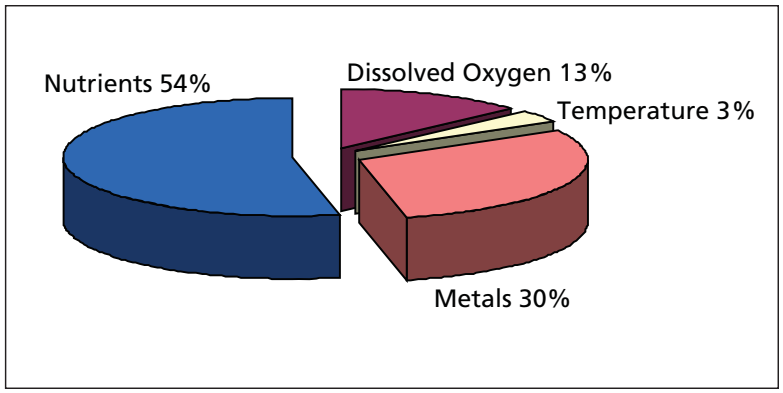


Figure 3-23. Most commonly exceeded water quality standards at Dinosaur NM, 2006–2009.

Table 3-6. Exceedances of surface water quality standards for sites sampled in or near Dinosaur NM, 2006–2009.

	Site	Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
1	Brush Ck at U149 Crossing	2B, 3A	Phosphorus, Total	0.05	mg/L	9	44
		3A	Selenium, Dissolved	4.6	µg/L	2	50
2	Pot Creek above Calder Reservoir	3A	Dissolved oxygen	6.5	mg/L	4	25
		2B, 3A	Phosphorus, Total	0.05	mg/L	4	25
3	Pot Creek above Matt Warner Reservoir	2B, 3A	Phosphorus, Total	0.05	mg/L	6	17
		3A	Dissolved oxygen	6.5	mg/L	4	25
		3A	Temperature, Water	20	°C	6	17
4	Yampa River at Deerlodge Park, CO	ALW1	Iron, Total Recoverable	1,900	µg/L	12	42

Use codes: ALW1 = aquatic life warm 1; 2B = secondary-contact recreation; 3A = cold-water game fish

cold-water game fish standard for dissolved oxygen for 25% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for secondary-contact recreation and cold-water game fish for 50% of evaluations. There were only four site visits at Pot Creek above Calder Reservoir during the period covered in this report.

3. ***Pot Creek above Matt Warner Reservoir.*** This site exceeded the cold-water game fish standard for temperature for 17% of evaluations, and exceeded the chronic and acute cold-water game fish standard for dissolved oxygen for 25% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for secondary-contact recreation and cold-water game fish for 17% of evaluations. There were only six site visits at Pot Creek above Matt Warner Reservoir during the period covered in this report.

4. ***Yampa River at Deerlodge Park, Colorado.*** This site exceeded the State of Colorado water segment-specific warm-water aquatic life standard for total recoverable iron for 42% of evaluations.

3.7.3 Discussion

3.7.3.1 Brush Creek

The Brush Creek watershed contains exposed portions of the Phosphoria Formation, a known source of industrial phosphorus, at the surface (http://minerals.usgs.gov/west/projects/phos.htm). The black shale deposits that comprise the Phosphoria Formation also commonly contain elevated levels of selenium and other metals. Overland flow events may transport significant loads of selenium from exposed shale deposits into surface water bodies (see Mancos Shale discussion, Section 3.1.3.4). Although elevated concentrations of total phosphorus and selenium in Brush Creek are likely derived from natural erosion processes within the watershed, the presence of a phosphate mine upstream from the sample site may also contribute to the observed levels of selenium and total phosphorus (http://minerals.usgs.gov/west/projects/phos.htm). Commensurate measurements indicate that elevated total phosphorus concentrations are not causing eutrophication. Available data were limited, and conclusive statements cannot be made regarding sources of selenium and phosphorus in the watershed.

3.7.3.2 Pot Creek

The water quality results available for Pot Creek were collected as a part of an increased monitoring effort following the placement of Matt Warner and Calder reservoirs on the 303(d) list of impaired water bodies for elevated total phosphorus and low dissolved oxygen concentrations. Eutrophication of these water bodies caused large algal blooms in the past. A few dozen cattle were

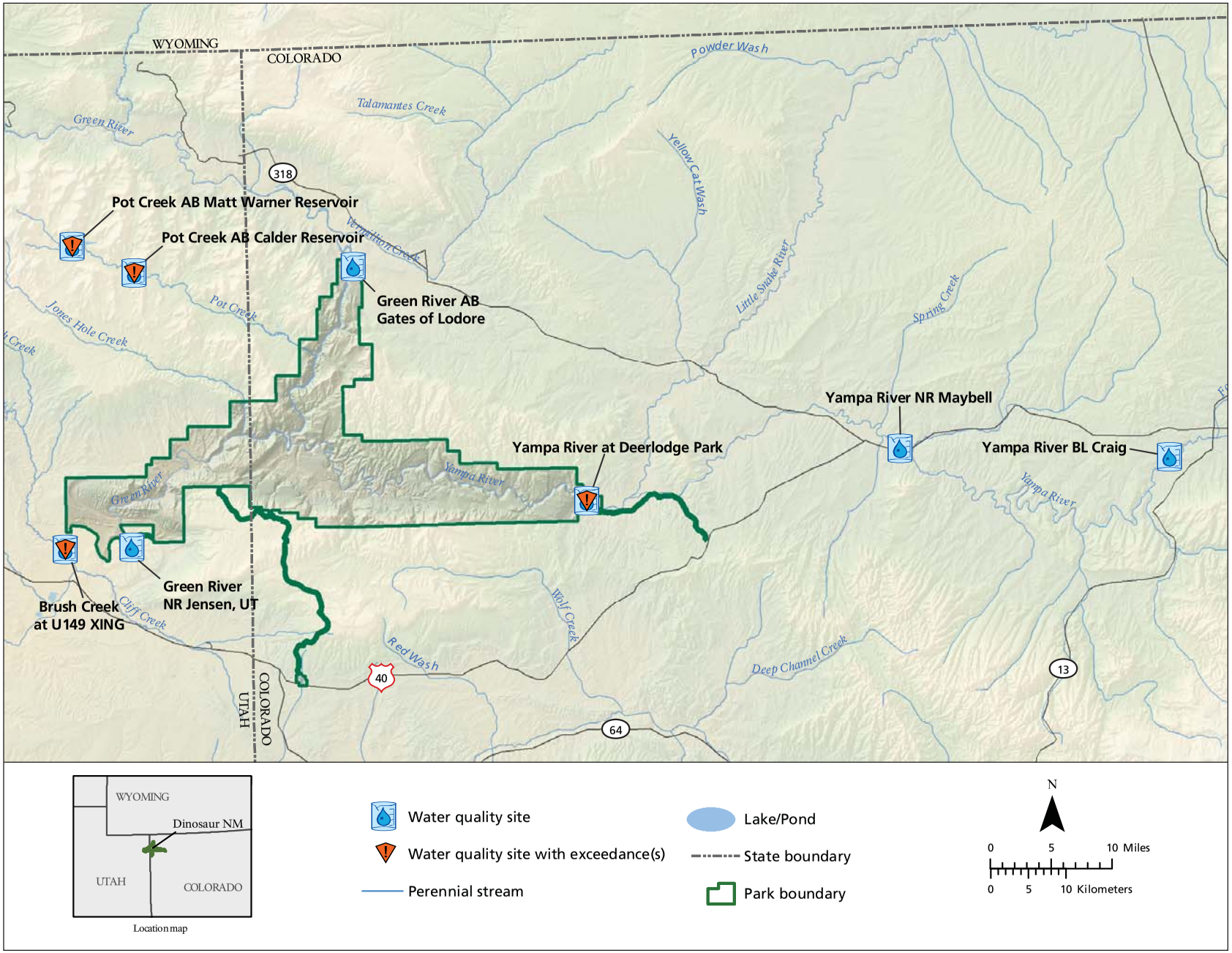


Figure 3-24. Water quality sites sampled in Dinosaur NM, 2006–2009.

reported dead (due to liver failure), after consuming water from Matt Warner Reservoir during one of these algal blooms, and a large fish kill event in 2004 was also observed. However, the fish kill occurred just prior to ice-off, and was attributed to a prolonged period of drought in the watershed. A TMDL study was initiated in response to the adverse conditions observed in Matt Warner and Calder reservoirs (UDWQ 2007).

Water quality exceedances in Pot Creek appear identical to those observed in Matt Warner and Calder reservoirs (i.e., high temperature, elevated total phosphorus, and low dissolved oxygen). However, the combination of drought and reservoir water allocation may have contributed to extreme low-flow conditions present in Pot Creek during summer 2006. The presence of stagnant low- or no-flow pools throughout the creek may have produced the low dissolved oxygen conditions observed. It is not known if elevated total phosphorus conditions caused eutrophication and resulted in the low dissolved oxygen concentrations observed. However, considering the conditions observed in both reservoirs, it is likely that some degree of eutrophication occurred in Pot Creek.

3.7.3.3 Metals (Yampa River)

Elevated iron and manganese concentrations in the Yampa River have been well documented (Roehm 2004; Harza 2002; Thoma et al. 2007). Naturally occurring mineralization of iron and manganese minerals is prevalent in the watershed. Elevated concentrations may also be a result of runoff from mining operations throughout the basin. Iron and manganese exceedances have been regularly observed in the past, are included in two State of Colorado watershed management plans, and are not unique to the lower portions of the Yampa River watershed.

The manganese criterion for drinking water is considered a secondary standard because it is designated for "welfare" impacts, such as color, odor, and staining, and not human health. Secondary standards for drinking water are based upon the 85th percentile value of relevant historic data since January 1, 2000 (CDPHE 2006). Less than 10% of site visits for the Yampa River below Craig, Colorado (69.7 μg/L) and at Deerlodge Park (260.9 μg/L) exceeded the secondary standard for manganese.

In 2006, the aquatic life criterion for total recoverable iron was changed from 1,000 μg/L to 1,900 μg/L for the segment of the Yampa River that includes Dinosaur NM (CDPHE 2006). Total recoverable iron concentrations in the Yampa River at Deerlodge Park, Colorado, were consistently higher than concentrations observed at Craig, Colorado, indicating that there is a distinct source of iron located between these two sites.

3.7.4 Management implications

Overall water quality in Dinosaur NM is excellent. Elevated iron concentrations on the Yampa River have been previously evaluated with respect to aquatic life (Roehm 2004; Harza 2002), and are used more as an indicator of sediment loading than of impacts on aquatic life, due to questions regarding toxicity (CDPHE 2008). Impacts associated with water depletions within the Yampa Basin, non-native and invasive aquatic organisms, and the cumulative effects of point and non-point source pollution throughout the watershed have tended to receive the greatest attention with respect to aquatic life (Roehm 2004; Harza 2002).

Adverse water quality conditions in Pot and Brush creeks were observed during a prolonged period of drought in the watershed, and eutrophication conditions present in nearby reservoirs initiated a TMDL study. Water quality conditions in Pot Creek were similar to those present in Matt Warner and Calder reservoirs. Results of the TMDL study indicated that water quality conditions in Matt Warner Reservoir supported its cold-water fishery beneficial-use designation, while water quality conditions in Calder Reservoir only partially supported its cold-water fishery beneficial-use designation. Load reductions for Calder Reservoir, and riparian habitat improvements along Pot Creek, were recommended accordingly.

3.8 Golden Spike National Historic Site

3.8.1 Water quality summary

A total of 13 designated beneficial-use evaluations were completed for water quality results obtained between July 10, 2006 and June 20, 2007, at one site near Golden Spike National Historic Site (NHS). Of those 13 evaluations, one (7.7%) exceeded water quality standards (Figure 3-25). Water quality standards were exceeded for one constituent category, total dissolved solids (Figure 3-25).

3.8.2 Reportable exceedances

Blue Creek at County Road 504 was the only site monitored in or near Golden Spike NHS during the period covered in this report. It exceeded the water quality standard for total dissolved solids for the State of Utah (Table 3-7, Figure 3-26).

Blue Creek at County Road 504. The concentration of total dissolved solids was greater than the agricultural-uses standard for the only site visit that occurred at this site.

3.8.3 Discussion and management implications

3.8.3.1 Total dissolved solids

Naturally elevated concentrations of total dissolved solids in surface water bodies are not uncommon in Utah; they result from the weathering of various mineral-rich lithologies. Natural weathering of mineral-rich deposits left behind from Prehistoric Lake Bonneville is likely contributing dissolved solids to Blue Creek.

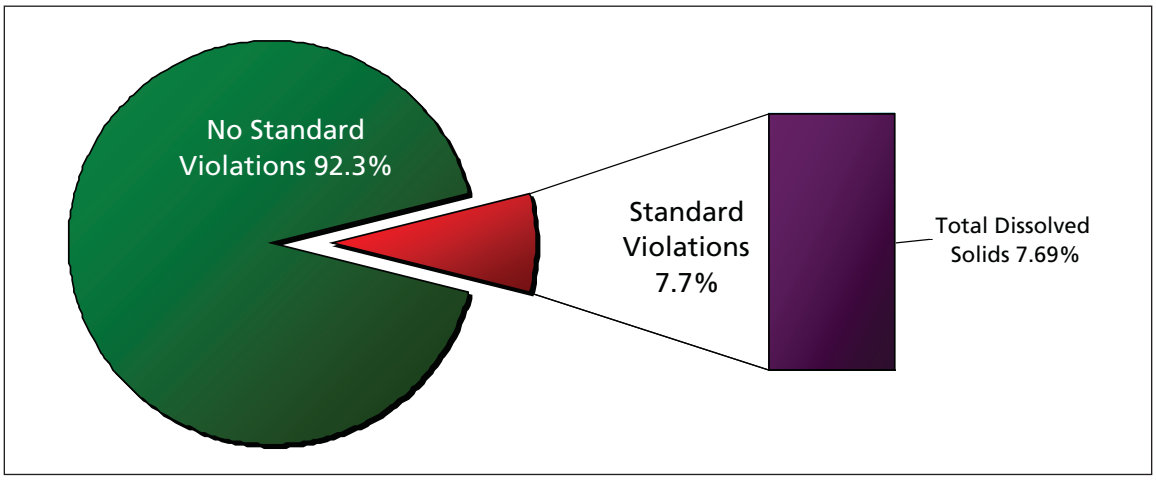


Figure 3-25. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Golden Spike NHS, 2006–2007.

Table 3-7. Exceedances of surface water quality standards for sites sampled in or near Golden Spike NHS, 2006–2007.

