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**Water Quality Vital Signs Monitoring Protocol
for Park Units in the Northern Colorado Plateau Network**

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This Water Quality Monitoring Protocol consists of this protocol narrative, and the following Standard Operating Procedures (SOPs):

SOP 1: Safety for Water Quality Monitoring

SOP 2: Staff Training, Colorado Units

SOP 3: Staff Training, Utah Units

SOP 4: Site Selection

SOP 5: Preparations and Equipment Calibration, Handling and Storage

SOP 6: Cumulative Bias

SOP 7: Quality Assurance Project Plan (QAPP), All Units

SOP 8: Field Methods for Core Parameters, Turbidity and Discharge, All Units

SOP 9: Sample processing, Colorado Units

SOP 10: Field Sample Collection and Processing for Water Chemistry, Nutrients and TSS, Utah Units

SOP 11: Fecal Indicator Bacteria, All Units

SOP 12: Laboratory Analysis Methods for Water Quality, Colorado Units

SOP 13: Laboratory Analysis Methods for Water Quality, Utah Units

SOP 14: Data Management, All Units

SOP 15: Data Analysis and Reporting, All Units

SOP 16: Protocol Revision

SOP 17: Annual Review

Table of Contents

1. Background and Objectives	7
1.1. Introduction	7
1.1.1. Hydrologic Setting and Influences on Water Quality	8
1.1.2. Uses of Water and Ecological Significance of Water Quality	8
1.1.3. State Standards and Protected Uses	9
1.2. Waters on the 303d List in NCPN Park Units	10
1.3. Qualitative Desired Future Conditions	13
1.3.1. Utah parks	14
1.3.2. Colorado parks	15
1.3.3. Other parks	15
1.3.4. Thresholds of Concern	15
1.4. Water Quality Vital Signs	16
1.4.1. Historic Observations and Existing Conditions	16
1.4.2. Nutrients	19
1.4.3. Trace Elements (Metals)	20
1.4.4. Selenium	21
1.4.5. Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)	21
1.4.6. Pesticides	22
1.4.7. Springs, Seeps, Hanging Gardens, and Tinajas	22
1.4.8. Chlorophyll and Carbon	23
1.5. Historic Variability	23
1.6. Minimum Detectable Difference	25
1.7. Sample Size	25
1.8. Power Analysis	30
1.9. Realistic Sample Size Goal	30
1.10. Monitoring questions	31
1.11. Measurable Objectives	32
1.12. Management use of Monitoring Data	33
2. Sampling Design	33
2.1. Target Population	33
2.2. Rationale for Sampling Design	34
2.3. Influences on Sampling Design	34
2.3.1. Partnerships	34
2.3.2. Monitoring By Others that Supports NCPN Goals	35
2.3.3. Other design considerations	35
2.3.4. Boundary of Monitoring Effort	37
3. Site Selection	38
4. Revisit design	49
5. Site locations	49
6. Strengths and Limitations of Monitoring Design	57
7. Field and Laboratory Methods	58
7.1. Standard Operating Procedures	58
7.2. Measurable attributes	61
7.3. Site specific attributes and protocols	61
8. Data Management	63
8.1. Data Management in Utah Parks in partnership with UDWQ	66
8.2. Data Management in Colorado NCPN Parks	67
8.3. Data Management for Sites with a USGS Partner	67
9. Data Analysis and Reporting	67
9.1. Annual Summary Report	68
9.2. Triennial Report	68
10. Coordination Meetings	69
11. Roles and Responsibilities	69
12. Operational Requirements	70
12.1. Annual workload and Field Schedule	70
12.2. Facility and Equipment Needs	71

12.3. Startup Costs and Budget Considerations	71
12.3.1. Approximate Costs of Sample Collection and Analysis	71
13. References	72
14. Appendix A: Protected Uses for Northern Colorado Plateau Parks in Utah, Wyoming, Arizona and Colorado	77
15. Sources.....	89

List of Tables

Table 1. Sources for water quality standards for NCPN states.....	10
Table 2. Number of sites, samples and results with sample period for all sites located within parks by parameter category for compiled historical water-quality data through 2002.	16
Table 3. Nutrient exceedances in NCPN units, indicated by stream name(s) or “X” for multiple sources.....	19
Table 4. Trace-element exceedances in NCPN units, indicated by stream name(s) or “X” for multiple sources.	20
Table 5. TDS and TSS exceedances in NCPN units, indicated by stream name(s) or “X” for multiple sources.	22
Table 6. NCPN park waters with available chlorophyll and carbon, indicated by stream name(s) or “X” for multiple sources.	23
Table 7. Statistics for historic water quality data in ZION and computed MDD, power, and sample size.....	26
Table 8. Overview of partnerships and approaches to sampling and analysis.	35
Table 9. Planning considerations that influenced the Sampling design for NCPN water quality monitoring.	36
Table 10. Water-quality vital signs monitoring sites for NCPN with other significant monitored sites.....	39
Table 11. Site implementation schedule through first complete round of sampling.	49
Table 12. Standard Operating Procedures (SOPs) for water quality monitoring.	59
Table 13. Water-quality attributes grouped by sample type.....	61
Table 14. Target waters, parameters to be monitored and protocols to be used.	62
Table 15. Elements of Data Management for each Approach to Water Quality Vital Signs Monitoring in the NCPN.	66
Table 16. Annual Reporting Responsibilities.....	68
Table 17. Areas of responsibility for staff involved in NCPN water quality monitoring. The level or responsibility is indicated by specific park(s), “group” of parks serviced by that water quality specialist, or “NCPN” for all network parks.....	70
Table 18. Equipment requirements for each sampling node.....	71
Table 19. Projected Annual Budget for NCPN Water Quality Monitoring.	72
Table A-1. Protected uses designated for Northern Colorado Plateau Parks in Utah.	77
Table A-2. Protected uses designated for Northern Colorado Plateau Parks in Wyoming.	80
Table A-3. Protected uses designated for Northern Colorado Plateau Parks in Arizona.....	80
Table A-4. Protected uses designated for Northern Colorado Plateau Parks in Colorado (including portions of Dinosaur and Hovenweep National Monuments in Utah).	81
Table A-5. Definitions of Colorado and Utah designated protected uses.	86

List of Figures

Figure 1. Northern Colorado Plateau Network parks.	7
Figure 2. Reaches of (a) the Fremont River near Capitol Reef National Park, (b) North Creek in Zion National Park, and (c) Red Rock Creek in Black Canyon that currently are listed as water-quality impaired on Utah and Colorado 303(d) lists.	12
Figure 3. Power analysis as sample size increases for core parameters P and N. Data sets were from historic monthly site visits spanning the date range listed in Table 7.	31
Figure 4. Map of sampling locations in Zion National Park.	50
Figure 5. Map of sampling locations in Bryce Canyon National Park.	51
Figure 6. Map of sampling locations in Capitol Reef National Park.	52
Figure 7. Map of sampling locations in Canyonlands National Park.	53
Figure 8. Map of sampling locations in Arches National Park.	54
Figure 9. Map of sampling locations in Natural Bridges and Hovenweep National Monuments. .	55
Figure 10. Map of sampling locations in Currecanti National Recreation Area and Black Canyon of the Gunnison National Park.	56
Figure 11. Map of sampling locations in Dinosaur National Monument.	57
Figure 12. Flow chart of data management activities.	65

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List of Acronyms and Abbreviations

General acronyms

303d	Section 303d of Clean Water Act requiring a reporting of waters not meeting standards
as N	as Nitrogen
as P	as Phosphorus
AZ	Arizona
B	Fecal Indicator Bacteria
CDPHE	Colorado Department of Public Health and Environment
cfs	cubic feet per second
CO	Colorado
CP	Core Parameters
CWA	Clean Water Act
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EPA	United States Environmental Protection Agency
FIB	Fecal Indicator Bacteria
GPRA	Government Productivity and Results Act
H ₂ S	Hydrogen sulfide
I&M	Inventory and Monitoring Program
MI	Major Ions
Mg	Magnesium
mg/L	milligrams per liter
Nut	Nutrients
NPS	National Park Service
NTU	nephelometric turbidity units [turbidity]
NWIS	National Water Information System (USGS)
ONRW	Outstanding Natural Resource Waters
pci/L	picocuries per liter
Q	Discharge (in cubic feet per second)
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SC	Specific Conductance
Secchi	Secchi Disk for measuring light penetration
SOP	Standard Operating Procedure
STORET	USEPA Storage and Retrieval System database
T	Temperature
TDS	Total Dissolved Solids
TBA	To Be Arranged
TMDL	Total Maximum Daily Loading
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TU	Turbidity

WRD	National Park Service Water Resources Division
µg/L	micrograms per liter
µS/cm	microsiemens per centimeter [specific conductance]
UT	Utah
UDEQ	Utah Division of Environmental Quality
UDWQ	Utah Division of Water Quality
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USGS	United States Geological Survey
WY	Wyoming

Acronyms for NPS Units

ARCH	Arches National Park
BLCA	Black Canyon of the Gunnison National Park
BRCA	Bryce Canyon National Park
CANY	Canyonlands National Park
CARE	Capitol Reef National Park
CEBR	Cedar Breaks National Monument
COLM	Colorado National Monument
CURE	Curecanti National Recreation Area
DINO	Dinosaur National Monument
FOBU	Fossil Butte National Monument
GOSP	Golden Spike National Historic Site
HOVE	Hovenweep National Monument
NABR	Natural Bridges National Monument
NCPN	Northern Colorado Plateau Network
PISP	Pipe Spring National Monument
SCPN	Southern Colorado Plateau Network
SEUG	South East Utah Group (includes ARCH, CANY, HOVE and NABR)
TICA	Timpanogos Cave National Monument
ZION	Zion National Park

1. Background and Objectives

1.1. Introduction

Sixteen national-park units comprise the Northern Colorado Plateau Network (NCPN). Eight are located exclusively in the state of Utah, three are located in the state of Colorado, one unit each is located in Wyoming and Arizona, and two straddle the Utah–Colorado border (Figure 1). Most of the units are in the Colorado River Basin. Exceptions are the parks along the northern and western margins of the network that drain to the Great Basin: FOBU, GOSP, TICA and CEBR.