Site	Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
Blue Ck at CR504 crossing E of Golden Spike NHS	4	Total Dissolved Solids	1,200	mg/L	1	100

Use codes: 4 = agricultural uses

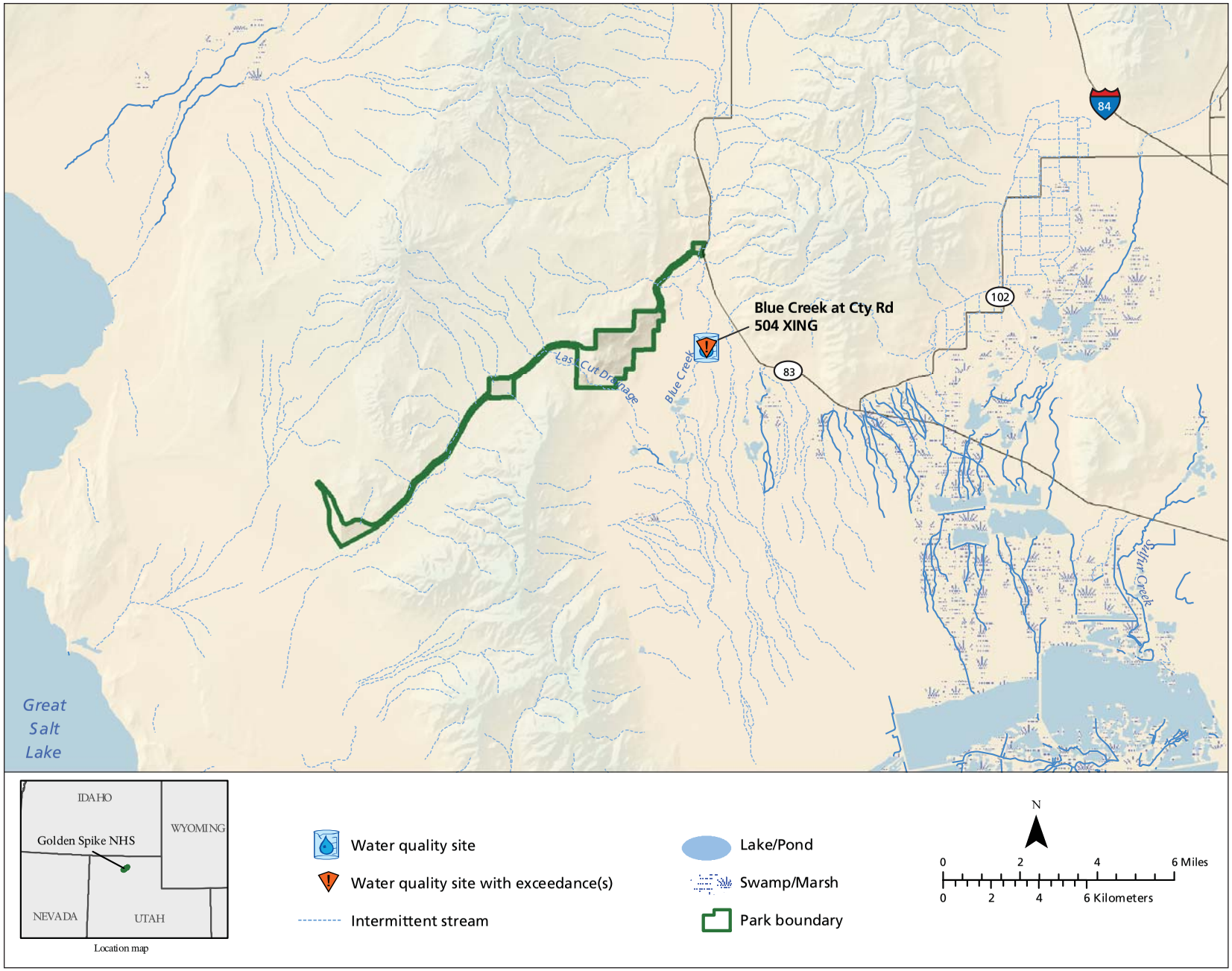


Figure 3-26. Water quality sites sampled in or near Golden Spike NHS, 2006–2007.

3.9 Hovenweep National Monument

3.9.1 Water quality summary

A total of 628 designated beneficial-use evaluations were determined for water quality results obtained between July 10, 2006 and June 7, 2007, at three sites in Hovenweep NM. Of those 628 evaluations, 25 (4.0%) exceeded water quality standards or indications of impairment (Figure 3-27). Water quality standards were exceeded for five constituent categories, most commonly nutrients, dissolved oxygen, and pH (Figure 3-28).

3.9.2 Reportable exceedances

One of the three sites sampled did not have water quality exceedances for the State of Utah, based upon 243 total evaluations: Hackberry House Spring. The other two sites had exceedances (Table 3-8, Figure 3-29). The following discussion focuses on the two sites that had exceedances.

1. *Square Tower Spring.* Dissolved oxygen concentrations at Square Tower Spring failed to meet both the chronic dissolved oxygen standard for warm-water game fish and the acute warm-water game fish (early life stage present) (5.0 mg/L) standard for 27% of evaluations.

2. *Cajon Spring.* Cajon Spring had exceedances for dissolved aluminum, dissolved oxygen, and pH for 100%, 43%, and 17% of evaluations, respectively. Cajon Spring also had an indication of impairment for total phosphorus for 71% of evaluations. The aluminum concentrations exceeded the chronic warm-water game fish standard, but not the acute (750 µg/L) standard. Only two aluminum results were available for analysis during the period covered in this report. Dissolved oxygen concentrations failed to meet the chronic and acute warm-water game fish (early life stage present) (5.0 mg/L) standards. One of

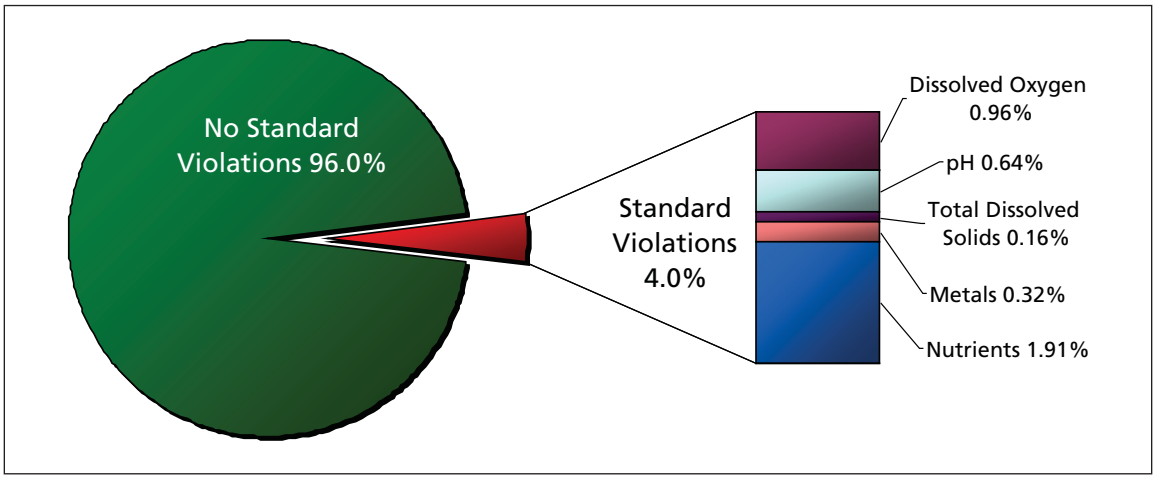


Figure 3-27. Percentage of use evaluations that exceeded standards, and the causes of exceedances, Hovenweep NM, 2006–2007.

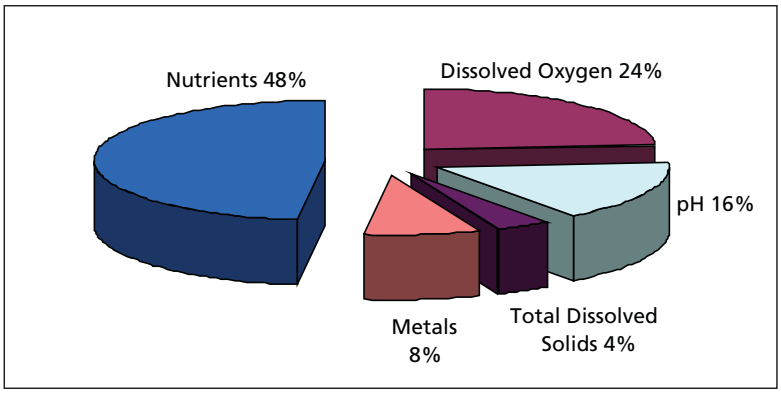


Figure 3-28. Most commonly exceeded water quality standards at Hovenweep NM, 2006–2007.

Table 3-8. Exceedances of surface water quality standards for sites sampled in or near Hovenweep NM, 2006–2007.

	Site	Use code	Constituent	Numeric standard	Units	Total evaluations	% evaluations exceeded standard
1	Square Tower Spring	3B	Dissolved oxygen	5.5	mg/L	11	27
2	Cajon Spring	3B	Aluminum, Dissolved	87	µg/L	2	100
		3B	Dissolved oxygen	5.5	mg/L	7	43
		1, 2A, 3B, 4	pH	9	none	6	17
		2A, 3B	Phosphorus, Total	0.05	mg/L	7	71

Use codes: 3B = warm-water game fish; 1 = drinking-water standard; 2A = primary-contact recreation; 4 = agricultural uses

six evaluations resulted in a pH exceedance for the drinking-water, primary-contact recreation, warm-water game fish, and agricultural-uses standards.

3.9.3 Discussion

3.9.3.1 Dissolved oxygen

Dissolved oxygen exceedances likely resulted from separate and distinct processes at Cajon Spring and Square Tower Spring. Cajon Spring has little-to-no actual spring input and is largely or completely a rain-catchment pool. Surface water influx during precipitation and/or snowmelt events cause DO concentrations to rise in the Cajon pool. After a rain event, the pool, which is relatively deep, stagnates, and concurrent processes, such as elevated temperatures and increased microbial decomposition, cause dissolved oxygen concentrations to decrease.

On the other hand, Square Tower Spring is a small, constant, spring-fed pool in the back of a protected alcove; it receives little direct influence from precipitation events. The oxygen-depleted groundwater discharged at the Square Tower Spring site is a natural phenomenon, and indicates that the water has been underground long enough to achieve complete or significant biological reduction of oxygen.

3.9.3.2 Metals

Two samples from Square Tower Spring exceeded the chronic warm-water game fish standard for aluminum. Because this site is predominantly groundwater-fed, the observed aluminum concentrations are likely the result of natural weathering. However, potential sources of aluminum in the watershed could not be verified. Because there were only two metals results available for analysis during the period covered in this report, and neither exceeded the acute warm-water game fish standard, continued monitoring and further investigation is warranted to understand the nature of aluminum concentrations in Square Tower Spring.

3.9.3.3 pH

One site visit at Cajon Spring resulted in a pH exceedance for four different designated-use standards: drinking water, primary-contact recreation, warm-water game fish, and agricultural uses. Because all four standards (identical criteria) were exceeded as a result of one site visit, and the overall number of standard evaluations at Hovenweep NM was relatively small, the percentage of exceedances per constituent category is somewhat disproportionate for pH. The pH level that caused the exceedance (9.04) was only slightly greater than the standard. Extreme physical–chemical conditions that cause water quality fluctuations are expected to occur at Cajon Spring, because it is a rain-catchment pool. Above-average DO concentrations, colder than average temperatures, and clear water conditions existed at the time of the pH exceedance, in November 2006. Elevated photosynthetic activity may have produced the conditions that resulted in the pH exceedance. The highest pH value recorded between 1999 and 2004 was 8.55 (Schelz

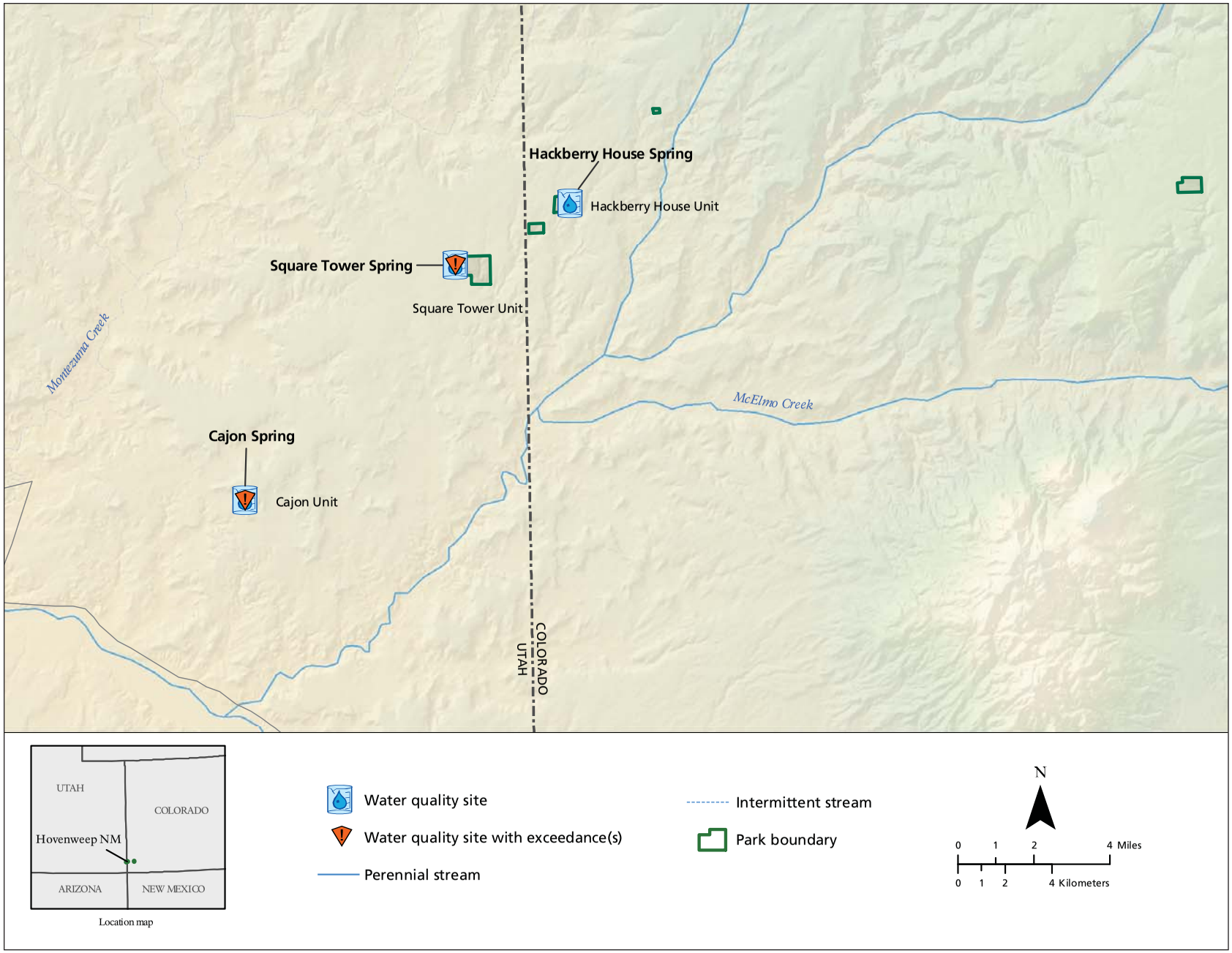


Figure 3-29. Water quality sites sampled in Hovenweep NM, 2006–2007.

and Moran 2005). There were only six results available for analysis during the period covered in this report, and there was only one observed exceedance. No conclusive statements can be made with regard to the significance of this site visit on long-term water quality.