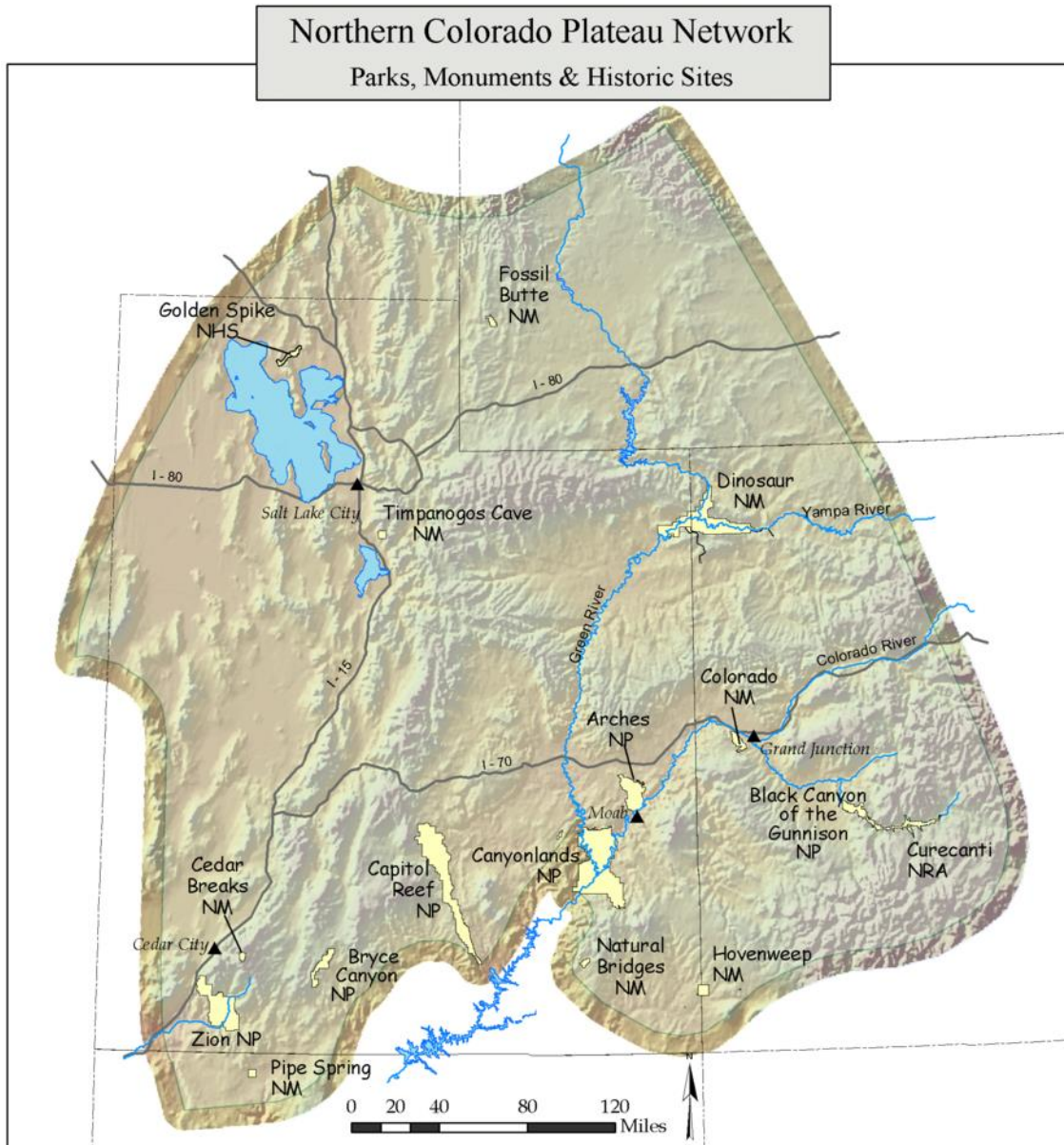


Figure 1. Northern Colorado Plateau Network parks.

1.1.1. Hydrologic Setting and Influences on Water Quality

In the Colorado Plateau, the relatively arid climate and geology strongly influence water resources and water quality. Segments of the Colorado River and its major tributaries are protected within DINO, CURE, BLCA, and CANY. These are large rivers with mean annual discharges of 5.6–56 m³/s. In some cases, the large rivers are nearly free-flowing, while other segments are entirely controlled by large reservoirs upstream. CURE contains three large reservoirs and CANY includes the upstream end of Lake Powell, the majority of which is managed by Glen Canyon National Recreation Area, in the Southern Colorado Plateau Network. Tributaries with mean annual discharges of 1.1–2.8 m³/s are major rivers in CARE and ZION. Smaller streams with seasonal and perennial discharges of less than 0.03 m³/s, though not abundant, are found in many parks.

Springs are significant resources in the network because they are the only water sources in many areas. A type of spring characteristic of the Colorado Plateau is the hanging garden, where groundwater seeps or trickles from a saturated vertical sandstone face, creating a large area of wetted rock. These vertical oases are habitat for wetland species and some endemics in ZION, CARE, CANY, and DINO. Other water sources in the NCPN include tinajas (small water catchments eroded into bedrock that hold water for a few weeks or months) and other small reservoirs developed for livestock, wildlife, or NPS water supply.

Precipitation is strongly correlated with elevation across the Colorado Plateau and surrounding mountains. As a result, the park units, or portions of larger park units, with the greatest amounts of precipitation are those with the highest elevations; CEBR, CURE, and TICA receive 50–100 cm of annual precipitation. Parks at lower elevations—particularly those in rain shadows of higher terrain, such as ARCH, CARE, HOVE, and PISP—receive 20–40 cm annually. The result of this distribution is that perennial water in park units either originates at high elevation and flows (sometimes for long distances) to the park or travels as groundwater and arises in the vicinity of the park. It also means that perennial water sources in low- and mid-elevation parks are often separated by wide expanses of arid terrain.

Two other climatic characteristics that strongly influence water flow and quality are snowmelt and monsoonal rains. At higher elevations a large part of the annual precipitation occurs as snow, building a substantial snowpack resulting in a spring runoff for any rivers with headwaters that reach these higher elevations. For larger watersheds, the greatest discharge of the year is usually the spring snowmelt. Spring floods are associated with lower concentrations of most dissolved constituents, but higher suspended loads. The NCPN is at the northern limits of the Southwest Monsoon, a moist southerly airflow that contributes to thunderstorm downpours from mid -July to mid -August. Runoff from these intense storms often results in flood events with extraordinarily high sediment loads.

1.1.2. Uses of Water and Ecological Significance of Water Quality

Water in NCPN units controls much of the abundance, distribution and diversity of floral and faunal assemblages. Additionally it continues the inexorable sculpting of landscape features that are synonymous with many NCPN parks. Flowing water on the surface or underground is a major mechanism of nutrient and ion transport in natural systems. Water quality can also have a substantial influence on human uses of the water, both inside and outside of parks. The water dependent ecosystems in these unique landscapes as well as all other natural and

cultural resources found therein are protected by the NPS Organic Act and the enabling acts or proclamations for each unit.

River water in NCPN parks can generally be characterized as moderate to high in dissolved solids, turbid at higher flows, slightly basic in pH, well-buffered, and dominated by calcium, magnesium, and sodium cations and carbonate, sulfate and chloride anions. Notable exceptions are the higher elevation streams draining into CURE from watersheds dominated by metamorphic rocks that are very low in dissolved solids. The seasonality of precipitation, snowmelt runoff and monsoonal floods combine with a landscape where water infiltration and groundwater storage are generally low to create a high degree of spatial and temporal variation in discharge, temperature and dissolved solids. Rivers in the NCPN also tend to be very turbid much of the year because the landscape is highly erodible and lacks a dense vegetative cover. The majority of sediment washed from the landscape is transported during floods, but the fine sediment that contributes to turbidity can cloud the water for months after a flood event. Endemic aquatic organisms are adapted to the natural high sediment loading and turbidity of the rivers.

Other uses of water include domestic supply for park employee residences, park operations, and for visitor facilities like concessionaire-run lodges and campgrounds. Reservoirs and larger rivers are used for water-based recreation, including boating, swimming and fishing. The NPS diverts water from some streams for irrigation of landscape plantings in several units, and irrigation of historic orchards in CARE. Wildlife and domestic livestock use water at its source or from spring developments or diversions.

In addition to NPS use of water, water is diverted from sources in parks for private and public uses outside the park boundary. These diversions for domestic and municipal use, stock watering and irrigation generally pre-date establishment of the parks. The large dams in BLCA and CURE are significant sources of hydroelectric power generation by the U.S. Bureau of Reclamation.

1.1.3. State Standards and Protected Uses

NCPN Water Quality monitoring will emphasize the support of protected uses through water quality standards as developed by the states of Arizona, Colorado, Utah and Wyoming. These states have developed a regulatory system under the Clean Water Act and EPA guidance that provides for specific standard concentrations or measures for water quality constituents that are desired to protect a class of uses. The specific protected uses vary somewhat state by state, but generally include irrigated agriculture, domestic water supply, cold-water aquatic life, warm-water aquatic life, water-based recreation and livestock watering. A detailed listing of protected uses for each water source and segment in all NCPN parks is provided in Appendix A and current sources for water quality standards for each state are listed in Table 1. The complete water quality standards for each state are presented in appendices in the data analysis and reporting standard operating procedure (SOP 15). Quantitative standards are established for several parameters that the states and EPA believe are necessary to protect each of these uses. Standards are typically of two types – most are fixed quantities, others vary in response to another water quality value, typically hardness or temperature. In some cases qualitative standards or recommended levels are used.

Table 1. Sources for water quality standards for NCPN states.

State	Regulation	Website
Arizona	Arizona Administrative Code, title 18. Environmental Quality, Chapter 11.	http://www.azsos.gov/public_services/Title_18/18-11.htm
Colorado	Water Quality Control Commission Regulations: 5 CCR 1002, Regulations 21 through 94	http://www.cdphe.state.co.us/op/regs/waterqualityregs.asp
Utah	Standards of Quality for Waters of the State, R317-2, Utah Administrative Code. Utah Dept of Environmental Quality, Div. of Water Quality.	http://www.rules.utah.gov/publicat/code/r317/r317.htm
Wyoming	Wyoming Surface Water Quality Standards, Water Quality Rules and Regulations,	http://deq.state.wy.us/wqd/watershed/surfacestandards/index.asp
EPA	Access to all state and protected use designations.	http://www.epa.gov/waterscience/standards/states/

Unaltered documents can be found in appendices of SOP 15.

1.2. Waters on the 303d List in NCPN Park Units

Under the Clean Water Act (CWA), states must identify all waters that do not meet or are not expected to meet water quality standards. The identification and public notification of water-quality-limited waters is accomplished through what has become known as “303(d) Lists” after the CWA section in which the requirement is contained (EPA 2006). States are required to perform an analysis of the cause(s) of this non-attainment of standards and develop a plan for bringing the problem water body into compliance. These plans analyze the Total Maximum Daily Loading of contaminants to the water and are therefore referred to as “TMDL” plans. States can consider a wide variety of remedies, including reducing the contaminant loading, changing the designated protected uses (such as from Cold Water Fishery to Warm Water Fishery) to more accurately reflect ambient conditions, or documenting that the “poor” quality of the water is due to natural causes and is not correctable.

Four water sources in parks in the NCPN have been reported on the non-attainment or 303d List (Figure 2). A brief description of each follows.

North Creek in ZION is listed for total dissolved solids (TDS), primarily from natural sources. A total maximum daily load (TMDL) plan has been completed and the State of Utah proposed to establish source-specific standards that recognize the naturally high TDS.

The Fremont River Upstream of CARE for total phosphorus, organic enrichment and low dissolved oxygen from agricultural sources upstream of the park. Additionally, the Fremont River segment immediately downstream of the park is listed for high salinity, total dissolved solids and chlorides. A TMDL report for the upstream reach identified numerous livestock feeding operations and other agricultural practices as contributors to the nutrient loading.

State monitoring found the river to routinely exceed the standard for total phosphorus at Hickman Bridge inside the park. A TMDL report has been completed for the Fremont River segment immediately downstream of the park. Both river segments are currently Category 4A, for waters that are impaired and have a completed TMDL.

Red Rock Creek in BLCA was recently added for high selenium, along with all “Gunnison River Tributaries between Crystal Creek and the Colorado River (not including USFS land)” for high selenium. The TMDL analysis for these waters is a high priority but has not been initiated at this time. Selenium is a widespread problem in the upper Colorado River Basin, particularly in streams that drain Mancos Shale geology. Agricultural runoff from irrigated lands increases the contribution of selenium.

Additional waters of concern near NCPN units:

Paria River downstream of BRCA is listed for salinity, TDS and chlorides. The state does not extend this listing to springs in BRCA because they do not have a perennial surface flow connection to the Paria River.

Kolob Reservoir upstream of ZION is sometimes out of compliance for low dissolved oxygen. It has been assigned category 5D by the Utah DEQ, meaning that it has been intermittently out of compliance for dissolved oxygen during some monitoring cycles, but not others.

Blue Creek upstream of GOSP is subject of a TMDL review of industrial discharges upstream of the park. The state of Utah categorizes it as a “5C” water, meaning that the permitted discharge loading to the stream is significant and requires TMDL analysis.

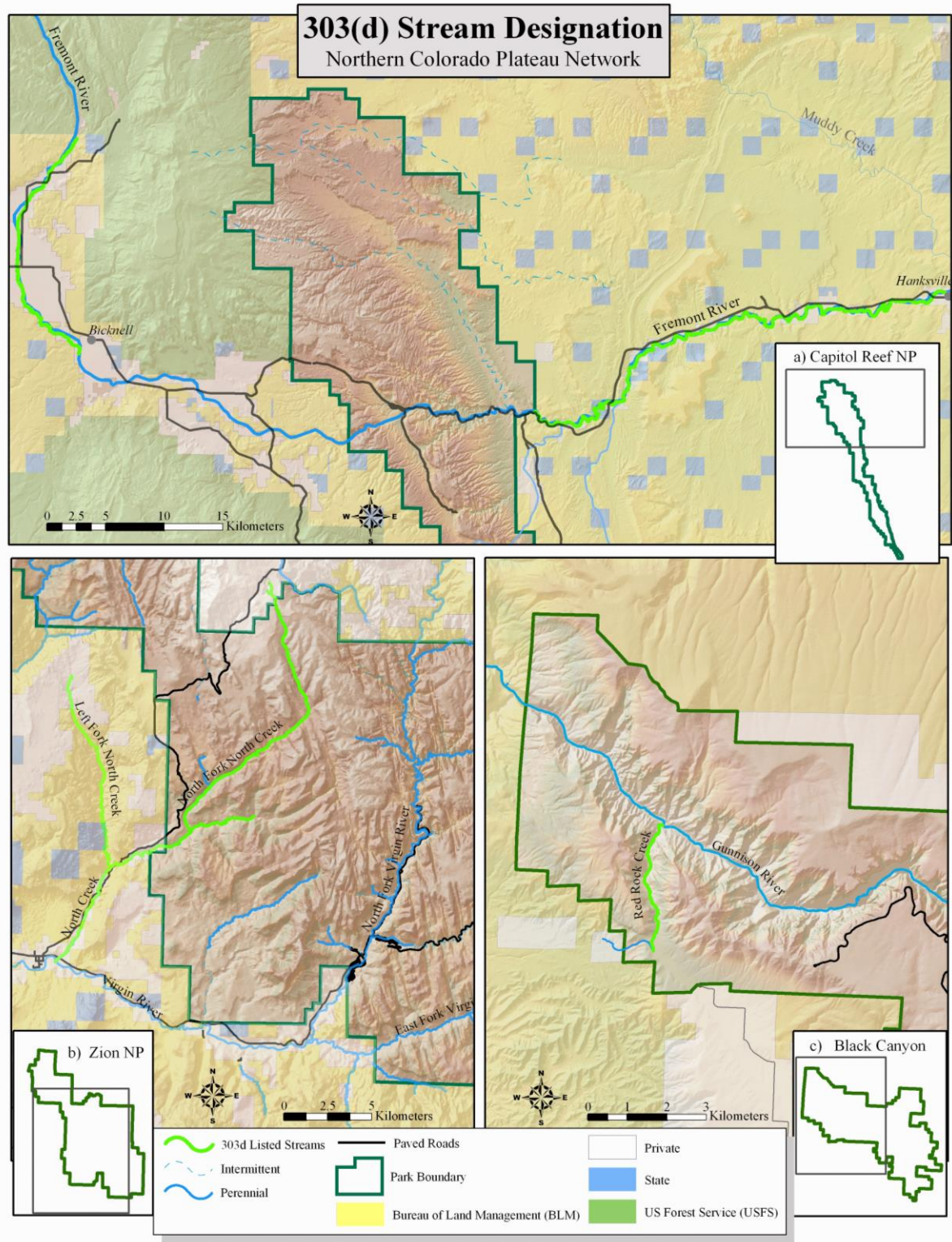


Figure 2. Reaches of (a) the Fremont River near Capitol Reef National Park, (b) North Creek in Zion National Park, and (c) Red Rock Creek in Black Canyon that currently are listed as water-quality impaired on Utah and Colorado 303(d) lists.

1.3. Qualitative Desired Future Conditions

The following Desired Future Conditions (DFC) represents what National Park Service policies and federal law allow. It is expected that the DFC for individual water bodies will differ and evolve depending on current status, changing conditions and management objectives. The DFC can be used as a starting point to develop quantitative performance measures.

Listed here is a summary of the DFC's and how they will be achieved with more detailed rationale and explanation following.

1. Achieve water quality standards for designated beneficial use
2. Keep impairments to minor or negligible levels
3. Meet anti-degradation provisions of the CWA

DFCs require that this program develop quantitative performance measures that allow managers to

1. Quantitatively evaluate achievement of water quality standards
2. Quantitatively evaluate change relative to definitions of impairment and anti-degradation
3. Do this in an adaptive management sense that allows detection of a true change outside of natural variability. This in turn might initiate a management action.

It is instructive to review policies and concepts outlined in guidance documents for water quality that help establish a starting point for DFC.

The National Park Service Management Policies, Chapter 4 (NPS 2001) state:

The National Park Service will strive to understand, maintain, restore, and protect the inherent integrity of the natural resources, processes, systems, and values of the parks. The Service recognizes that natural processes and species are evolving, and will allow this evolution to continue, minimally influenced by human actions...

The Service manages the natural resources of parks to maintain them in an unimpaired condition for future generations in accordance with NPS- specific statutes, including the NPS Organic Act and the National Parks Omnibus Management Act of 1998; general environmental laws such as the Clean Air Act, the Clean Water Act, the Endangered Species Act of 1973, NEPA, and the Wilderness Act; Executive orders; and applicable regulations.

Thus, the integrity and character of pristine water bodies should be maintained in accordance with the antidegradation provision of the CWA to ensure sustainable ecological function and enjoyment by park visitors. The highest level of water-quality protection under standards associated with the CWA applies to certain waters that constitute an outstanding state or national resource. These waters, which are those designated as Outstanding Natural Resource Waters (ONRWs), shall be maintained and protected at their existing quality. The anti-degradation provision states that existing instream water uses and the level of water quality

necessary to protect the existing uses shall be maintained and protected. The Clean Water Act specifically mentions national parks and the special status of waters therein.

Where high quality waters constitute an outstanding national resource, such as waters of national and state parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected." (GPO, 2006; Title 40 CFR 131.12)

The antidegradation provision is interpreted differently by states, but in general has two or three classes or tiers that represent degrees of antidegradation ranging from none whatsoever to short term impairment with no long term consequences. A good summary of the antidegradation provision as interpreted by the states can be found at: <http://www.blm.gov/nstc/WaterLaws/abstract2.html>

It is recognized that variability is large within and across water bodies in NCPN parks making defined standards difficult to identify. For this reason management should evaluate water quality data relative to water quality standards and long-term natural variability to the extent that ‘natural’ can be separated from anthropogenic-induced change, with careful consideration of proposed changes in watersheds that may result in anthropogenic-induced impairment.

For waters that originate or lie wholly within park units, anthropogenic activities should be managed so that they have *minor or negligible* impacts on water quality according to defined levels of impact under National Environmental Protection Act (NEPA) (NPS 2003e).

Negligible Water Quality Impacts are described as “Impacts are effects that are not detectable, well below water quality standards, and within historical baseline water quality conditions.”

Minor: Impacts are effects that are detectable but well within or below water quality standards and within historical baseline water quality conditions.