3.9.3.4 Nutrients

Naturally elevated phosphorus conditions are common throughout the Northern Colorado Plateau, and are suspected, in many cases, to be geologic in origin. Anthropogenic activities, such as pasture irrigation, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Further investigation is warranted to determine if the observed total phosphorus concentrations are natural or anthropogenic in origin.

3.9.4 Management implications

All three sites in Hovenweep NM are protected for warm-water aquatic life; however, the isolated nature of these water bodies differentiates them from others nearby. The aquatic life standards for Square Tower and Cajon springs were intended to protect the segment of the San Juan River and its tributaries between Lake Powell and the Colorado–Utah state line. These standards are applicable by law; however, the ephemeral and intermittent nature of these water bodies significantly differentiates them from the San Juan River. In fact, there are no known breeding populations of fish within Square Tower or Cajon springs, and all water that enters the San Juan River from the park is derived from episodic or seasonal-driven events that likely do not reflect long-term water quality conditions at these sites. Comparison of water quality results against long-term trends observed within these systems will better detect the timing and occurrence of degradation (if present) than comparison of these systems against water quality standards designed for large water bodies, such as the San Juan River.

The volume of water present at all three sites monitored in Hovenweep NM was below average during summer 2009; in fact, Cajon Spring pool was completely dry from July through October. A dry winter (2008–2009) and summer (there were no major monsoonal thunderstorms during summer 2009) may have contributed to the low water levels observed in these pools (see Figure B, next page). A correspondence was evident between below-normal precipitation in 2009, depressed vegetation growth in the area, and reduced spring flow and pool elevations (see feature, next page). This prolonged drought period effectively reduced the amount of water available for aquifer recharge from precipitation for some water resources at the park. Water levels at all three sites increased during fall 2009, returning to near-average pre-drought volumes.

Relationships between Precipitation, NDVI, and Spring Flow at Hovenweep NM in 2009

Background

The 10-year record of Normalized Difference Vegetation Index (NDVI), averaged across all units of Hovenweep NM (Figure A), shows that in most years there are two peaks in vegetation greenness: one in spring, related to cumulative soil-moisture recharge from the previous fall, winter, and early spring; and another in late summer, stimulated by monsoon weather patterns. NDVI peaks, and their timing, result from the interaction of plant functional types (annual/perennial, early season/late season), phenology, substrate, and suitability of moisture and temperature for growth. Below-normal fall, winter, and spring precipitation resulted in poor vegetation condition in spring 2002 and 2006, whereas below-normal monsoon precipitation seems to explain poor vegetation condition in late summer 2009.

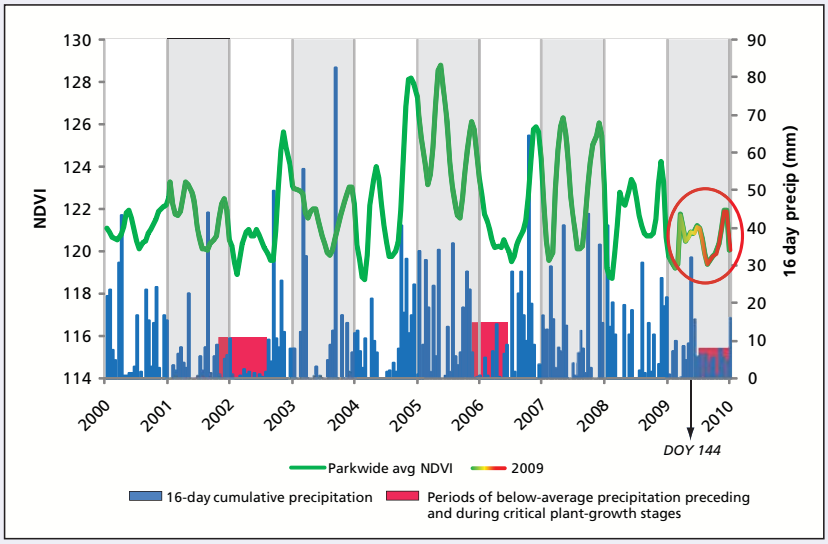


Figure A. The 10-year record of Normalized Difference Vegetation Index for Hovenweep NM, with the anomalous year 2009 circled. Late-season productivity (yellow/red line) was the lowest in 10 years at the park, corresponding with the lowest spring pool levels since 2005. This may indicate a short-term link between precipitation timing and groundwater recharge.

What Happened in 2009?

A closer look at NDVI and precipitation indicates how different 2009 was from previous years. In 2009, there were more periods of below-normal than above-normal precipitation relative to the historical mean, most noticeably during the monsoon season. The magnitude and duration of the corresponding impact to vegetation can be seen in the NDVI deficit, as NDVI was well below the historical average during the monsoon season. In 2009, monsoon precipitation (DOY 208–288), which sustains plant growth for the remainder of the year, was 62.4 mm (or 77%) below the historical average for the same period. Post-monsoon NDVI was 19.8 (8.1%) below the historical average.

The timing of precipitation is important for plant growth. For instance, although 32 mm (1.3 in) of precipitation fell near DOY 144 (May 22–May 31; Figure A), this moisture likely occurred too late to effect a response in early-season plants (at that time, early season species were already mature), but was too early or insufficient to stimulate abundant late-season growth without additional monsoon precipitation, as indicated by a below-normal late-season NDVI. The weak monsoon in 2009 corresponded with dramatically low late-season productivity and the lowest spring flow and pool elevations observed since measurements began in 2004 (Figure B).

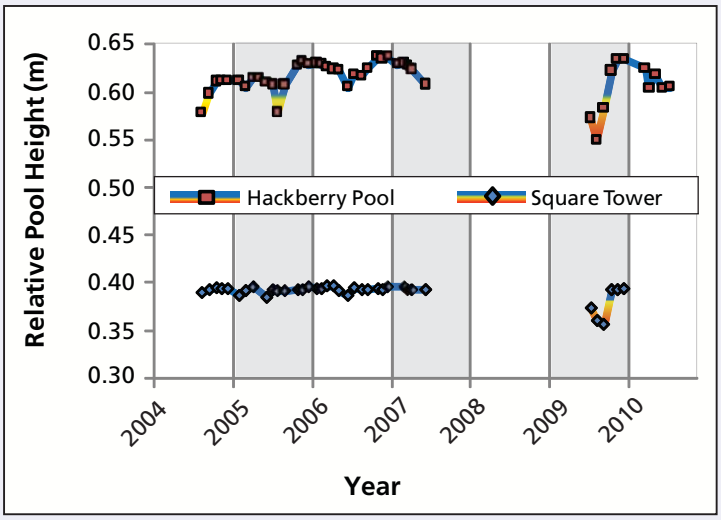


Figure B. Square Tower and Hackberry Spring pool stage. July, August, and September 2009 had the lowest pool stages recorded since monitoring began in 2004, corresponding with lower than normal precipitation and vegetation growth for the same period.

Tying it All Together

The time series of precipitation and NDVI paint a clear picture of the importance of precipitation abundance and timing for plant growth and, apparently, spring flows at Hovenweep NM that was previously not well understood. Initially, the dramatic NDVI deficit prompted a closer look at precipitation data, which in turn showed a shortfall in 2009. When these data were examined in conjunction with pool-elevation data collected by Southeast Utah Group staff, it soon became clear that at least some springs and pools respond to short-term fluctuations in precipitation.

Having the ability to quantitatively monitor vegetation response to abundance and timing of precipitation over large areas will improve our overall understanding of biophysical relationships in NCPN parks. At Hovenweep NM, knowing that recharge rates for some springs and pools is fairly brief can aid interpretation of spring and seep monitoring results, as monitoring of plant growth and spring flows continues under a changing climate.

3.10 Natural Bridges National Monument

3.10.1 Water quality summary

A total of 626 designated beneficial-use evaluations were completed for water quality results obtained between July 10, 2006 and June 20, 2007, at three sites at Natural Bridges NM. Of those 626 evaluations, 23 (3.5%) exceeded water quality standards or indications of impairment (Figure 3-30). Water quality standards were exceeded for four constituent categories, most commonly nutrients, dissolved oxygen, and metals (Figure 3-31).

3.10.2 Reportable exceedances

All three sites sampled had water quality exceedances for the State of Utah (Table 3-9, Figure 3-32).

1. ***Armstrong Canyon near Kachina Natural Bridge.*** Armstrong Canyon Creek, one-half mile upstream of Kachina Bridge, exceeded the chronic dissolved oxygen standard for warm-water game fish for 27% of evaluations, and had an indication of impairment for total phosphorus for the secondary-contact recreation and warm-water game fish standards for 22% of evaluations.

2. ***Owachomo Bridge Spring at confluence of Armstrong and Tuwa Canyons.*** Owachomo Bridge Spring had exceedances for dissolved aluminum, dissolved copper, and dissolved oxygen, and an indication of impairment for total phosphorus. Dissolved aluminum and dissolved copper concentrations exceeded the chronic warm-water game fish standard for 33% of evaluations. Dissolved copper concentrations also exceeded the acute standard for warm-water game fish (13 µg/L). Dissolved oxygen concentrations were below the chronic warm-water game fish standard and the acute warm-water game fish (early life stage present) standard (5.0 mg/L) for 30% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for the secondary-contact

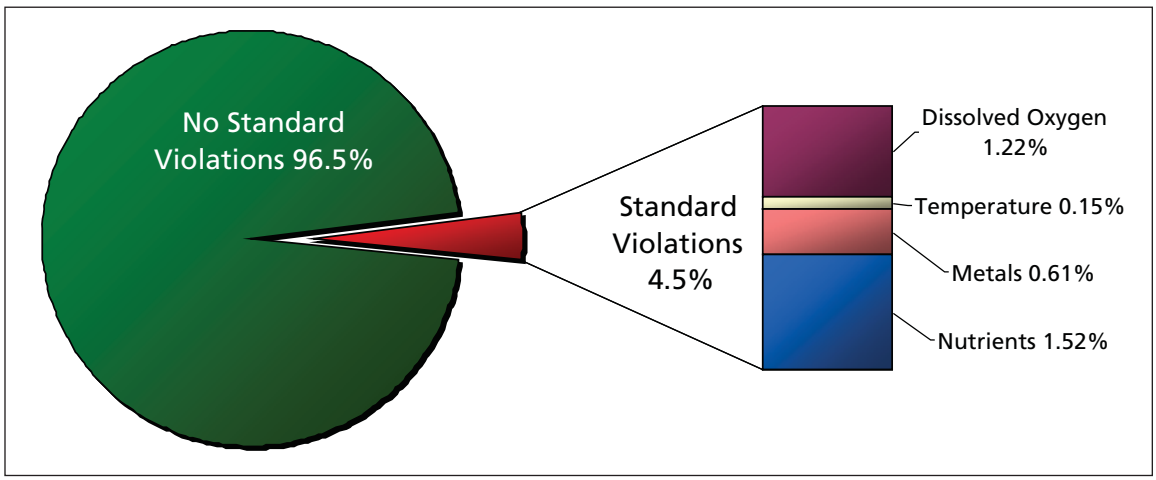


Figure 3-30. Percentage of use evaluations that exceed standards, and the causes of exceedances, Natural Bridges NM, 2006–2007.

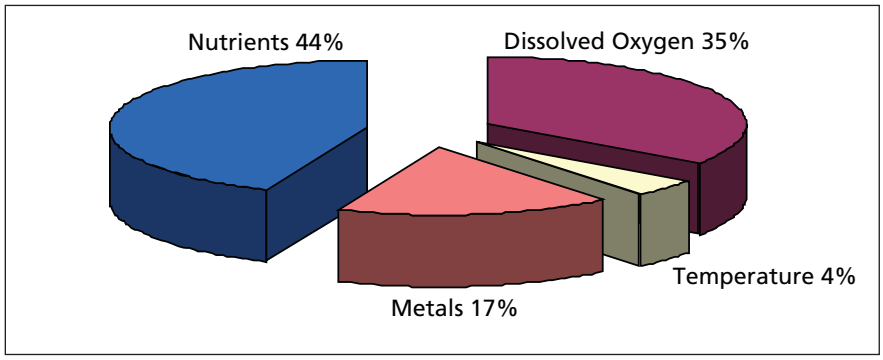


Figure 3-31. Most commonly exceeded water quality standards at Natural Bridges NM, 2006–2007.

Table 3-9. Exceedances of surface water quality standards for sites sampled in Natural Bridges NM, 2006–2007.

	Site	Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
1	Armstrong Canyon near Kachina Natural Bridge	3B	Dissolved oxygen	5.5	mg/L	9	22
		2B, 3B	Phosphorus, Total	0.05	mg/L	9	22
2	Owachomo Bridge Spring at confluence of Armstrong and Tuwa canyons	3B	Aluminum, Dissolved	87	µg/L	3	33
		3B	Copper, Dissolved	HD	µg/L	3	33
		3B	Dissolved oxygen	5.5	mg/L	10	30
		2B, 3B	Phosphorus, Total	0.05	mg/L	10	10
3	Sipapu Bridge Spring 0.25 mi above Bridge	3B	Aluminum, Dissolved	87	µg/L	3	67
		3B	Dissolved oxygen	5.5	mg/L	10	30
		2B, 3B	Phosphorus, Total	0.05	mg/L	10	20

Use codes: 3B = warm-water game fish; 2B = secondary-contact recreation

recreation and warm-water game fish standards for 10% of evaluations.

3. ***Sipapu Bridge Spring 0.25 mi above Bridge.*** Sipapu Bridge Spring had exceedances for dissolved aluminum, and dissolved oxygen, and an indication of impairment for total phosphorus. Dissolved aluminum concentrations exceeded the chronic warm-water game fish standard for 67% of evaluations, but did not exceed the acute warm-water game fish standard (750 µg/L). Dissolved oxygen concentrations failed to meet the chronic and acute (5.0 mg/L) warm-water game fish standard for 30% of evaluations. Total phosphorus concentrations exceeded the indication of impairment for the secondary-contact recreation and warm-water game fish standards for 20% of evaluations.

3.10.3 Discussion

3.10.3.1 Dissolved oxygen

Dissolved oxygen exceedances of the warm-water game fish standard are likely the result of environmental conditions and hydrologic processes. The oxygen-depleted groundwater discharged at Armstrong Canyon—and possibly the Owachomo Bridge Spring and Sipapu Bridge Spring sites—is a natural phenomenon, indicating that the water has been underground for long enough to achieve complete or significant biological reduction of oxygen. DO concentrations at all three sites undergo significant seasonal fluctuations.

These sites are canyon-bottom pools that probably receive groundwater flow at most times. They also receive seasonal surface flow from snowmelt and precipitation events. The Armstrong Canyon site is a large pool that receives both pool-bottom and back-wall groundwater seepage. Sipapu Bridge Spring is a much smaller pool than Owachomo Bridge Spring. Both are likely replenished, to some extent, via pool-bottom groundwater recharge, but recharge from overland flow events is likely the dominant source at these sites.

Environmental conditions deplete oxygen in surface water during summer low-flow periods, affect the Sipapu and Owachomo sites specifically, and may strongly influence water quality conditions observed in the Armstrong Canyon site, as well. Solar heating of the unshaded pools (Sipapu and Owachomo) increases temperatures and reduces the amount of oxygen that can be dissolved in water. Additionally, low-flow conditions produce stagnant pools that are poorly mixed (all three sites). Microbes that decompose organic matter also consume oxygen, decreasing dissolved oxygen in these warm pools. Intense DO stratification was noted at Sipapu Bridge Spring once during summertime macroinvertebrate monitoring, when DO concentration approached zero near pool bottoms. Exceedances occurred at

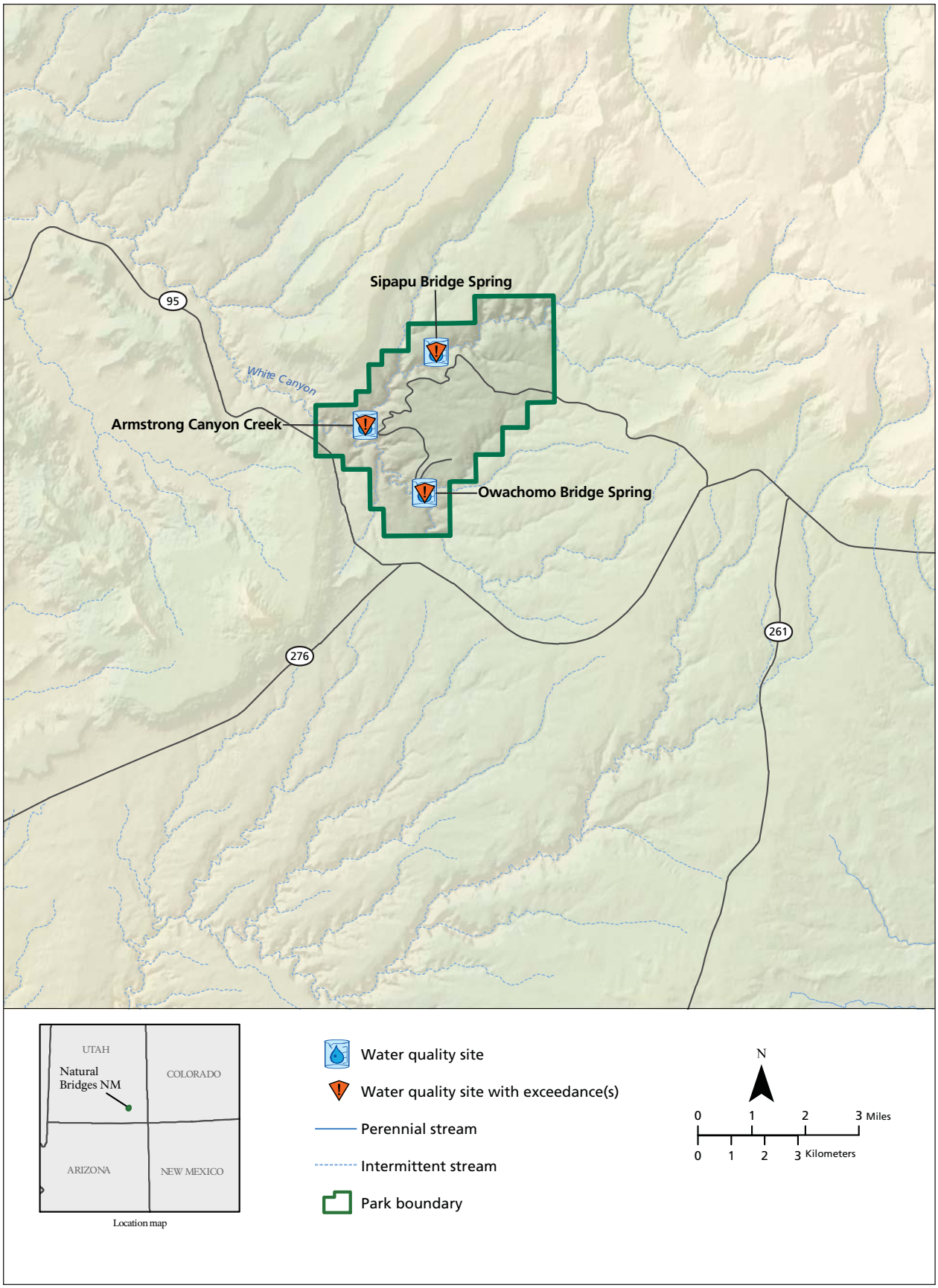


Figure 3-32. Water quality sites sampled in Natural Bridges NM, 2006–2007.

all three sites between June and mid-September 2006 and 2007.

3.10.3.2 Nutrients

Naturally elevated phosphorus conditions are common throughout the Northern Colorado Plateau, and are suspected, in many cases, to be geologic in origin. Anthropogenic activities, such as logging, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Further investigation is warranted to determine if the observed total phosphorus concentrations noted here are likely natural or anthropogenic in origin.

Total phosphorus concentrations at Owachomo and Sipapu bridge springs appear to be inversely related to flow (Figure 3-33). The elevated total phosphorus conditions observed from 2006 to 2007 occurred during summer low-flow periods, when a large groundwater component to surface water (i.e., baseflow) is expected to occur in spring-fed systems. Precipitation and snowmelt during the fall and winter dilute the overall contribution of groundwater flow to total flow. In areas where erosion is a major contributing factor to phosphorus in surface water, there is usually a direct relationship between flow and TP concentration (see Section 3.5, Figure 3-17). The inverse flow/TP relationship at Natural Bridges NM may imply that the source of total phosphorus at these sites is derived from groundwater rather than runoff, and is, thus, natural in origin.

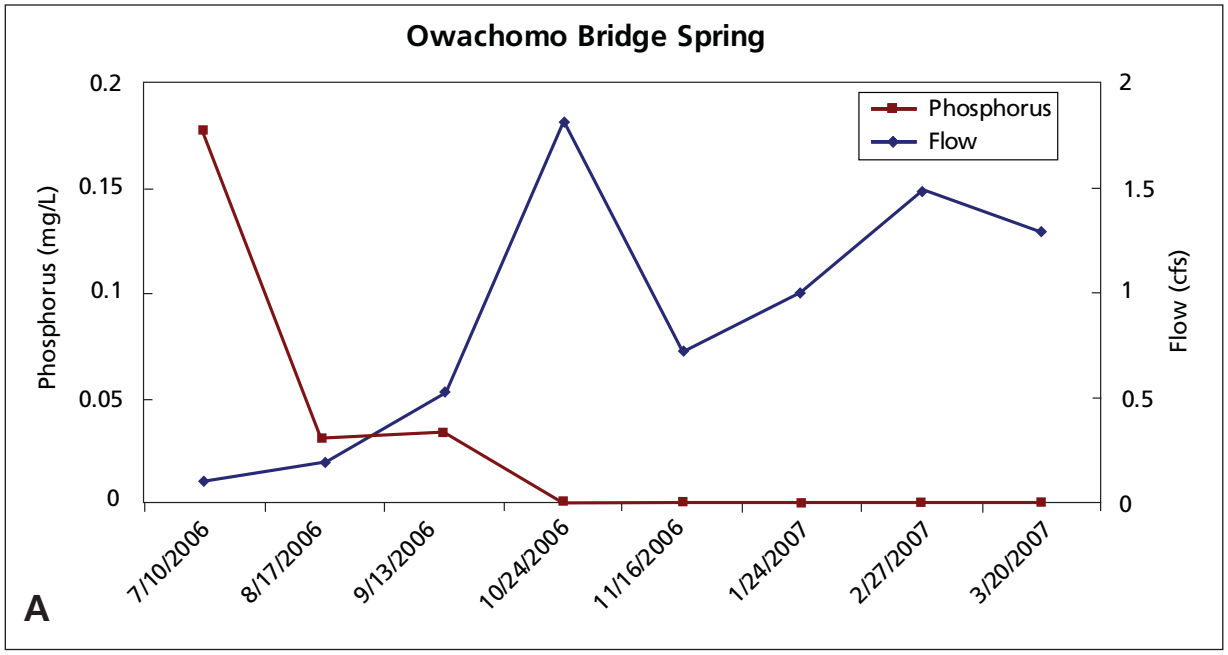
The Armstrong Canyon near Kachina Bridge site also has periodically elevated total phosphorus concentrations, but there was no clear relationship between flow and total phosphorus concentrations at this site. Because there was no surface flow at the site during any of the 2006–2007 visits, the phosphorus source here may also be derived from groundwater. However, phosphorus sorbed to sediments and deposited in the pool during runoff events may contribute to the observed levels. Continued monitoring will help determine likely sources of phosphorus.

3.10.3.3 Metals

One of three samples from Owachomo Bridge spring exceeded the chronic warm-water game fish standard for dissolved copper and dissolved aluminum, and two of three samples from Sipapu Bridge Spring exceeded the chronic warm-water game fish standard for dissolved aluminum. Because these sites are predominantly groundwater-fed, natural sources of aluminum and copper may be the cause of elevated concentrations. However, there were only three metals results available for analysis from each site, and further investigation is warranted to understand the nature of dissolved aluminum and copper concentrations in the Owachomo and Sipapu bridge springs.

3.10.4 Management implications

All three sites in Natural Bridges NM are protected for warm-water aquatic life; however, they are not expected to support all forms of aquatic life protected by their designated beneficial use (e.g., fish), due to intermittent flow and standards intended to protect designated uses in Lake Powell. Although these standards are applicable by law, the ephemeral, intermittent nature of these water bodies significantly differentiates them from Lake Powell and its major tributaries. In fact, there are no known breeding populations of fish within the park, and the vast majority of water that enters Lake Powell from Natural Bridges NM is derived from episodic or seasonally driven events that likely do not reflect the base-flow water quality conditions observed in these sites. Comparing results from these sites against standards written for Lake Powell gives an incomplete understanding of their condition. Whereas comparison against standards for Lake Powell does provide an indication of contributing loads to Lake Powell, it may be better to evaluate conditions at these sites by other means. Comparison of current observations against future long-term trends will serve to better protect these water bodies than comparison against applicable state water quality standards.



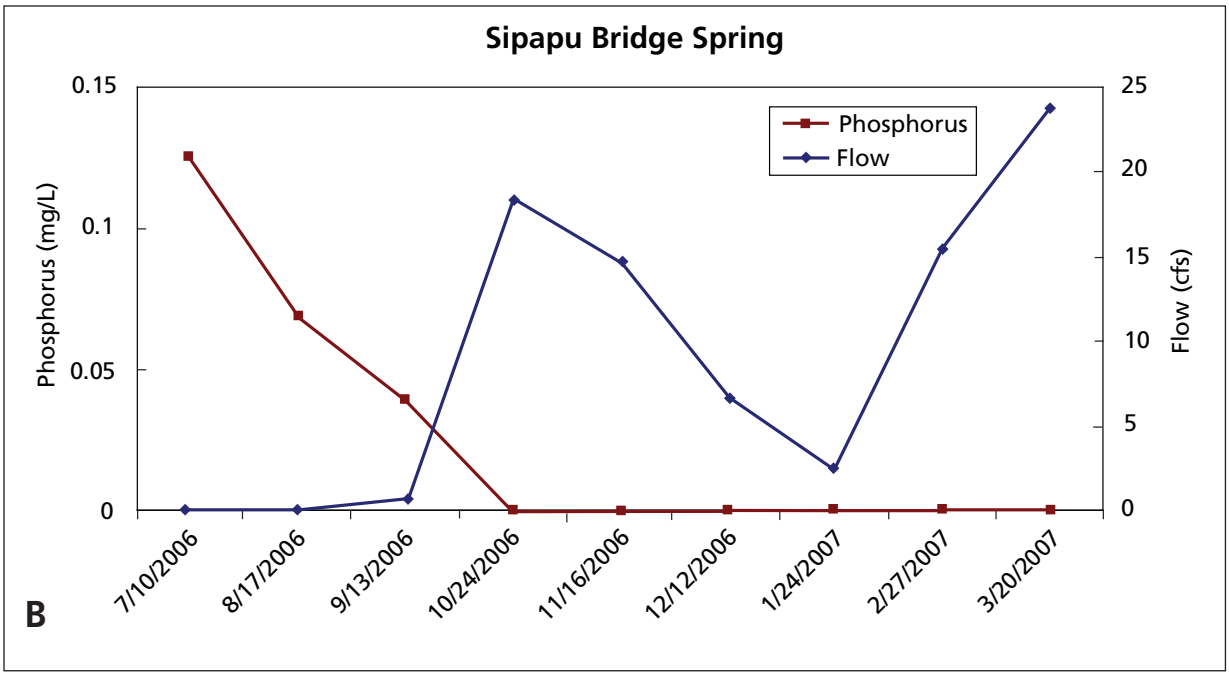


Figure 3-33. Total phosphorus versus flow at (a) Owachomo Bridge Spring and (b) Sipapu Bridge Spring, 2006–2007.