Moderate: For most waters, impacts are effects that are detectable, within or below water quality standards, but historical baseline water quality conditions are being altered on a short-term basis. However, in outstanding natural resource waters (ONRWs), this threshold may approach the requirements for statutory impairment.

Major: For most waters, impacts are effects that are detectable and significantly and persistently alter historical baseline water quality conditions. Water quality standards are locally approached, equaled, or slightly and singularly exceeded on a short-term and temporary basis. However, in ONRWs this threshold would probably constitute statutory impairment.

1.3.1. Utah parks

Due to the high standard of protection outlined in the NPS Management Policies, regardless of designated beneficial use established by the State, it is expected that park managers will consider waters that originate or lie wholly within Utah parks be managed as Category 1 and

2 waters defined as follows (Utah Admin Code R317-2-3.2 which can be found at <http://www.rules.utah.gov/publicat/code/r317/r317-002.htm>):

Category 1 - Waters of high quality that have been determined by the [Water Quality] Board to be of exceptional recreational or ecological significance or have been determined to be a state or national resource requiring protection, shall be maintained at existing high quality through designation, by the Board after public hearing, as High Quality Waters - Category 1. New point source discharges of waste water, treated or otherwise, are prohibited in such segments after the effective date of designation.”

Category 2 - Water segments which are treated as High Quality Waters - Category 1 except that a point source discharge may be permitted provided that the discharge does not degrade existing water quality.

1.3.2. Colorado parks

Although no network parks currently have water bodies with ONRW status, BLCA and CURE are monitoring water quality at several sites to determine whether or not they qualify for this status. These parks have collected water-quality data since the 1980s as part of a baseline water quality monitoring program. These data are being used to determine constituent fluxes into the reservoir system and to characterize existing water quality conditions. Based on limited data and types of constituents collected, certain streams and rivers have shown existing water quality that is of higher quality than standards directed by the CWA and enacted by Colorado. An ongoing investigation has begun to evaluate the feasibility of attaining ONRW status for all monitored water bodies, with the exception of Red Rock Creek (Matt Malick personal comm.). This designation will protect the waters of BLCA and CURE beyond current standards, consistent with Service-wide and park guidelines.

1.3.3. Other parks

No continuous monitoring of water bodies in Wyoming or Arizona parks is being implemented at present. However, if park waters in those states are monitored in the future by NCPN personnel or resources, it is expected they will be monitored and managed in the spirit of the CWA antidegradation provision as interpreted by the States of WY and AZ.

1.3.4. Thresholds of Concern

Thresholds of concern for NCPN waters will be the same as water quality standards used by states to evaluate compliance with CWA. Water quality standards can be found in state administrative codes (Table 1). These standards will be used to warn of potential problems because they are quantitative and have built-in margins of safety. The number of site visits necessary to detect a true change outside of natural variability that might initiate a management action is discussed below in the section on power analysis and effect size (2.7).

States have narrative standards that protect water bodies against pollutants for which quantitative standards do not exist, as well as quantitative numeric standards for acute and chronic exceedances. In practice, consultation with state water quality professionals will be necessary to determine if acute and chronic exceedances warrant action on the part of park

managers. In some cases, acute exceedances may result from natural causes that cannot reasonably be controlled by management.

1.4. Water Quality Vital Signs

A description of Water Quality Vital Signs for each park unit prepared by USGS-WRD is presented in O'Dell et al. (2005), Appendix F. This analysis is the primary basis for developing the sampling design. It provides the status of 303(d) listed waters, streamflow gauges, and current monitoring activities within each park, along with a detailed summary of existing water quality data, screening of that data against standards and threat levels, and a discussion of findings from the analysis. The analysis was conducted for each important water body identified in NCPN parks with available water quality data.

1.4.1. Historic Observations and Existing Conditions

The number of water quality samples and constituents measured varies considerably between and within parks. There is a paucity of data for several of the parks, including BRCA, CEBR, COLM, FOBU, HOVE, and PISP (except for flow). Additionally, though sufficient data may be available for a few water sources or sites in some parks, many of the water sources are lacking adequate data to characterize water quality conditions in ARCH, CANY, CARE, CURE, DINO, NABR, TICA, and ZION. Table 2 presents a summary of the overall number of sample sites, samples and results through 2002 for each NCPN unit.

Table 2. Number of sites, samples and results with sample period for all sites located within parks by parameter category¹ for compiled historical water-quality data through 2002.

Park	Parameter category	Number of sites	Number of samples	Number of results	Earliest sample	Latest sample
Arches National Park	Major Ions	42	305	2,666	9/15/1970	6/4/2002
	Trace Elements	29	235	3,256	9/15/1970	3/14/2002
	Core Field Parameters ²	45	523	1,568	9/15/1970	6/4/2002
	Nutrients	27	247	671	9/15/1970	5/14/2002
	Microorganisms	7	59	99	12/21/1984	5/3/1990
Black Canyon of the Gunnison National Park	Major Ions	3	83	1,128	9/26/1977	9/18/2002
	Trace Elements	3	76	315	9/26/1977	9/18/2002
	Core Field Parameters ²	4	480	1,032	6/16/1959	11/23/2002
	Nutrients	3	113	1,324	11/18/1987	9/18/2002
	Microorganisms	3	37	37	5/8/1996	9/5/2002
Bryce Canyon National Park	Major Ions	42	62	594	9/29/1956	6/9/1998
	Trace Elements	28	36	259	9/29/1956	4/30/1998
	Core Field Parameters ²	50	76	193	9/29/1956	6/9/1998
	Nutrients	22	40	80	9/29/1956	6/9/1998
	Microorganisms	15	34	146	6/23/1981	8/18/1981
Canyonlands National Park	Major Ions	110	879	8,142	8/19/1961	6/10/2002
	Trace Elements	78	755	6,397	10/24/1967	4/9/2002

Park	Parameter category	Number of sites	Number of samples	Number of results	Earliest sample	Latest sample
	Core Field Parameters ²	131	946	3,416	8/19/1961	8/15/2002
	Nutrients	98	837	2,821	5/18/1965	6/10/2002
	Microorganisms	43	166	283	6/17/1980	5/22/1990
Capitol Reef National Park	Major Ions	41	393	2,579	10/3/1951	7/17/2002
	Trace Elements	26	188	1,581	10/3/1951	7/11/2001
	Core Field Parameters ²	47	4,390	12,894	10/3/1951	7/17/2002
	Nutrients	36	432	1,709	10/3/1951	7/11/2001
	Microorganisms	26	2,363	2,374	9/9/1976	12/1/1994
Cedar Breaks National Monument	Major Ions	6	11	146	8/2/1967	11/1/1988
	Trace Elements	5	8	27	9/3/1970	11/1/1988
	Core Field Parameters ²	5	29	46	8/2/1967	11/1/1988
	Nutrients	4	10	16	8/2/1967	11/1/1988
	Microorganisms	2	10	15	7/10/1984	5/18/1993
Colorado National Monument	Major Ions	17	25	342	3/7/2001	11/8/2001
	Trace Elements	17	25	544	3/7/2001	11/8/2001
	Core Field Parameters ²	17	25	100	3/7/2001	11/8/2001
	Nutrients	17	24	48	3/7/2001	11/8/2001
	Microorganisms	14	15	15	3/7/2001	5/15/2001
Curecanti National Recreation Area	Major Ions	76	420	1,428	4/1/1965	9/19/2002
	Trace Elements	67	264	1,674	7/24/1944	9/19/2002
	Core Field Parameters ^{2,3}	142	10,823	41,734	4/4/1962	10/1/2003
	Nutrients	77	1,298	7,647	5/28/1974	9/19/2002
	Microorganisms	24	1,011	1,286	7/7/1981	9/15/1997
Dinosaur National Monument	Major Ions	117	1,023	13,421	9/18/1948	10/23/2002
	Trace Elements	124	627	5,097	5/4/1950	10/23/2002
	Core Field Parameters ²	169	1,866	4,909	9/18/1948	10/23/2002
	Nutrients	117	819	3,795	9/18/1948	10/23/2002
	Microorganisms	5	209	439	4/11/1972	10/23/2002
Fossil Butte National Monument	Major Ions	6	9	101	6/8/1975	6/16/1993
	Trace Elements	5	7	63	7/26/1977	4/21/1989
	Core Field Parameters ²	6	8	16	6/8/1975	6/16/1993
	Nutrients	5	8	17	6/8/1975	4/21/1989
	Microorganisms	2	2	2	5/5/1988	5/5/1988
Golden Spike National Historic Site	Major Ions	1	7	38	5/7/1967	6/2/1967
	Trace Elements	0	--	--	--	--
	Core Field Parameters ²	1	7	18	5/7/1967	6/2/1967
	Nutrients	0	--	--	--	--
	Microorganisms	0	--	--	--	--

Park	Parameter category	Number of sites	Number of samples	Number of results	Earliest sample	Latest sample
Hovenweep National Monument	Major Ions	7	30	363	5/1/1959	12/6/2000
	Trace Elements	6	22	242	9/7/1963	12/6/2000
	Core Field Parameters ²	7	30	95	5/1/1959	12/6/2000
	Nutrients	6	27	65	5/1/1959	12/6/2000
	Microorganisms	0	--	--	--	--
Natural Bridges National Monument	Major Ions	5	108	992	11/20/1958	11/30/2000
	Trace Elements	5	90	736	11/20/1984	11/30/2000
	Core Field Parameters ²	5	107	418	11/20/1958	11/30/2000
	Nutrients	5	107	316	11/20/1958	11/30/2000
	Microorganisms	5	36	68	9/18/1985	6/4/1990
Pipe Spring National Monument	Major Ions	3	16	265	7/27/1976	8/30/2001
	Trace Elements	3	16	155	7/27/1976	8/30/2001
	Core Field Parameters ²	3	16	69	7/27/1976	8/30/2001
	Nutrients	2	14	137	7/27/1976	8/30/2001
	Microorganisms	0	--	--	--	--
Timpanogos Cave National Monument	Major Ions	9	103	1,070	6/4/1990	9/18/1991
	Trace Elements	0	--	--	--	--
	Core Field Parameters ²	8	98	196	6/4/1990	9/18/1991
	Nutrients	0	--	--	--	--
	Microorganisms	0	--	--	--	--
Zion National Park	Major Ions	35	167	1,622	10/16/1954	6/12/2002
	Trace Elements	25	88	788	10/16/1954	1/16/2002
	Core Field Parameters ²	64	640	1,395	10/16/1954	6/12/2002
	Nutrients	24	142	508	11/8/1963	6/12/2002
	Microorganisms	19	358	447	2/4/1976	9/21/2001

¹ Selected parameter categories shown include constituents of common concern for the NCPN network; all categories represent samples from the water column.