3.11 Timpanogos Cave National Monument

3.11.1 Water quality summary

A total of 226 designated beneficial-use evaluations were completed for water quality results obtained between July 29, 2008 and October 20, 2009, at Timpanogos Cave NM (TICA). None of those evaluations (0.0%) exceeded water quality standards or indications of impairment. Two sites were monitored in TICA during the period covered in this report, Hansen Cave Spring and Hidden Lake (Figure 3-34). In general, water quality at TICA is excellent.

3.11.2 Discussion and management implications

Water quality conditions in TICA are pristine. Continued water quality monitoring is warranted for the purpose of long-term trend assessments. A trend assessment is likely a better method for evaluating condition than comparison against state water quality standards protective of the American Fork River and its tributaries, and will provide early detection of degradation if it occurs. It is unlikely that water from either site in TICA supplies surface water recharge to the American Fork River.

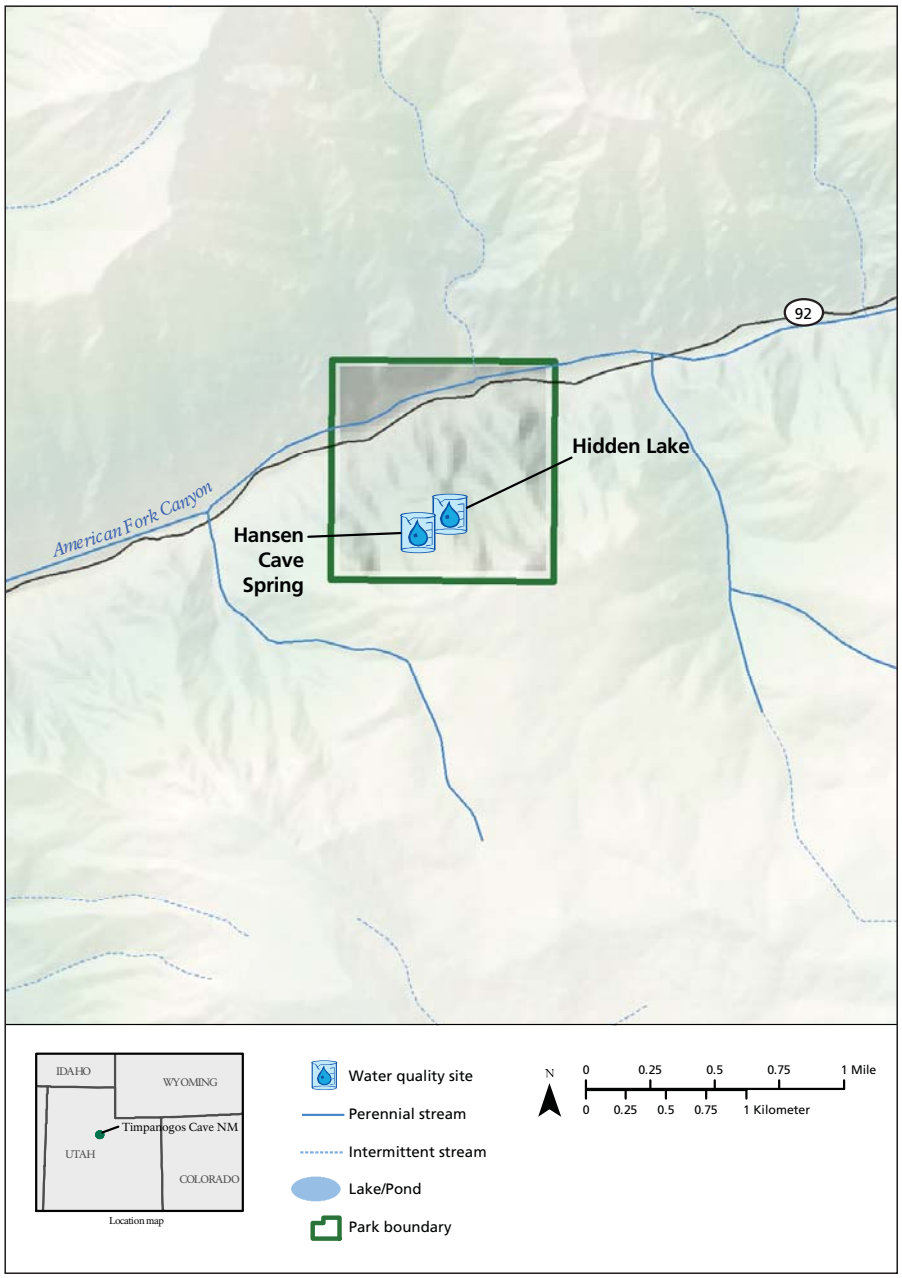


Figure 3-34. Water quality sites sampled in Timpanogos Cave NM, 2008–2009.

3.12 Zion National Park

3.12.1 Water quality summary

A total of 3,450 designated beneficial-use evaluations were completed for water quality results obtained between January 14, 2006 and November 17, 2009, at nine sites in and around Zion NP. Of those 3,450 evaluations, 97 (2.8%) exceeded water quality standards or indications of impairment (Figure 3-35). Water quality standards were exceeded for four constituent categories, most commonly nutrients, *E. coli*, and pH (Figure 3-36).

3.12.2 Reportable exceedances

Of the 12 sites monitored in Zion NP, three did not have water quality exceedances for the State of Utah, based upon 62 total evaluations: North Fork Virgin River at Virgin, Utah (52 total evaluations), North Fork Virgin River at Temple of Sinawava (6 total evaluations), and North Fork Virgin River at Bulloch Canyon (4 total evaluations). Nine of 12 sites sampled had exceedances (Table 3-10, Figure 3-37). The following discussion focuses only on sites that had exceedances.

1. ***La Verkin Creek at Lee Pass Trail.*** Total phosphorus concentrations at this site, in the Kolob Canyons area of the park, exceeded the State of Utah indication of impairment for secondary-contact recreation and non-game fish for 27% of site visits.
2. ***La Verkin Creek at U17 crossing.*** Total phosphorus concentrations at this site exceeded the State of Utah indication of impairment for secondary-contact recreation and non-game fish for 27% of site visits.
3. ***North Creek at planned gage in park.*** This site, which is near the park boundary, exceeded the State of Utah's pH standards for drinking water, secondary-contact recreation, non-game fish, and agricultural uses for 25% of site visits. Cattle trespass occurs occasionally at this site, and recreational use occurs upstream, in the park.

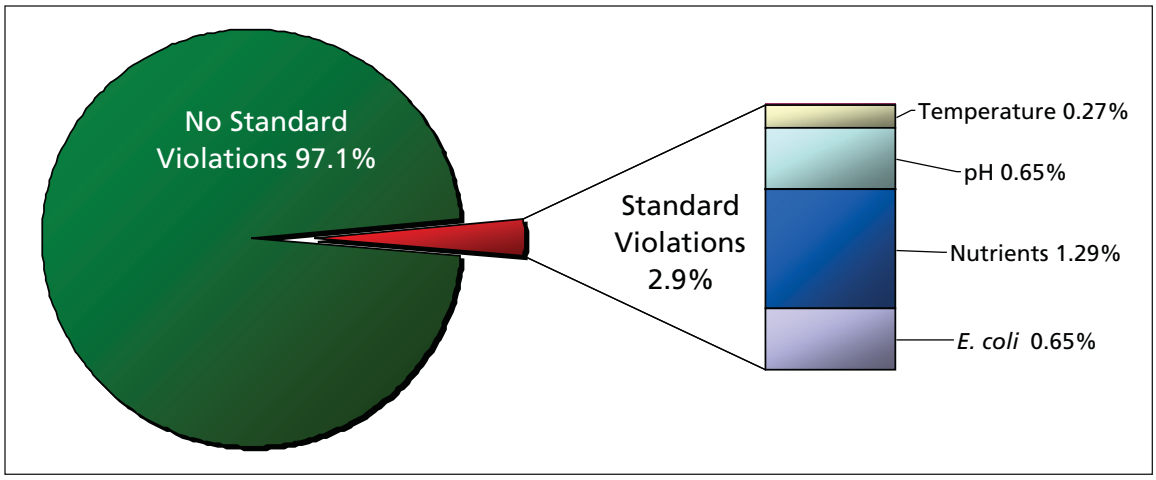


Figure 3-35. Percentage of use evaluations that exceed standards, and the causes of exceedances, Zion NP, 2006–2009.

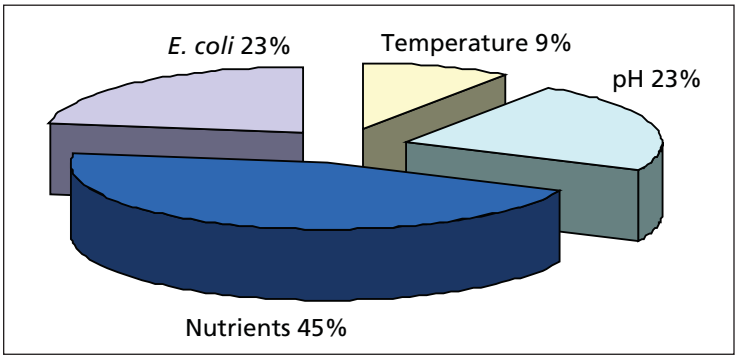


Figure 3-36. Most commonly exceeded water quality standards at Zion NP, 2006–2009.

Table 3-10. Exceedances of surface water quality standards for sites sampled in or near Zion NP, 2006–2009.

	Site	Use code	Constituent	Numeric standard	Units	Total evaluations	%evaluations exceeded standard
1	La Verkin Creek at Lee Pass Trail	2B, 3C	Phosphorus, Total	0.05	mg/L	22	27
2	La Verkin Creek at U17 crossing	2B, 3C	Phosphorus, Total	0.05	mg/L	13	23
3	North Creek at planned gage in park	1C, 2B, 3C, 4	pH	9	none	6	25
4	North Creek above confluence with Virgin River	2B, 3C	Phosphorus, Total	0.05	mg/L	13	23
5	East Fork Virgin River above confluence with North Fork Virgin River	2B, 3A	Phosphorus, Total	0.05	mg/L	19	32
		3A	Temperature, Water	20	°C	21	10
6	North Fork Virgin River above confluence with East Fork Virgin River	2B, 3A	Phosphorus, Total	0.05	mg/L	19	11
		3A	Temperature, Water	20	°C	21	10
7	North Fork Virgin River near Springdale, UT	3A	Temperature, Water	20	°C	11	18
8	North Fork Virgin River at North Fork Road	2A	*E. coli*	126	MPN	26	15
		1C	*E. coli*	206	MPN	26	12
9	North Fork Virgin River at Bureau of Land Management Wilderness Study Area (BLM-WSA) boundary	2A	*E. coli*	126	MPN	20	40
		1C	*E. coli*	206	MPN	20	35

Use codes: 1C = drinking water; 2A = primary-contact recreation; 2B = secondary-contact recreation; 3A = cold-water game fish; 3C = non-game fish; 4 = agricultural uses; CH = chronic; AC = acute

4. ***North Creek above confluence with Virgin River.*** Total phosphorus concentrations at this site exceeded the State of Utah indication of impairment for secondary-contact recreation and non-game fish for 23% of site visits.

5. ***East Fork Virgin River above confluence with North Fork Virgin River.*** This site exceeded the State of Utah standard for temperature, and the indication of impairment for total phosphorus, for 32% and 10% of site visits, respectively. Temperatures exceeded the cold-water game fish standard, and total phosphorus concentrations exceeded the secondary-contact recreation and cold-water game fish indications of impairment.

6. ***North Fork Virgin River above confluence with East Fork Virgin River.*** This site exceeded the State of Utah standard for temperature, and indication of impairment for total phosphorus, for 11% and 10% of site visits, respectively. Temperatures exceeded the cold-water game fish standard, and total phosphorus concentrations exceeded the secondary-contact recreation and cold-water game fish indications of impairment.

7. ***North Fork Virgin River at Springdale, Utah.*** This site exceeded the State of Utah temperature standard for cold-water game fish for 18% of site visits.

8. ***North Fork Virgin River at North Fork Road.*** This site exceeded the State of Utah chronic *E. coli* standard for primary-contact recreation and drinking water for 15% and 12% of site visits, respectively.

9. ***North Fork Virgin River at BLM-WSA boundary.*** No water quality results for this site were available from EPA STORET for this report. The NCPN processes *E. coli* samples internally, and has made those data available for inclusion in this report. This site exceeded the chronic and acute State of Utah *E. coli* standards for primary-contact recreation and drinking water. *E. coli* concentrations exceeded the chronic and acute (409 MPN) standards for primary-contact recreation for 40% and 15% of site visits, respectively. *E. coli* concentrations exceeded the chronic and acute (668 MPN) standards for drinking water for 35% and 10% of site visits, respectively.

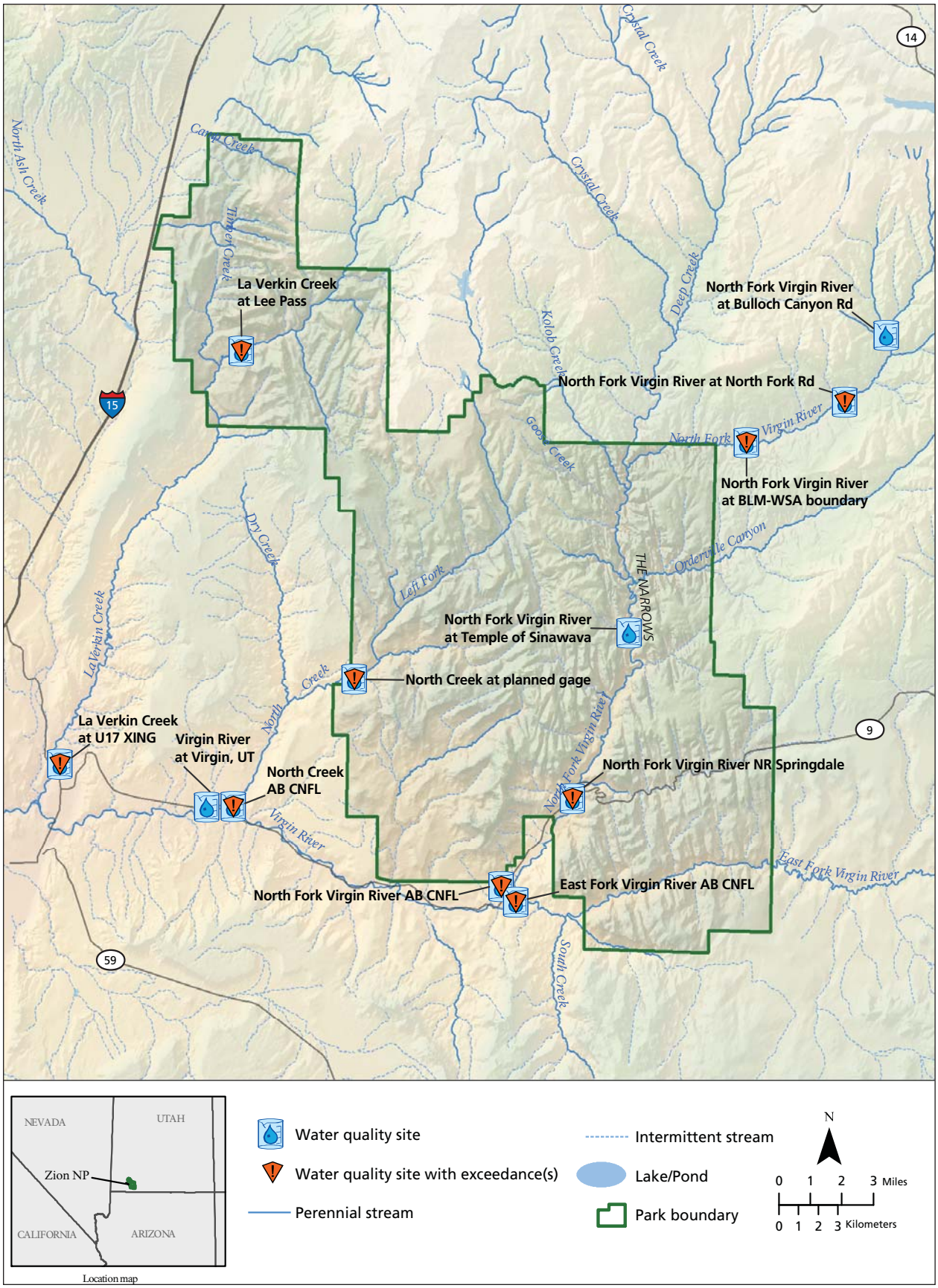


Figure 3-37. Water quality sites sampled in or near Zion NP, 2006–2009.

3.12.3 Discussion

3.12.3.1 Nutrients

Naturally elevated phosphorus conditions are common throughout the Northern Colorado Plateau, and are suspected, in many cases, to be caused by natural weathering of geologic strata containing phosphorus. Anthropogenic activities, such as pasture irrigation, grazing, and OHV recreation, can accelerate erosion and transport of phosphorus sorbed to sediment particles to surface water bodies. Further investigation is warranted to determine if the observed total phosphorus concentrations are likely natural or anthropogenic in origin.

If the observed total phosphorus exceedances were strongly correlated with low dissolved oxygen conditions, then management action would be warranted. However, because there are no such corresponding conditions, it is unlikely that the observed total phosphorus concentrations are causing eutrophication processes in La Verkin Creek that negatively impact aquatic ecological functions. Therefore, the observed total phosphorus concentrations in La Verkin Creek do not warrant management concern.

No indication of impairment was observed for total phosphorus on North Creek. However, visual observations indicated some degree of summertime eutrophication occurring during the period covered in this report. Algal blooms, elevated pH, and DO concentrations indicated nutrient enrichment. Drops in DO below aquatic life standards were not observed, perhaps due to the well-mixed conditions in this relatively high-velocity stream. However, algal muck, smelling strongly of reduced sulphur, was observed once in July 2009 (see Figure 3-39b, next page).

3.12.3.2 pH

The number and frequency of exceedances on North Creek near the park boundary has not changed since the fire that burned much of the watershed in June 2006. During warm summer months, pH levels still occasionally exceed applicable standards (Figure 3-38).

The 2006 wildfire removed the vegetation cover that provided shade protection to the river corridor and erosion control within the watershed near the sampling site and upstream along the Right Fork of North Creek. The associated increase in solar energy and influx of nutrients sorbed to sediments that resulted from this disturbance most likely increased the rate of photosynthetic activity within North Creek, triggering algal blooms (Figure 3-39).

The combination of warm summer temperatures and low-flow conditions in North Creek, in conjunction with the reduced riparian overstory and

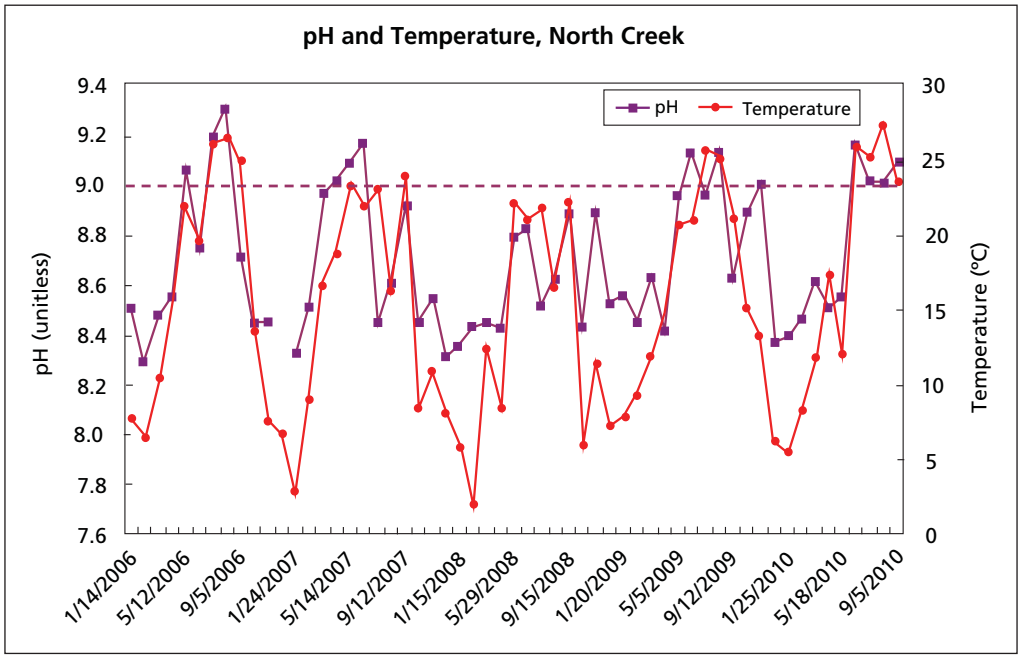


Figure 3-38. North Creek pH levels compared with temperature, 2006–2010. Maroon dashed line = State of Utah exceedance criteria for pH.

increased influx of nutrients, likely established ideal conditions for algal growth. Photosynthesis simultaneously consumes carbon dioxide (CO_2) and produces oxygen (O_2). Once dissolved in water, carbon dioxide forms carbonic acid (H_2CO_3), which disassociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-) according to Equation 1:

$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

Equation 1. Disassociation of carbon dioxide in water (left to right).

In the day, photosynthesis consumes carbon dioxide and, therefore, removes hydrogen ions from water, raising the pH. The opposite occurs at night, when organisms respire CO_2; pH subsequently decreases as a result of the increased concentration of H^+ ions.

Results from a continuous, 24-hour monitoring effort that the NCPN executed in 2008 (see feature, next page) demonstrate the process described above. During daylight hours, super-saturated oxygen conditions (greater than 100%) were observed in conjunction with the gradual elevation of pH levels (Figure 3-40). The opposite process was observed at night. After aquatic organisms began to respire, the dissolved oxygen saturation percentage and pH levels simultaneously decreased. The DO concentration (mg/L) has an inverse relationship with temperature; the higher the temperature, the less oxygen can be dissolved. In this case, photosynthesis increased the DO concentration (super-saturated) above physical limits imposed by the water temperature.

The geochemical components of watersheds throughout the Northern Colorado Plateau and, more specifically, in North Creek, naturally cause the pH of surface water to be slightly basic. However, the above-normal rate of photosynthesis during the summer months in North Creek appears to cause alkalinization of water, resulting in periodic State of Utah water quality exceedances for pH.

3.12.3.3 Temperature

Temperature exceedances in the North Fork Virgin River near Springdale, North Fork Virgin River above the confluence with East Fork Virgin River, and in the East Fork Virgin River above the confluence with the North Fork Virgin River occurred during July and August, and exceeded the State of Utah standard for cold-water game fish. Low-flow conditions, in concert with hot summer air temperatures, cause periodic surface-water temperature exceedances during the summer months at these sites. Continuous temperature monitoring at the North Fork Virgin River gage site in Springdale was initiated in February 2010, to determine the timing and duration of temperature exceedances.

Figure 3-39a. Algal bloom.

Figure 3-39b. Decomposed algae scooped from the North Creek streambed, July 14, 2009. This deposit was almost entirely organic, with very little mineral material. A distinct methane and sulfuric odor emanated from this material when disturbed.

3.12.3.4 E. coli

In summer months, *E. coli* contamination in the North Fork Virgin River upstream from the Narrows has been relatively consistent since the NCPN started monitoring efforts in 2006 (see feature on page 60). Zion NP staff noted exceedances above the Narrows in 2001 (D. Sharrow, ZION Hydrologist, pers. comm.).

Diurnal pH Monitoring on North Creek, Zion NP

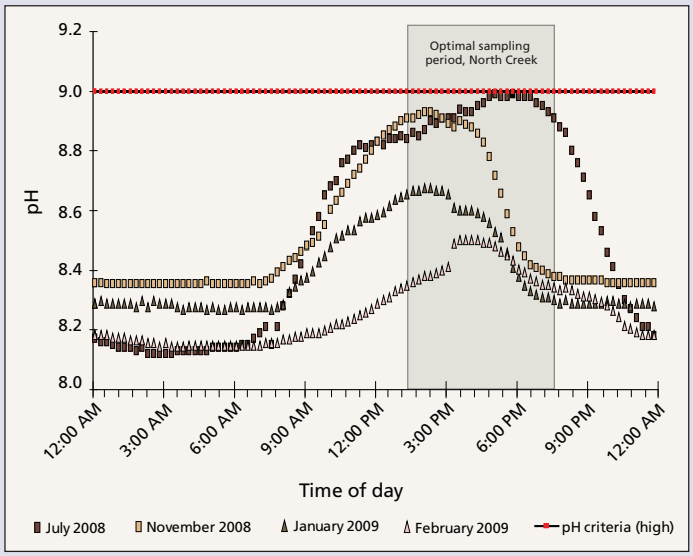
Most NCPN water quality sampling is conducted monthly, with the goal of quantifying status and trends over time and evaluating results against Clean Water Act standards. However, annual, seasonal, and even diurnal (daily) variations in water chemistry can confound the interpretation of these data. Understanding how core parameters vary diurnally will help us to determine the time of day when water quality violations are most likely to occur, and to target our sampling during those times. After noting unusually high summertime pH and temperatures in North Creek (Zion NP) in 2006 and 2007, we began a pilot study of diurnal cycles. On four different days in 2008 and 2009, the NCPN used continuous water quality monitoring sensors to monitor parameters in North Creek at five-minute intervals for 24 hours.

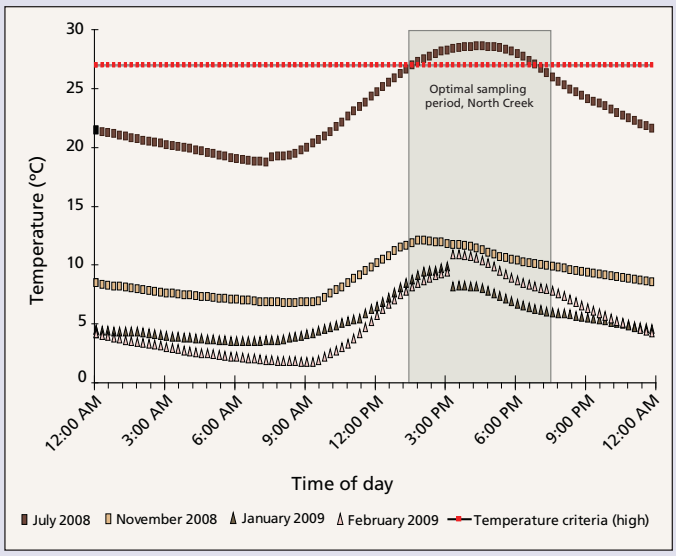
Photosynthetic activity in streams is one driver of diurnal cycles, which are characterized by repeating, predictable patterns. With sunlight as an energy source, aquatic vegetation produces carbohydrates by consuming carbon dioxide and producing oxygen as a byproduct. Diurnal monitoring shows that as soon as morning sunlight hits the water, the photosynthetic engine begins producing oxygen, which increases in concentration throughout the day (as water temperature and light intensity increase), until a peak in late afternoon. In the evening, energy from the sun diminishes and reduces photosynthesis. As plants use energy for metabolism but don't photosynthesize, they release CO_2 back into the water. The CO_2 reacts to form carbonic acid, thus lowering pH.

Diurnal monitoring also demonstrates seasonal effects. Daily cyclic patterns in temperature and pH that are strongly expressed in summer are dampened by cold temperatures and lower sun angles in winter (see figures below). In North Creek and other low-flow NCPN streams, summer peak temperatures and pH can exceed the water quality criteria for aquatic organisms. If extreme, these stressful effects can affect reproduction and even cause death.

The Subway, Left Fork of North Creek, Zion National Park.

Based on diurnal monitoring in North Creek, it appears that sampling conducted between 1:30 and 7:30 p.m. would be most likely to document water quality criteria violations and best describe the stress on aquatic organisms that may be recurring on a daily basis. Other NCPN sites affected by high summer temperatures tend to be low-flow springs and pools in ephemeral washes. Larger rivers may also be subject to the same set of conditions—especially during drought years, when the diminished volume of water is more effectively heated by the sun. Understanding how parameters vary diurnally and seasonally will increase our ability to determine water quality status, detect long-term change, and identify criteria violations. All of this information will be used to help improve management of NCPN water resources.





Effect of season and time of day on pH and water temperature in North Creek, Zion National Park. Monitoring at any time outside the window of 1:30 and 7:30 p.m. would not have captured the exceedances and near-exceedances that occurred.