² Core field parameters, as determined servicewide by NPS, include pH, SC, DO, and water temperature.

³ Number of samples is large due to many multiple-depth (i.e., profile) samples in reservoirs.

Of the 161 water sources identified by park resource managers in the NCPN as being of interest, approximately 110 (or 68%) are data deficient (where generally fewer than 10 water-quality samples were collected in the last 15 years), and approximately half of these water sources have essentially no water-quality data in the record.

Overall, there are relatively few violations of water-quality standards. The most common violations were for dissolved oxygen, water temperature, nutrients (phosphorus and unionized ammonia), aluminum (dissolved), selenium (dissolved), total dissolved solids, and total

suspended solids. Some water-quality constituents of widespread concern across the network are discussed below.

1.4.2. Nutrients

Nutrients, in particular total phosphorus and unionized ammonia, are a concern for many of the NCPN parks. Possible sources of these elevated nutrients include upstream activities (grazing, irrigation return flows and other agricultural activities, residential development, wastewater discharges) within-park activities (waste disposal facilities, leaking septic systems, visitor activities, campgrounds, trespass or permitted grazing), and wildlife. It is also possible that the natural geology contributes to elevated levels, a conclusion at least partly supported by the widespread occurrence of high nutrient levels combined with the low occurrence of algal blooms and other nutrient-related problems. Of the 14 parks with recent nutrient data available, recurring phosphorus and/or unionized ammonia exceedances were identified in 12 parks (Table 3).

Table 3. Nutrient exceedances in NCPN units, indicated by stream name(s) or “X” for multiple sources.

Park code	Multiple total phosphorus exceedances	Multiple unionized ammonia exceedances	Few unionized ammonia & total phosphorus exceedances (surface water)	Total phosphorus exceedances (major water sources)	Unionized ammonia (concern)	Elevated total Phosphorus /unionized ammonia exceedances (springs)
ARCH			X			X
BLCA			X		Red Rock Creek	X*
BRCA			X			
CANY	X	X		Green, Colorado Rivers	Green, Colorado Rivers	X
CARE	X	X		Fremont River, Pleasant & Sulphur Creeks	Fremont River, Pleasant & Sulphur Creeks	
CURE		X			Cimarron River, Squaw Creek	X*
DINO	X	X		Green River	Green River	X*
GOSP	X			Blue Creek	Blue Creek	
HOVE						X
NABR			X	White Canyon Creek	White Canyon Creek	X
TICA			X	North Fork American River	North Fork American River	

Park code	Multiple total phosphorus exceedances	Multiple unionized ammonia exceedances	Few unionized ammonia & total phosphorus exceedances (surface water)	Total phosphorus exceedances (major water sources)	Unionized ammonia (concern)	Elevated total Phosphorus /unionized ammonia exceedances (springs)
ZION	X	X		North Fork Virgin River, East Fork Virgin River, La Verkin Creek, North Creek, Kolob Creek	North Fork Virgin River, East Fork Virgin River, La Verkin Creek, North Creek, Kolob Creek	

*Though not regulated in Colorado, elevated total phosphorus concentrations (>0.05 mg/L, the Utah recommendation) were identified for water sources in these parks.

1.4.3. Trace Elements (Metals)

Trace elements, including metals, were identified as a potential water-quality concern in several of the NCPN parks. Activities or sources that could be contributing to elevated metals and/or water-quality exceedances include historic and current mining and gas development activities adjacent and upstream of the park, nearby coal-fired power plants and waste incinerators, the underlying geology, and upstream wastewater discharges. Very limited trace element data were collected at BLCA, BRCA, CANY (springs), CARE (seeps and springs), COLM, FOBU, and PISP. No data were collected at CEBR or cave sites at TICA.

Exceedances are noted in Table 4. Of the 14 parks with recent trace element data available, recurring exceedances were identified in 10 parks.

Table 4. Trace-element exceedances in NCPN units, indicated by stream name(s) or “X” for multiple sources.

Park code	Recurring aluminum exceedances	Manganese	Lead	Copper	Cadmium	Iron	Mercury
ARCH	X						
CANY	Colorado, Green Rivers	Cebolla Creek ² , Cimarron and Lake Fork Gunnison Rivers ² ; Red and East Elk Creeks ³	Gunnison River ² , Cebolla Creek ²	Cebolla Creek ²	Blue River ²	Cebolla Creek ² , Cimarron and Gunnison Rivers ²	

Park code	Recurring aluminum exceedances	Manganese	Lead	Copper	Cadmium	Iron	Mercury
CURE	Cebolla Creek						
DINO	Yampa, Green Rivers	Yampa River ⁴	Yampa River ¹	Yampa River ¹		Yampa River ³	
GOSP	Blue Creek			Blue Creek ¹			Blue Creek ¹
HOVE	X		East and West Square Tower Canyon Springs ¹	Holly House Spring ¹	East and West Square Tower Canyon Springs ¹	Holly House Spring ¹	
NABR	X			Sipapu Bridge Spring ¹			
PISP			West Cabin and Spring Room Springs ¹		West Cabin and Spring Room Springs ¹		
TICA			American Fork River ¹				American Fork River ¹
ZION	X						

¹single exceedance; ² one to several exceedances; ³multiple exceedances; ⁴few exceedances

1.4.4. Selenium

Selenium is a trace element of particular concern throughout much of the Colorado River basin with elevated levels due to irrigation practices and development (Butler and Lieb 2002). Natural background levels are high and associated with particular soil types and geological features such as Mancos Shale. Of the 16 NCPN parks, ARCH, BLCA, CANY (surface water only), CURE, DINO, HOVE, and ZION had water bodies with selenium exceedances. CEBR had no selenium data available for evaluation.

1.4.5. Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)

Elevated TDS and TSS are a water-quality concern throughout the network. Activities contributing to elevated TDS and/or TSS concentrations occur upstream and within the park and include: natural geologic sources, visitor activities in and around water sources (e.g., stream bank collapse); off-road recreational vehicle use; grazing and other agricultural activities; road development and repair; and upstream residential development. Six parks (BLCA, CEBR, COLM, CURE, PISP, and ZION) had little to no TDS and/or TSS data.

Exceedances occurred in all of the remaining 10 parks with recent TDS and TSS data, and these are listed in Table 5.

Table 5. TDS and TSS exceedances in NCPN units, indicated by stream name(s) or “X” for multiple sources.

	Recurring total dissolved solids (TDS) exceedances	Recurring total suspended solids (TSS) exceedances	TDS and/or TSS exceedances (one to few exceedances)
ARCH	Salt Wash, Salt Valley Wash, Salt Springs		X
BRCA	Sheep Creek	Tropic Ditch	
CANY		Colorado and Green Rivers, Salt Creek, Cave Spring	
CARE	Sulphur, Oak Creeks (limited data)	Fremont River, Pleasant and Sulphur Creeks	
DINO		Green River	
FOBU			X
GOSP	Blue Creek	Blue Creek	
HOVE			X
NABR			X
TICA			X

1.4.6. Pesticides

ARCH, CARE, CEBR, DINO, and NABR identified pesticides as a management concern. Pesticide (or herbicide) applications are used within ARCH, NABR and ZION for *Tamarix* control, within park orchards at CARE, and are used on lands adjacent to CEBR and DINO. Only GOSP had any pesticide exceedances identified (for phenol); however, water sources located in Colorado were not evaluated for pesticide exceedances. Four parks have conducted very limited pesticide sampling:

- CANY (1 site, 40 samples; 4 sites, 1 sample)
- DINO (1 site, 1–5 samples)
- GOSP (2 sites, 1–3 samples)
- ZION (1 site, 1 sample)

Pesticide monitoring is of interest to several parks; however, this concern would have to be addressed outside the basic NCPN monitoring program due to the very high laboratory costs of pesticide analyses.

1.4.7. Springs, Seeps, Hanging Gardens, and Tinajas

Springs, seeps, hanging gardens, and tinajas are common water features in NCPN parks. These sources of water are critical to flora and fauna, and are aesthetically appealing to park visitors. Monitoring is sometimes difficult because individual water sources, though often

diminutive, can be numerous and can have diffuse discharge points difficult to sample. A network approach applicable to many springs is to rotate sampling from year-to-year among several springs, as is currently done in the Southeast Utah Group.

The amount of data for identified springs and seeps varies considerably between parks and is usually minimal. Some spring sites are included in the proposed NCPN water quality monitoring program. A related NCPN effort to specifically inventory seeps and springs has been implemented and will greatly improve the knowledge base.

1.4.8. Chlorophyll and Carbon

Chlorophyll and carbon were listed as vital signs that may be considered for inclusion in a monitoring program. Chlorophyll is monitored only at CURE in Blue Mesa Reservoir. This parameter is effective in relaying information about eutrophication levels in reservoirs, lakes, ponds and even streams. At present, chlorophyll monitoring at other parks is not recommended in flowing waters since few eutrophication problems have been observed, and state standards do not exist.

Monitoring carbon in its various forms (benthic organic matter, total organic matter, coarse organic matter, dissolved organic matter etc.) is useful in describing structure and function of lotic systems, and can relay information about changes in an aquatic system. Limited data are available for NCPN parks (Table 6). These measurements are difficult and expensive. Measurement of this parameter is left to special studies.

Table 6. NCPN park waters with available chlorophyll and carbon, indicated by stream name(s) or "X" for multiple sources.

	Chlorophyll monitoring locations	Total organic carbon (TOC) data availability	Dissolved organic carbon (DOC) data availability	Volatile particulate organic matter (VPOM) data availability
ARCH		X		
CANY		X (3 sites)		
CARE		Fremont River		
CURE	Blue Mesa Reservoir		Gunnison River	
DINO		Green River	Yampa River	
GOSP		Blue Creek		
ZION		X		X

1.5. Historic Variability

An evaluation of historic parameter variability is useful in determining the expected sample size required to detect a significant change beyond natural variability. This analysis helped determine realistic time frames for the duration of data collection and the number of site visits necessary to detect a significant change that may be of concern to park managers. Although it is recognized that power and sample size tests based on hypothesis testing have limits, they

are a good starting point for determining how natural variability and sample size interact. Another shortcoming is that these tests are designed for normally distributed data. However, it is generally accepted that results from these easy-to-use calculators are within 10% of more complicated non-parametric sample size tests (Irwin 2006). Therefore, this type of analysis will be used as one line of evidence suggesting a sufficient sample size or change when other lines of evidence are considered as well in light of the fact that statistical significance alone may not imply biological significance.