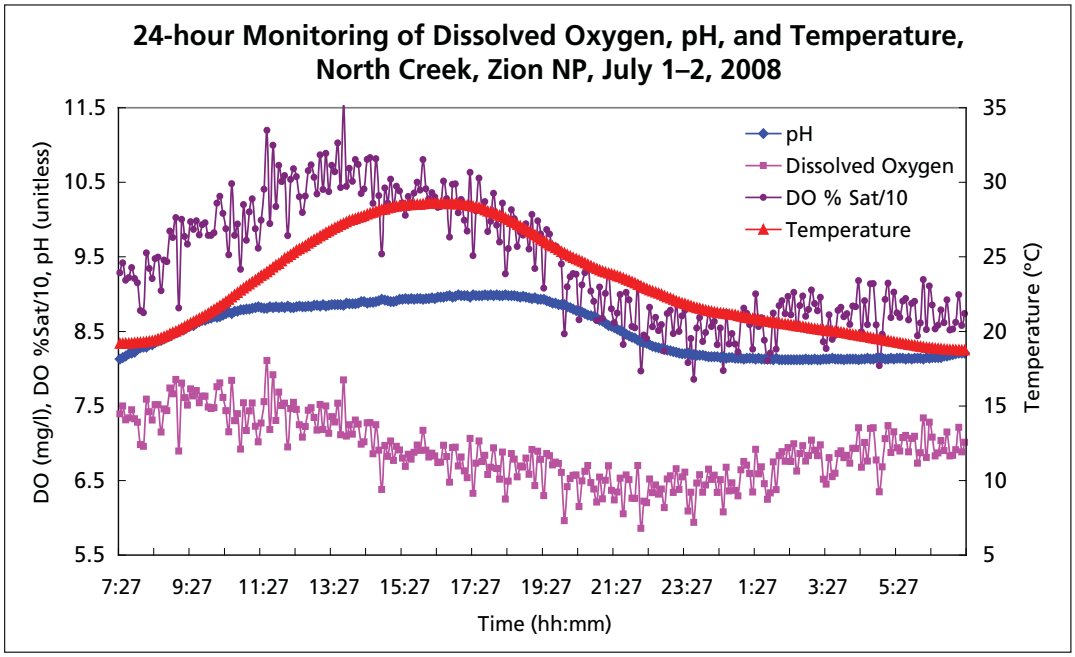


Figure 3-40. North Creek pH levels compared with dissolved oxygen (concentration and percent saturation) and temperature over a 24-hour period, July 2008. Percent saturation values were divided by 10 for proportional display purposes.

Persistent *E. coli* exceedances occurred during the summer of 2009 at the Bureau of Land Management Wilderness Study Area (BLM-WSA) site (Figure 3-41). In response, NCPN and Zion NP staff initiated an increased spatial and temporal monitoring effort along the North Fork Virgin River. Results from data collected during 2009 were provided to the UDWQ, contributing to the inclusion of the North Fork Virgin River on the 2010 draft 303(d) list of impaired water bodies, due to its failure to meet the primary-recreation contact standard for *E. coli* concentrations.

The listing resulted in public meetings and a more intensive monitoring effort that will be conducted during 2010, in cooperation with the NCPN, Zion National Park, UDWQ, and University of Utah (see feature, next page). Results from monitoring efforts in 2010 seek to distinguish between possible sources of contamination upstream from the BLM-WSA site through a combination of microbial source tracking analysis and an increased spatial and temporal frequency of sample collection along the North Fork Virgin River.

Comparison of the results of intensive monitoring in 2009 and historic results reveals a discrete and persistent contaminant source on the North Fork Virgin River between the BLM-WSA site and the North Fork Road Bridge location, upstream from the Zion NP boundary (see Figure 3-37 for location).

3.12.4 Management implications

On North Creek, the continuation of routine monthly monitoring and installation of a continuous monitoring station should provide additional information about the recovery of post-fire water quality. After enough data are obtained, a long-term trend analysis will be performed for various parameters, which should facilitate discussion about fire effects and post-fire watershed recovery.

Upon request from the NCPN and Zion NP, the State of Utah officially re-classified the recreation standard for the North Fork Virgin River from secondary-contact to primary-contact in February 2009 (Appendix E). The primary-contact recreation standard better reflects the type of use occurring in the North Fork Virgin River, and consequently strengthened human health-related water quality standards by lowering the acceptable permitted concentration of *E. coli*.

Cooperative Efforts for Cleaner Water

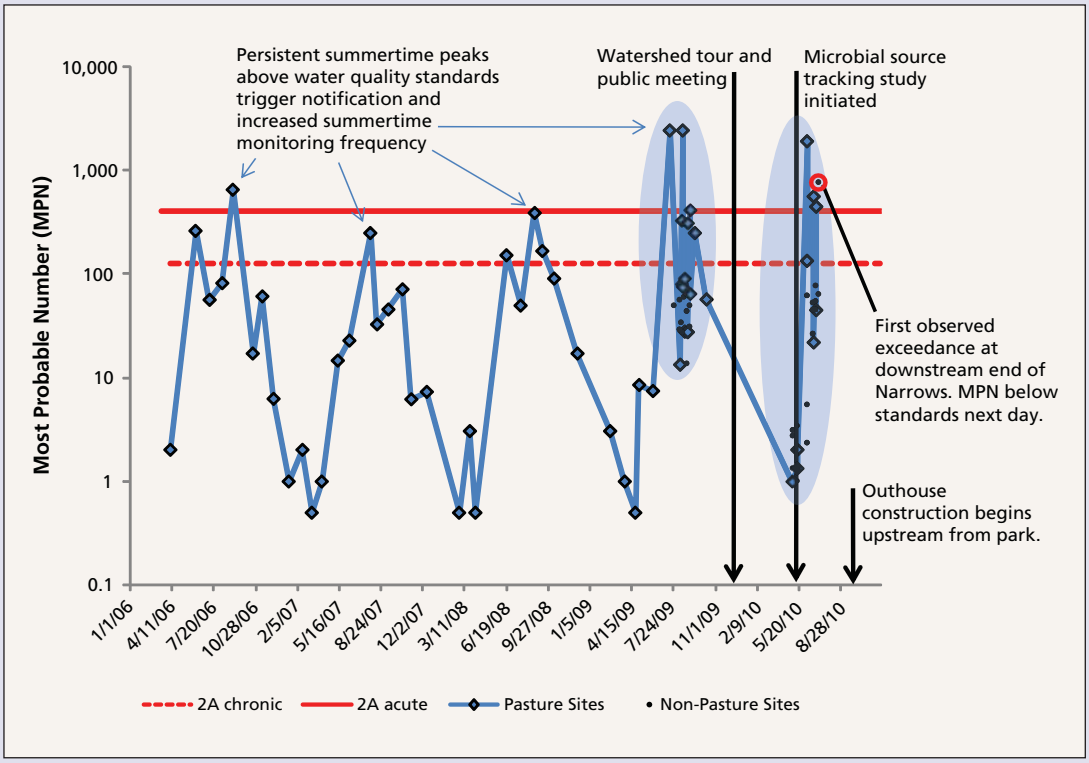
In 2006, the NCPN began monitoring for *E. coli* on the North Fork Virgin River upstream from Zion NP and the Narrows, where the river flows through pastures that are irrigated and grazed. In summer 2006, 2007, and 2008, the network noted and reported elevated *E. coli* levels to Zion NP staff (see figure). In 2009, hikers entering the Virgin River upstream of the park were issued warnings about these elevated levels, and an intensive study was initiated to isolate the source of contamination and help determine if the problem was persistent or intermittent.

Under the study, monitoring was conducted more frequently at the original pasture site and at two additional sites 1–2 miles upstream, plus a heavily used visitor site at the mouth of the Zion Narrows, 16 miles downstream (these latter three sites are lumped as non-pasture sites in the figure below). Results from 2009 confirmed that the contamination source was located near the pasture and was persistent during the summer season.

Definitively identifying the source of contamination is complicated by several factors. Land ownership in the area is mixed federal and private. Cattle graze pastures near the stream in summer, hundreds of visitors also use the stream, and there are second homes situated higher in the watershed.

A public meeting, hosted by the Utah Division of Water Quality (UDWQ) and attended by staff from the NPS, Bureau of Land Management, and county conservation district, resulted in a course of action that included additional intensive monitoring and a microbial source tracking study to determine if the bacterial source was human or animal in origin. The UDWQ also provided funds for the BLM to build an outhouse at the trailhead upstream from the park, to mitigate potential human sources of bacteria. Continued multiagency cooperation will help us to determine the source of bacteria and arrive at solutions involving federal and state agencies as well as local landowners.

Conducting bacterial monitoring on the North Fork Virgin River, upstream from Zion NP.



The single incidence of an exceedance at a non-pasture site (770 MPN on July 6, 2010) occurred at the mouth of the Zion Narrows, where more than 2,000 people enter the water each summer. On the next day, concentrations were back below the 2A chronic criteria (68 MPN, July 7, 2010).

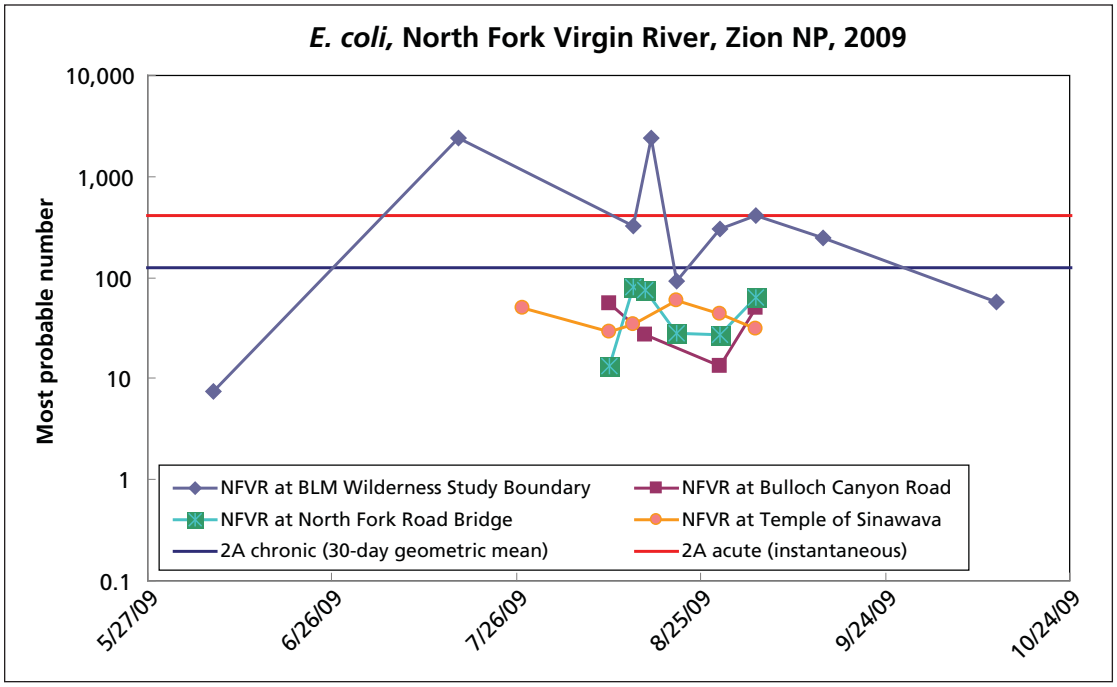


Figure 3-41. *E. coli* concentrations at four locations in the North Fork Virgin River, 2009, and the State of Utah acute and chronic primary-contact recreation standards (see Figure 3-34 for site locations).

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Appendix A. Water Quality Sites Sampled, 2006–2009

Station ID	Station name	Date range of site visits	Latitude	Longitude	Designated Beneficial Uses
Arches National Park					
09163500	Colorado River NR CO-UT state line	2/7/2006–11/5/2009	39.133	-109.027	ALW1, RECE, AG
5995220	Salt Wash at Wolfe Ranch	1/18/2006–12/17/2007	38.735	-109.519	1C, 2A, 3B, 4
5995240	Lower Courthouse Wash	1/18/2006–12/20/2007	38.613	-109.579	1C, 2A, 3B, 4
5995270	Willow Spring	7/30/2007–12/17/2007	38.700	-109.628	1C, 2A, 3B, 4
5995200	Freshwater Spring	7/30/2007–12/17/2007	38.744	-109.525	1C, 2A, 3B, 4
5995250	Sleepy Hollow Spring	7/31/2007–12/20/2007	38.671	-109.639	1C, 2A, 3B, 4
09180000	Dolores River NR Cisco	2/27/2006–11/17/2009	38.797	-109.195	2B, 3C, 4
09180500	Colorado River NR Cisco	2/8/2006–11/16/2009	38.811	-109.293	1C, 2A, 3B, 4
Black Canyon of the Gunnison National Park					
09128000	Gunnison River BL tunnel	1/18/2006–8/21/2007	38.529	-107.649	ALC1, RECE, DWS, AG
383418107471401	Red Rock Canyon NR NPS BNDRY	6/7/2006–8/14/2007	38.572	-107.788	ALW2, RECE, DWS, AG
383537107471500	Red Rock Canyon at mouth	6/7/2006–8/14/2007	38.594	-107.788	ALW2, RECE, DWS, AG
Bryce Canyon National Park					
4951857	Yellow Creek	1/13/2006–1/18/2008	37.574	-112.141	2B, 3C, 4
4951855	Sheep Creek	1/13/2006–1/29/2008	37.571	-112.201	2B, 3C, 4
4951915	Mossy Cave	7/23/2008–11/5/2009	37.665	-112.115	2B, 3C, 4
N/A	Tropic Ditch	7/23/2008–11/5/2009	37.665	-112.115	2B, 3C, 4
Canyonlands National Park					
5995050	Cave Spring	1/20/2006–6/21/2006	38.157	-109.753	1C, 2A, 3B, 4
5995540	Horseshoe Canyon Spring	1/21/2006–5/26/2006	38.454	-110.198	1C, 2A, 3B, 4
5995420	Chocolate Drops Spring	3/2/2006–6/26/2006	38.226	-110.002	1C, 2A, 3B, 4
5995120	Little Spring Canyon Creek	1/20/2006–6/22/2006	38.184	-109.801	1C, 2A, 3B, 4
5995500	Maze Overlook Spring	3/2/2006–6/26/2006	38.229	-109.998	1C, 2A, 3B, 4
5995020	2.4 mile Loop Spring	1/20/2006–6/22/2006	38.125	-109.822	1C, 2A, 3B, 4
5995160	Salt Creek NR Peekaboo Spring	1/20/2006–6/22/2006	38.119	-109.750	1C, 2A, 3B, 4
5995150	Salt Creek NR Crescent Arch	1/20/2006–12/18/2007	38.085	-109.766	1C, 2A, 3B, 4
4930150	Green River at Mineral Bottom	5/27/2006–8/10/2006	38.527	-109.993	1C, 2A, 3B, 4
4952400	Colorado River AB CNFL	5/5/2006–9/27/2007	38.193	-109.884	1C, 2A, 3B, 4
4956290	Colorado River at Potash	4/24/2006–8/16/2007	38.467	-109.666	1C, 2A, 3B, 4
4930010	Green River AB CNFL	5/5/2006–9/27/2007	38.190	-109.889	1C, 2A, 3B, 4
4952380	Colorado River BL Big Drop #3	4/26/2006–9/27/2007	38.071	-110.046	1C, 2A, 3B, 4
09315000	Green River at Green River	3/15/2006–11/20/2009	38.986	-110.151	1C, 2A, 3B, 4
09272400	Green River at Ouray	5/26/2009–12/1/2009	40.085	-109.677	1C, 2A, 3B, 4

Appendix A. Water quality sites sampled, 2006–2009, cont.