Evaluation of historic variability in the context of change detection was made by computing mean and variance for water quality stations that had the longest data record. These statistics were used in the S-plus 7.0.3 parametric power and sample size calculator (Insightful 2005) to 1) determine the minimum detectable difference (MDD), or the effect size that could be detected outside the natural range in variability for historic data; 2) determine power, the probability of rejecting the null hypothesis when it was false; and 3) the sample size required to detect a significant change in the mean with alpha and beta set. The S-Plus module compared favorably (within sample size of 1 and effect size < 2%) to accepted power and sample size calculators recommended in Part B Lite (Irwin 2006). It has an advantage over on-line calculators in that multiple input variables can be evaluated in one calculation and stored and manipulated in a command line. Due to inexactness of results (parametric vs. non-parametric issues) and the desire to ensure sufficient sample sizes were considered, the calculations were made for a large range in sample size to evaluate the relationship between sample size and power for parameters that range from low variability (pH) to high (ortho phosphorus).

As per guidance from WRD (Irwin 2006 and Irwin personal comm.) alpha was set to 0.1 and beta 0.05. This was because as a resource conservation agency, the NPS should be more concerned with beta (the conservationist's risk) than alpha (the polluter's risk). We used the one sample, two-tailed test and set the alternative hypothesis to +30% of the historic mean.

Three calculations and one simulation were conducted:

1. Calculate sample size necessary to observe a difference greater than 30% of the mean when $\alpha = 0.1$ and $1-\beta = 0.95$.
2. Calculate the MDD when $\alpha = 0.1$ and $1-\beta = 0.95$ using the historic data set sample size
3. Calculate the power of historic data to detect a change in 30% of the mean when $\alpha = 0.1$
4. Simulate the relationship between a range in sample size and associated power based on historic mean and variance when $\alpha = 0.1$ and $H_a = H_o + 30\%H_o$. This is an iteration of step 3 using a range of sample sizes assuming the mean and variance remain constant.

The data sets used in the calculations were from ZION, which had the longest historic record, and from the first 9 months of sampling conducted by NCPN on the same streams. Because the NCPN pilot results are for core parameters only and are unlikely to represent the full range in conditions, less emphasis is placed on those results. However, as more data are

collected from NCPN monitoring sites, these calculations can be repeated to evaluate potential for change detection.

1.6. Minimum Detectable Difference

The Minimum Detectable Difference (MDD) is the magnitude of observable change (in observation units) that is required to allow management of the water resource in an optimal, proactive, and precautionary manner. The MDD magnitude is driven in part by variability, sample sizes, significance level and power selected. It is related to signal to noise ratio and the degree to which small differences can be detected quantitatively (Irwin 2006).

In the absence of specific guidance on MDD for NCPN parks, an initial MDD of 30% difference in means was selected for preliminary analysis of required sample size, with the caveat that this level may be changed in the future as more high quality monitoring data are available and a better understanding of parameter variability emerges.

The effect size for historic data sets (Table 7) is considerably lower than the desired minimum detectable difference for specific conductivity, DO and pH, but much larger for ortho phosphorus, total phosphorus and nitrogen. This is due to not only the low variability and large sample size for SC, DO and pH, but also the high variability, low sample size and near detection limits of phosphorus and nitrogen. Many of the phosphorus and nitrogen results were censored to the detection limit prior to analysis. These results indicate that changes in SC, DO and pH will be easily detected but changes in P and N will be difficult to detect even if they are large and significant.

1.7. Sample Size

The required sample size to detect 30% change in the mean differs greatly by parameter corresponding to variability in results. In general, the required sample size is less than the intended number of visits in a 2-year panel rotation for ZION streams for all parameters analyzed except ortho phosphorus and specific conductivity of LaVerkin Creek at the highway 17 bridge. A plot of specific conductivity through time at this site indicates a downward trend from 1976 through 2002, which may explain the high variance around a single mean for the duration. This analysis indicates that for the core parameters a monthly sampling period (assuming variability remains similar) will be sufficient to detect change in annual means for pH and DO, but two years of sampling will be required to detect significant change in SC. An unreasonable number of site (>300) visits would be required to detect a change in phosphorus. But two years of monthly site visits (23) should be sufficient to detect change in unionized ammonia.

Although change detection in phosphorus and some nitrogen species will not be possible, this data will continue to be collected for both compliance and its role in the analysis suite provided to cooperators by the state of Utah.

Table 7. Statistics for historic water quality data in ZION and computed MDD, power, and sample size.

Parameter	Site	Historic Stdev (σ)	Historic mean = H_0	Historic sample n	Desired MDD $+30\%(\mu_0)$	+30% change from historic mean H_a	$\alpha=0.1$, $\beta=0.95$ n = Historic Solve for effect size	$\alpha=0.1$ $H_a =$ $\mu_0+30\%(\mu_0)$ Solve for power (1- β)	set power (1- β)	set alpha α	$\alpha=0.1$, $\beta=0.95$ $H_a =$ $\mu_0+30\%(\mu_0)$ solve for n	monthly site visits date range
SpCond.	North Fork Virgin 4493 (above confluence w/ E. Fk.)	197.520	710.1	190	213.0	923.1	47.19	1	0.95	0.1	13	1979– 2002
SpCond.	North Creek 4482 (near Virgin, UT)	235.110	696.8	41	209.0	905.8	122.90	1	0.95	0.1	15	1985– 1991
SpCond.	LaVerkin Creek 4476 (at hwy 17 bridge)	554.570	1092.8	127	327.9	1420.7	162.80	1	0.95	0.1	32	1976– 2002
SpCond.	North Fork Virgin at N. Fork Road (NCPN)	49.108	442.7	9	132.8	575.5	53.90	1	0.95	0.1	2	2006
SpCond.	North at S. Park Boundary (NCPN)	62.254	346.8	9	104.0	450.9	68.30	1	0.95	0.1	4	2006
SpCond.	LaVerkin at Lee Pass Trail (NCPN)	67.314	740.3	9	222.1	962.4	73.81	1	0.95	0.1	1	2006
pH	North Fork Virgin 4493 (above confluence w/ E. Fk.)	0.239	8.33	187	2.50	10.83	0.057	1	0.95	0.1	1	1979– 2002
pH	North Creek 4483 (Mouth)	0.243	8.12	13	2.44	10.56	0.221	1	0.95	0.1	1	1976– 1982

Parameter	Site	Historic Stdev (σ)	Historic mean = μ_0	Historic sample n	Desired MDD +30%(μ_0)	+30% change from historic mean μ_a	$\alpha=0.1$, $\beta=0.95$ n = Historic Solve for effect size	$\alpha=0.1$ $\mu_0+30\%(\mu_0)$ Solve for power (1- β)	set power (1- β)	set alpha α	$\alpha=0.1$, $\beta=0.95$ $\mu_0+30\%(\mu_0)$ solve for n	monthly site visits date range
pH	LaVerkin Creek 4476 (at hwy 17 bridge)	0.336	8.04	125	2.41	10.45	0.307	1	0.95	0.1	1	1976–2002
pH	North Fork Virgin at N. Fork Road (NCPN)	0.066	8.51	9	2.55	11.06	0.072	1	0.95	0.1	1	2006
pH	North at S. Park Boundary (NCPN)	0.352	8.76	9	2.63	11.39	0.386	1	0.95	0.1	1	2006
pH	LaVerkin at Lee Pass Trail (NCPN)	0.069	8.45	9	2.54	10.99	0.076	1	0.95	0.1	1	2006
DO	North Fork Virgin 4493 (above confluence w/ E. Fk.)	1.383	9.09	179	2.73	11.82	0.340	1	0.95	0.1	3	1979–2002
DO	North Creek 4483 (Mouth)	1.302	10.06	13	3.02	13.08	1.188	1	0.95	0.1	3	1976–1982
DO	LaVerkin Creek 4476 (at hwy 17 bridge)	1.529	8.63	112	2.59	11.23	0.475	1	0.95	0.1	4	1976–2002
DO	North Fork Virgin at N. Fork Road (NCPN)	1.783	9.52	9	2.86	12.37	1.955	0.999	0.95	0.1	5	2006
DO	North at S. Park Boundary	1.167	8.98	9	2.69	11.68	1.300	1	0.95	0.1	3	2006

Parameter	Site	Historic Stdev (σ)	Historic mean = H_o	Historic sample n	Desired MDD +30%(μ_o)	+30% change from historic mean H_a	$\alpha=0.1$, $\beta=0.95$ n = Historic Solve for effect size	$\alpha=0.1$ $H_a = \mu_o+30\%(\mu_o)$ Solve for power (1- β)	set power (1- β)	set alpha α	$\alpha=0.1$, $\beta=0.95$ $H_a = \mu_o+30\%(\mu_o)$ solve for n	monthly site visits date range
	(NCPN)											
DO	LaVerkin at Lee Pass Trail (NCPN)	1.419	9.14	9	2.74	11.88	1.556	1	0.95	0.1	3	2006
OrthoP	North Fork Virgin 4493 (above confluence w/ E. Fk.)	0.073	0.029	61	0.009	0.038	0.080	0.125	0.95	0.1	672	1981–1990
OrthoP	North Creek 4483 (Mouth)	0.013	0.010	10	0.003	0.013	0.024	0.18	0.95	0.1	204	1981–1982
OrthoP	LaVerkin Creek 4476 (at hwy 17 bridge)	0.204	0.075	51	0.023	0.098	0.094	0.205	0.95	0.1	876	1980–1990
Total P (unfiltered)	North Fork Virgin 4493 (above confluence w/ E. Fk.)	0.170	0.100	147	0.030	0.1	0.046	0.689	0.95	0.1	348	1979–2002
Total P (unfiltered)	North Creek 4483 (Mouth)					no total P data available for North Creek						
Total P (unfiltered)	LaVerkin Creek 4476 (at hwy 17 bridge)	0.230	0.130	95	0.039	0.2	0.208	0.95	0.95	0.1	377	1980–2002
unionized ammonia	North Fork Virgin 4493 (above confluence w/	0.020	0.060	138	0.018	0.078	0.006	1	0.95	0.1	14	1979–1999

Parameter	Site	Historic Stdev (σ)	Historic mean = H_0	Historic sample n	Desired MDD $+30\%(\mu_0)$	+30% change from historic mean H_a	$\alpha=0.1$, $\beta=0.95$ n = Historic Solve for effect size	$\alpha=0.1$ $H_a =$ $\mu_0+30\%(\mu_0)$ Solve for power (1- β)	set power (1- β)	set alpha α	$\alpha=0.1$, $\beta=0.95$ $H_a =$ $\mu_0+30\%(\mu_0)$ solve for n	monthly site visits date range
	E. Fk.)											
nitrate + nitrite filtered	North Creek 4482 (near Virgin, UT) LaVerkin	0.300	0.380	10	0.114	0.494	0.312	0.331	0.95	0.1	75	1981– 1982
unionized ammonia	Creek 4476 (at hwy 17 bridge)	0.030	0.070	98	0.021	0.091	0.010	1	0.95	0.1	23	1980– 1997

1.8. Power Analysis

The power of a statistical test is the probability that the test will reject a false null hypothesis (that it will not make a Type II error). A Type II error is the error of failing to observe a difference when in truth there is a difference. The power analysis indicates the probability (0.95) of rejecting a false null hypothesis ($H_0 = u$). This type of error can only occur when the statistician accepts the null hypothesis. As power increases, the chances of a Type II error decrease, and vice versa. The probability of a Type II error is referred to as β . Therefore power is equal to $1 - \beta$.

Based on historic data, we have sufficient power for all evaluated sites and evaluated parameters, with the exception again being phosphorus when sites are visited monthly for a 2-year panel rotation. The same analysis carried out using NCPN data for 2006 ($n = 9$) had similar results, except the desired power was reached with fewer sample numbers due to lower overall variability in parameter values. This simulation can be repeated after NCPN site data sets become more robust and when laboratory data become available. Currently there is a year lag time between sample submission and receipt of results.

The simulation of power versus sample size for different parameters (Figure 3) provides valuable insight into the relationship between sample size and correct interpretation of hypothesis tests. This type of analysis is more informative than a single sample size calculation because it allows a qualitative sense of how power varies with sample size by parameter. It also provides a sense for how much over sampling might be necessary to ensure sufficient power is achieved to support change detection. As indicated in the previous section on sample size, monthly site visits should suffice to detect significant (+30%) bi-annual changes in mean parameter values, excepting phosphorus.

1.9. Realistic Sample Size Goal

It is recognized that monthly site visits may not always be possible given weather and road conditions. Furthermore, there will be data that must be censored for reasons not yet known or encountered. These considerations and the requirement of the state of Utah to collect samples monthly for compliance (see section 3.3.3) indicate that even if statistically significant differences can be determined annually when sites are visited every month, it is more likely that two years of effort will be required to achieve sufficient sample size of high quality data necessary to detect change.

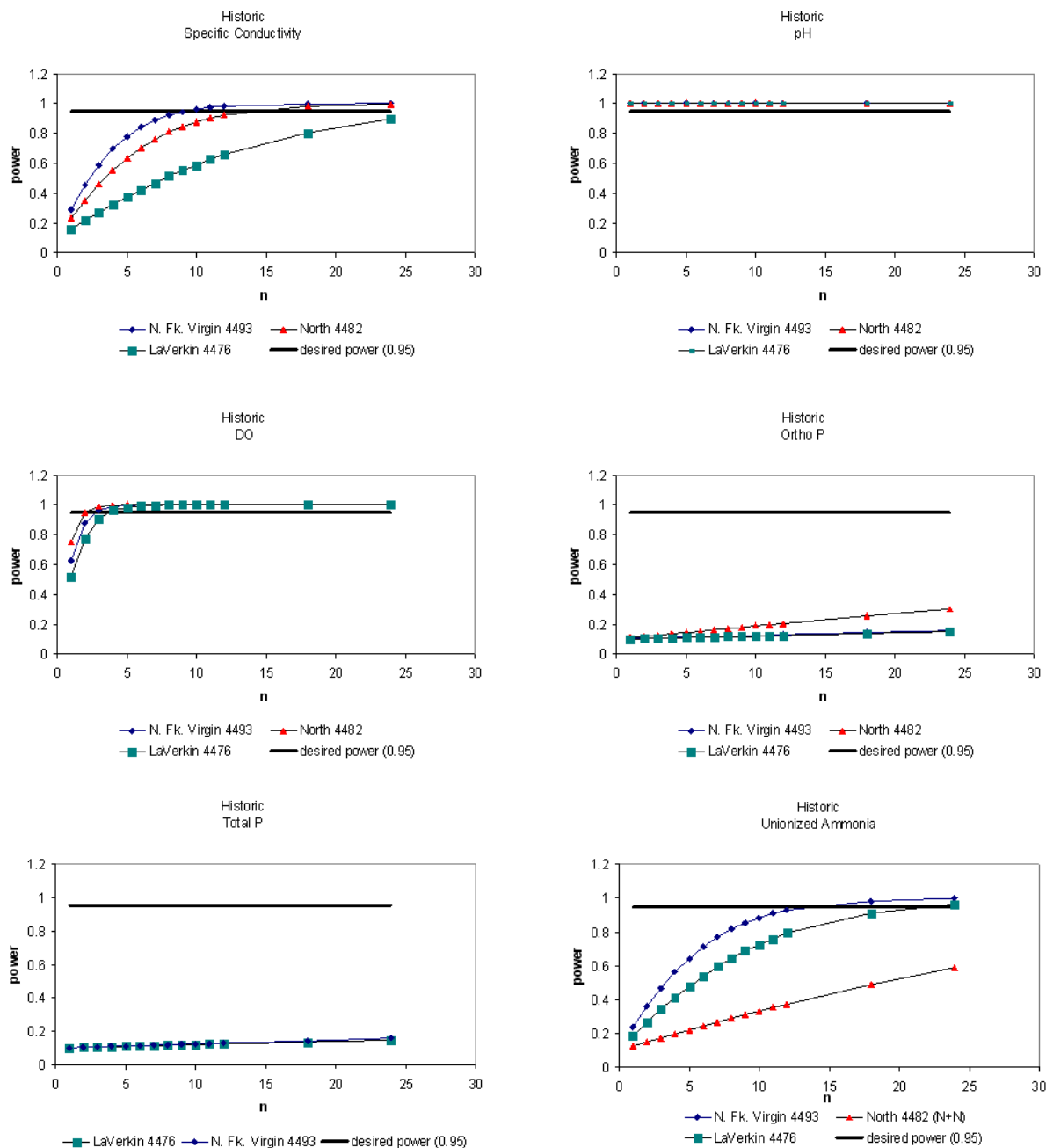


Figure 3. Power analysis as sample size increases for core parameters P and N. Data sets were from historic monthly site visits spanning the date range listed in Table 7.

1.10. Monitoring questions

The purpose of the water quality program can be framed in a series of general questions that can be answered quantitatively via measurable objectives.

1. What are the natural and existing chemical and biological ranges in water quality parameters within selected waters of NCPN parks?
2. What are the long-term status and trends in selected water quality parameters at selected sites on selected NCPN water bodies?
3. Are selected NCPN water bodies in compliance with designated beneficial uses?
4. Are the existing chemical and biological ranges at selected times and sites consistent with establishment of Outstanding Natural Resource Waters designation (ONRW)?
5. What are point and non-point pollution sources within the watersheds?

1.11. Measurable Objectives

The measurable objectives are related to water quality criteria presented by state in the Appendices of SOP 15 - Data Analysis and Reporting. These criteria provide the framework for developing specific questions, a sampling plan and data analysis techniques that will answer the questions. Answering the questions posed will be a tangible result of the monitoring effort. The amount of data collected, variability of results due to natural conditions and variability due to analysis technique will introduce a level of uncertainty that can be quantified in order to aid interpretation of results.

1. Establish range and variability of water quality parameters under base flow conditions as they vary with seasonal and climatic conditions using descriptive statistics discussed in SOP 15. *This will be determined over time as monthly data accumulate under different flow, seasonal and climatic conditions. It is recognized that insufficient data are collected on a monthly basis to fully understand diel and seasonal trends in parameters. For this reason efforts will be directed toward continuous monitoring of diel and seasonal trends at selected sites on a rotating basis as resources are available. This type of monitoring will focus on core parameters that do not require laboratory analysis but will provide useful information that is likely correlated to other parameters (ie. metals and nutrients). Otherwise special case studies may be initiated to evaluate diel effects on selected parameters.*
2. Determine status and trends in selected water quality parameters as a function of flow, season and climatic conditions, using trend analysis techniques outlined in SOP 15. *The power analysis above indicates that for the core parameters a monthly sampling period (assuming variability remains similar) will be sufficient to detect change in annual means for pH and DO, but two years of sampling will be required to detect significant change in SC. This is due to the high natural variability in streams, climatic variation and the rotating panel design of the monitoring program.*
3. Compare water quality data against state standards for chronic exceedance on a monthly and annual basis. *Multiple exceedances in a year typically indicate non-compliance, but this evaluation is made formal in conjunction with state officials.*
4. Analyze long term data for designation as ONRW. *Descriptive statistics and long term trends will help determine if a water body has the potential to be designated an ONRW. This will be possible after many years of monitoring and through cooperation with the state Water Boards.*

5. Determine point and non-point sources of pollution within watershed via association. *Some pollutants have unique or typical causes and thus can be assigned a source through association or by evaluation of ancillary data such as geology or land use using GIS or remote sensing resources coupled with field evaluation.*

1.12. Management use of Monitoring Data

The knowledge gained by answering the monitoring questions and measurable objectives will be used to evaluate and report on the condition of water bodies in NCPN park units.