Capitol Reef National Park					
4954812	Halls Creek BL Narrows	1/12/2006–1/29/2008	37.615	-110.892	2B, 3B, 4
4954770	Sulphur Creek AB CNFL	7/22/2008–8/15/2009*	38.287	-111.247	1C, 2B, 3A, 4
4954780	Pleasant Creek	7/22/2008–8/15/2009*	38.180	-111.181	1C, 2B, 3A
4954380	Fremont River NR Bicknell	1/25/2006–1/22/2008	38.307	-111.517	1C, 2B, 3A, 4
4954390	Fremont River at U12 XING	7/27/2006–10/23/2007	38.270	-111.375	1C, 2B, 3A, 4
4954550	Fremont River AB Mill Meadow Res.	8/1/2007–1/22/2008	38.520	-111.571	1C, 2B, 3A, 4
4954330	Fremont River at old U24 XING	2/8/2006–1/22/2008	38.391	-110.697	1C, 2B, 3C, 4
09330230	Fremont River NR Caineville	7/16/2008–10/6/2009	38.279	-111.066	1C, 2B, 3C, 4
4954775	Sulphur Creek BL Goosenecks	7/22/2008–8/15/2009*	38.307	-111.315	1C, 2B, 3A, 4
Curecanti National Recreation Area					
09125000	Curecanti Creek NR Sapinero	6/21/2006–8/7/2007	38.488	-107.415	ALC1, RECU DWS, AG
09127000	Cimarron River BL Squaw Creek	1/18/2006–8/23/2007	38.446	-107.556	ALC1, RECU DWS, AG
381633107054700	Cebolla Creek at Powderhorn	6/5/2006–8/22/2007	38.276	-107.097	ALC1, RECU DWS, AG
381934107133500	Lake Fork Gunnison River BL Gateview	1/19/2006–8/22/2007	38.326	-107.227	ALC1, RECE DWS, AG
382418107242600	Blue Creek at HWY 50	1/20/2006–8/23/2007	38.405	-107.408	ALC1, RECU DWS, AG
382702107203900	Pine Creek at HWY 50	1/20/2006–8/21/2007	38.451	-107.345	ALC1, RECU DWS, AG
382900107101600	East Elk Creek NR mouth	5/31/2006–8/2/2007	38.483	-107.172	ALC1, RECU DWS, AG
382902107140400	Red Creek NR mouth	5/23/2006–8/2/2007	38.484	-107.235	ALC1, RECU DWS, AG
382937107033500	Steuben Creek NR mouth	6/5/2006–8/1/2007	38.494	-107.060	ALC1, RECU DWS, AG
382943107015300	Beaver Creek at HWY 50	5/31/2006–8/1/2007	38.495	-107.032	ALC1, RECU DWS, AG
383028107162200	West Elk Creek BL USFS BNDRY	5/30/2006–8/7/2007	38.508	-107.273	ALC1, RECU DWS, AG
383103106594200	Gunnison River at CNTY Rd 32	2/2/2006–8/15/2007	38.517	-106.996	ALC1, RECE DWS, AG
383137107183600	Soap Creek AB Chance Creek	6/20/2006–8/2/2007	38.527	-107.311	ALC1, RECU DWS, AG
Dinosaur National Monument					
09247600	Yampa River BL Craig	2/13/2006–9/23/2009	40.481	-107.614	ALC1, RECE, DWS AG
09251000	Yampa River NR Maybell	1/30/2006–8/11/2009	40.503	-108.033	ALW1, RECE, DWS, AG
09260050	Yampa River at Deerlodge Park	2/7/2006–11/13/2009	40.452	-108.525	ALW1, RECE, DWS, AG
404417108524900	Green River AB Gates of Lodore	2/6/2006–11/12/2009	40.738	-108.880	ALC1, RECE, DWS AG
5937880	Pot Creek AB Matt Warner Res.	5/10/2006–8/15/2006	40.769	-109.320	2B, 3A, 4
4937760	Brush Creek at U149 XING	1/18/2006–6/21/2006	40.408	-109.340	1C, 2B, 3A, 4
5937810	Pot Creek AB Calder Res.	4/26/2006–6/7/2006	40.736	-109.224	2B, 3A, 4
09261000	Green River NR Jensen	1/4/2006–12/2/2009	40.409	-109.235	1C, 2A, 3B, 4
Golden Spike National Historic Site					
4960760	Blue Creek at CR 504 XING	2/21/2006–2/21/2006	41.636	-112.444	2B, 3A, 4

Appendix A. Water quality sites sampled, 2006–2009, cont.

Hovenweep National Monument					
5995700	Square Tower Spring	7/11/2006–6/7/2007	37.386	-109.081	1C, 2A, 3B, 4
5995710	Cajon Spring	7/10/2006–6/7/2007	37.297	-109.183	1C, 2A, 3B, 4
5995720	Hackberry House Spring	7/11/2006–6/7/2007	37.408	-109.025	1C, 2A, 3B, 4
Natural Bridges National Monument					
5995310	Armstrong Canyon Creek	7/10/2006–6/20/2007	37.600	-110.030	2B, 3B, 4
5995320	Owachomo Bridge Spring	7/10/2006–6/20/2007	37.582	-110.010	2B, 3B, 4
5995330	Sipapu Bridge Spring	7/10/2006–6/19/2007	37.620	-110.006	2B, 3B, 4
Timpanogos Cave National Monument					
4994970	Hansen Cave	7/30/2008–8/18/2009	40.438	-111.711	2B, 3A, 4
N/A	Hidden Lake	1/28/2009–10/22/2009	40.438	-111.709	2B, 3A, 4
Zion National Park					
4950920	North Ck at Planned Gage	1/14/2006–1/15/2008	37.261	-113.106	1C, 2B, 3C, 4
4950800	La Verkin Ck at Lee Pass	1/15/2006–1/16/2008	37.407	-113.176	1C, 2B, 3C, 4
4951260	North Fk Virgin at North Fork Rd	1/14/2006–1/23/2008	37.390	-112.826	1C, 2A, 3C, 4
4950890	North Ck AB CNFL	7/26/2006–6/26/2007	37.203	-113.174	1C, 2B, 3C, 4
4950950	North Fk Virgin AB CNFL	1/25/2006–1/8/2008	37.163	-113.013	1C, 2A, 3C, 4
4951400	East Fk Virgin AB CNFL	1/25/2006–1/8/2008	37.163	-113.010	2B, 3A, 4
4950770	La Verkin Ck at U17 XING	7/26/2006–6/26/2007	37.220	-113.275	1C, 2B, 3C, 4
09405500	North Fk Virgin NR Springdale	6/18/2008–12/9/2009	37.210	-112.979	1C, 2A, 3C, 4
09406000	Virgin River at Virgin, UT	7/23/2008–11/17/2009	37.204	-113.181	1C, 2B, 3C, 4
4951265	North Fk Virgin at BLM-WSA BNDRY	7/24/2008–11/6/2009*	37.371	-112.882	1C, 2A, 3C, 4

*Indicates only a subset of all data were available for analysis.

Appendix B. Utah Nonpoint Source MOU

FINAL DRAFT TEXT - UTAH NONPOINT SOURCE MOU
MOU Prep. Team
October 21, 2008
Nov. 20, 2008
Dec. 9, 2008
Dec. 17, 2008
Jan. 13, 2009

MEMORANDUM OF UNDERSTANDING
IMPLEMENTING THE NONPOINT SOURCE WATER QUALITY PROGRAM
IN THE STATE OF UTAH

I. PARTIES TO THE MEMORANDUM OF UNDERSTANDING

This Memorandum of Understanding (MOU) is made between: Utah Division of Water Quality (DWQ), Utah Department of Agriculture and Food (UDAF), Utah Division of Forestry, Fire and State Lands (FFSL); U.S. Department of Agriculture, Forest Service, Intermountain Region (FS); the U.S. Department of Interior, Bureau of Land Management (BLM) and National Park Service (NPS) within the State of Utah.

II. PURPOSE

The purpose of this MOU is to coordinate State and Federal agency activities for nonpoint source water quality protection, monitoring and improvement activities on Federal Lands within the State of Utah. This MOU outlines the roles and responsibilities of the parties in implementing the nonpoint source water quality provisions of the federal Clean Water Act, the Utah Water Quality Act, the Utah Nonpoint Source Pollution Management Plan and the Utah Nonpoint Source Management Plan for Silvicultural Activities.

III. DEFINITIONS

Best Management Practice (BMP): Practices, techniques, or measures developed or identified by the designated agency and identified in the state Nonpoint Source Pollution Management Plan, which are determined to be a cost-effective and practicable means of preventing or reducing pollutants generated from nonpoint sources to a level compatible with water quality goals.

Federal Land Management Agencies: For this MOU only, the Bureau of Land Management (BLM), National Park Service (NPS), and United States Forest Service (FS) collectively are identified herein as the Federal Land Management Agencies.

Federal Lands: For this MOU only, lands administered within the State of Utah by the USDA, Forest Service (National Forest System (NFS) lands), USDI, Bureau of Land Management (National System of Public Lands) and USDI, National Park Service.

Nonpoint Source Pollution: Ground and surface water pollution that comes from varied and diffuse sources and can be categorized by the general land disturbing activity that causes the pollution.

IV. AUTHORITIES, ROLES, AND RESPONSIBILITIES

Utah Department of Environmental Quality – Division of Water Quality

Authorities:

Appendix C. State of Utah Water Quality Standard Definitions

The text below was extracted from Utah Administrate Code: R317: Utah Standards of the State, 2010, and summarizes use designations applicable to NCPN water-bodies.

Class 1C—Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water

Class 2—Protected for recreational use and aesthetics.

> Class 2A—Protected for frequent primary contact recreation where there is a high likelihood of ingestion of water or a high degree of bodily contact with the water. Examples include, but are not limited to, swimming, rafting, kayaking, diving, and water skiing.
>
> Class 2B—Protected for infrequent primary contact recreation. Also protected for secondary contact recreation where there is a low likelihood of ingestion of water or a low degree of bodily contact with the water. Examples include, but are not limited to, wading, hunting, and fishing.

Class 3—Protected for use by aquatic wildlife.

> Class 3A—Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
>
> Class 3B—Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain.
>
> Class 3C—Protected for nongame fish and other aquatic life, including the necessary aquatic organisms in their food chain.

Class 4—Protected for agricultural uses including irrigation of crops and stock watering.

Appendix D. State of Colorado Water Quality Standard Definitions

Section IV of the document below summarizes use designations applicable to NCPN water bodies. http://water.epa.gov/scitech/swguidance/waterquality/standards/upload/2006_01_23_standards_wqslibrary_co_reg37-20050120.pdf)

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT
WATER QUALITY CONTROL COMMISSION

REGULATION NO. 37

CLASSIFICATIONS AND NUMERIC STANDARDS
FOR
LOWER COLORADO RIVER BASIN

	ADOPTED:	February 14, 1983
	EFFECTIVE:	March 30, 1983
TRIENNIAL	REVIEW:	April 7, 1986
	AMENDED:	September 12, 1986
	EFFECTIVE:	October 30, 1986
	AMENDED:	February 4, 1991
	EFFECTIVE:	March 30, 1991
TRIENNIAL	REVIEW:	October 6, 1992
	AMENDED:	March 1, 1993
	EFFECTIVE:	April 30, 1993
	AMENDED:	September 7, 1993
	EFFECTIVE:	October 30, 1993
	AMENDED:	July 10, 1995
	EFFECTIVE:	August 30, 1995
TRIENNIAL	REVIEW:	November 13, 1995
	AMENDED:	July 14, 1997
	EFFECTIVE:	August 30, 1997
	AMENDED:	October 9, 2001
	EFFECTIVE:	February 20, 2002
	AMENDED:	July 8, 2002
	EFFECTIVE:	August 30, 2002
	AMENDED:	September 8, 2003
	EFFECTIVE:	January 20, 2004

Appendix E. Summary of Water Quality Standard Rule Changes, State of Utah

See rules R317-13.2(a), below.

Summary of Proposed Rule Changes to Water Quality Standards and Definitions (R317-1 and 317-2)
December, 2009

Note: This summary is made available for the reader's convenience. The complete proposed changes can be viewed at http://www.waterquality.utah.gov/Rules/rulechange.htm

Minor Changes

Rule Affected	Change Summary and Rationale
R317-2-6.5(a)	Changed Union Pacific Causeway to Antelope Island Causeway to correctly define Farmington Bay
R317-2-12	Moved list of specific Category 2 Waters from R317-2-12.1 to referenced location in R317-2-12.2 Category 2 Waters.
R317-13.2(a)	Added "…Virgin River except as listed below" as originally intended to assign beneficial use classes to the whole Virgin River followed by beneficial use classes for specific reaches of the Virgin River.
R317-13.2(a)	Corrected the beneficial use class to 2A (primary contact) from 2B (secondary contact) for the North Fork of the Virgin River as originally intended.
R317-2.14.1	Added "dissolved" for inorganics analyses for clarification which is consistent with the analytical methods used for the inorganic analytes.
R317-2.14.1 Footnote 4	Corrected geographic reference from Quitchupah Creek to Ivie Creek because Quitchupah Creek is a tributary to Ivie Creek which is a tributary to the Muddy River. Quitchupah does not flow directly into the Muddy River.
R317-2.14.1	For site-specific total dissolved solids (TDS) standards on the Price River, changed the geographic reference from Soldier Creek to Coal Creek. As previously identified, the river reach between Soldier Creek and Coal Creek would have defaulted to the state-wide TDS standard between two reaches with 1,700 and 3, 000 mg/L site-specific standards. Deleted redundant listing of Green River to Soldier Creek reach.
R317-2.14.2 Footnote 9a	Added parenthesis to correct typographical error in formula for ammonia
R317-2.14.3a and R317-2.14.3b	Corrected log function typographical error in formulas from "In" to "ln"

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 960/106328, December 2010

National Park Service
U.S. Department of the Interior

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www.nature.nps.gov

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