Additionally, it can be used to inform management of water resources in order to:

1. 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.*
2. Improve water quality of impaired waters. *Justification: The NPS GPRA goal is that 99.3% of streams and rivers managed by NPS will meet State and Federal water quality standards. Several water bodies within NCPN are impaired or flow into an impaired water body. This falls under effectiveness monitoring, but will be useful in some situations if management activities occur in monitored watersheds.*
3. Demonstrate and maintain high water quality where it exists. *Justification: The antidegradation policy of the Clean Water Act specifies that high quality waters will be maintained (EPA 2006; section 303).*

2. Sampling Design

2.1. Target Population

The goals for water quality monitoring are to determine status and trends at specific sites, not to make inference to other sites. Thus, the target population is a subset of potential daytime water quality measurements in perennial waters selected through a judgmental process involving the participation of park resource managers, NCPN staff, and USGS and other water quality specialists. The process included on-site interviews of staff from parks and other nearby agencies, a review of existing formal and informal literature, and an extensive compilation and analysis of existing water quality data. The results of this process are summarized in Appendix F of the NCPN Plan for Natural Resource Monitoring (O'Dell et al., 2005).

Perennial waters were selected over ephemeral or seasonal water sources because the larger perennial sources are most likely to transport contaminants (natural or anthropogenic) long distances across park boundaries. This holds true primarily for rivers and larger reservoirs, but also can be applied to larger perennial springs where the recharge basin can extend many miles. Perennial waters are the sources for which standards are commonly established and are most frequently monitored for compliance with CWA-based standards.

Specific water sources were selected based on the following hierarchy:

1. **303d listed waters** - where previous sampling indicates one or more parameters regularly approach or exceed standards or recommended levels.
2. **Waters with demonstrated threat levels** - where an analysis of existing data indicate that measured conditions regularly approach or exceed standards or recommended levels, but where the frequency of exceedance, or the quality of the database do not support a 303d listing.
3. **Data gaps** - Waters identified as important, but where little or no water quality information exists.
4. **Waters of management concern** – where past sampling may not indicate constituent values of concern, but where anthropogenic activities indicate that contamination is a significant threat.
5. **Other perennial waters** with no specific threat

2.2. Rationale for Sampling Design

Given so many parks with water resources, water resource diversity and limited funding, making broader inference is not achievable. However, it is recognized that sampling will represent conditions in the watershed above the point of sample collection. A judgmental design will continue to be used in the long-term NCPN monitoring, both in the selection of water sources to be monitored, and in the selection of specific sample sites. A split-panel temporal sampling design is used, where some sites are visited at every sampling event, while others are sampled only in some years. This will allow tracking long-term trends while expanding the number of sites that can be monitored with limited financial resources.

2.3. Influences on Sampling Design

2.3.1. Partnerships

A primary goal is to capture a long-term record of water quality conditions across the parks and track the status of individual sites of high interest. To achieve this goal the NCPN partners with UT Department of Water Quality (UTDWQ), whereby NCPN staff collect samples in parks and the State runs laboratory analysis as part of its EPA funded Clean Water Act monitoring program. In CO parks NCPN relies on data collected by individual parks, or pays USGS to collect and analyze samples in parks where ongoing water quality monitoring has not been established. The primary influences on sampling design beyond monitoring objectives are the need for adequate temporal representation of water conditions, and requirements associated with partner (UT DWQ) analysis of samples. Typically sites are monitored monthly to meet these requirements.

The resulting program includes partnerships with the State of Utah, USGS-Colorado, and NPS units. The sampling design is not complex, but the logistics and data management are. While relying on so many partners introduces the potential for inconsistency, the existence of relatively uniform methods for water quality sample collection and analysis by EPA certified laboratories permits collection of reliable high-quality data. Guidelines for sample collection, analysis and quality assurance are presented in the SOP's. Table 8 depicts the framework that will be used with partners and responsibilities for various aspects of the monitoring.

Table 8. Overview of partnerships and approaches to sampling and analysis.

Park Units Affected	Number of NCPN monitoring sites affected	Partner	Sample collection	Laboratory analysis	Data screening, storage, and analysis
ARCH, BRCA, CARE, ZION, CANY, NABR, HOVE	9	Utah DWQ	NCPN/Park Staff	Utah State Lab	Utah DWQ/NCPN
BLCA, CURE	4	USGS	Park Staff	USGS or Private	Utah DWQ/NCPN
DINO	1	Utah DWQ	USGS	USGS	USGS
DINO	2	Utah DWQ	USFWS	Utah State Lab	Utah DWQ/NCPN

2.3.2. Monitoring By Others that Supports NCPN Goals

Water-quality monitoring that directly meets NCPN vital signs goals is currently conducted by the State of Utah, NPS (SEUG and BLCA/CURE staff), and the USGS for several significant water sources throughout the network. As a result, network water quality monitoring benefits from the data collected by others in and near ARCH, BLCA, CANY, CARE, CURE, DINO, GOSP, HOVE, NABR, and ZION, thus freeing NCPN resources to be directed toward monitoring gaps. For a more detailed description of the scope and utility of these monitoring efforts, see Appendix R in the NCPN Phase III Report (O'Dell et al., 2004). Where current monitoring meets NCPN needs, the design assumption is that the NCPN will, where feasible, compile the data from the current collecting agency rather than incurring the expense of sample collection.

2.3.3. Other design considerations

Myriad other factors affected the sampling design (Table 9). The result is that it is primarily judgmental in nature and consists of a set of long-term, fixed station sites. Building a more robust database for specific sites and water bodies was favored over a design that would provide a stronger picture of regional conditions. This approach was based on objectives that gave highest priority to determining compliance with the Clean Water Act, and the fact that the State of Utah, a major partner, requires monthly sampling under its monitoring protocols in order to ensure a robust database when determining if protected uses are supported.

Table 9. Planning considerations that influenced the Sampling design for NCPN water quality monitoring.

Planning Consideration	Influences on sampling design
Objectives	Water sources are included on the state 303d list, or have frequent exceedances for state standards are a high priority for monitoring. Waters that can provide a representative indicator if the status and trends of water quality conditions for important water resources in the parks are also considered important.
Funding is very limited considering the number of parks and water resources that could potentially be monitored.	NCPN must take advantage of existing monitoring conducted by the states, other federal agencies, and current monitoring by parks, and not duplicate these efforts. Measures will generally be selected where the laboratory analysis is relatively inexpensive. For this reason, analysis for organic compounds (including pesticides), and radionuclides is not considered practical. In most cases, even a major water body has only one sample site in a park. Some sites will be monitored on a rotating schedule where annual monitoring will be rotated among 2 to 3 sites.
The State of Utah has offered to cover the cost of laboratory analysis for as many as 15 sites in Utah parks.	Taking advantage of this valuable service will require adopting State of Utah schedules and techniques for sampling and sample handling, and developing a compatible process for data management.
NCPN Parks are widely separated and some are very large, requiring several hours of travel to reach some of the more remote water sources.	Accessible sample locations are often selected over those with difficult access. Most sample sites will be accessible by vehicle. Of the sites that require access by foot, most hikes will be short, and the longest would not exceed about 2 hours one-way. In some cases, water sources that are considered important will not be monitored due to the difficulty of access. In other cases where access by NCPN monitoring staff is impractical (such as at DINO), agreements with other agencies will be developed to accomplish sampling and analysis. Monitoring staff will be located so that they can service groups of 3-6 parks, because it would be impractical to monitor the entire network based from one central location.
Water quality data exists for many water resources in Network parks.	Existing data was used to identify where water quality approaches or exceeds standards. These sites are a high priority for monitoring. It will be advantageous to select vital sign monitoring locations where data exists in order to build on the existing information base.
Water quality data is absent for some high priority waters.	Filling these data gaps is a high priority.
Some parks currently conduct some water quality monitoring.	Having experienced staff, equipment and facilities in place will facilitate NCPN monitoring at reduced cost, and in some instances NCPN can enhance park programs.

Planning Consideration	Influences on sampling design
Laboratory analyses for water quality parameters are traditionally performed for groups of parameters.	Measures will often be selected as groups of parameters such as “major ions” and “nutrients” or “trace elements.”
Core Parameters have been mandated for water quality vital signs monitoring because they are useful basic indicators and are typically necessary for analyzing the findings for other parameters.	Core Parameters consisting of Discharge, pH, Dissolved Oxygen, Temperature and Specific Conductance will be measured in the field with every sample collected.
Some sources in the NCPN, such as seeps, springs and wetlands, do not occur in well-defined channels making discharge measurements difficult.	Techniques for discharge measurement and the quality of the resulting measurement will vary depending on the site. An attempt will be made to obtain the best practical discharge measurement given limitations on time, equipment and the nature of the flow.
There is a high degree of natural variability in some water quality characteristics due to seasonal variation and response to storm events.	Sampling will occur 8-12 times per year to capture seasonal and flow variation. Flow measurements will accompany sampling.
Groundwater in this setting is generally has less variability in discharge and chemistry.	Spring sampling may be less frequent.
Many of the sources of high levels of ions or trace element are believed to be natural.	The NPS generally does not wish to modify these natural conditions but is interested in monitoring these sources so that conditions can be determined with greater certainty and tracked over time for effective use in any 303d listing or TMDL planning.
Sample timing	Samples will typically be collected during periods of low / base flow. This is for the practical reason that wet backcountry roads in NCPN are impassable and waiting for dry travel conditions will result in base flow sampling conditions in most instances.
Sample variability	Due to high variability and the need for large sample sizes for statistical analysis, the most efficient sampling will occur when flow conditions are similar. This will be most easily achieved by targeting base flow conditions.

2.3.4. Boundary of Monitoring Effort

Monitoring will primarily be conducted within NCPN units. In some cases, sample sites may be located on waters that flow through the park but are a short distance upstream or downstream of the park. This is usually done (1) where physical access to the water source in the park is impractical, and (2) where another agency is already monitoring a site nearby a park, so additional sampling inside the park would be redundant. In both instances, these nearby sites are considered appropriate because we can make educated guesses about some of the intervening sections, but no definitive statistical inferences can be made.

Representativeness in this instance will be based on professional judgment that considers amount of flow, size of tributaries between the park and the gauge site (if any), proximity of

gauge site to park boundary, and changes in geology and land use between gage and park. Additional verification could be made by evaluating range and variability of over-sampled core parameters at gage site and a site thought to be similar within the park. However, with long-term data from sites at various levels of the watershed including a reference or upper watershed site and a site at the bottom of a watershed, we can make educated guesses about some of the intervening sections, but no definitive statistical inferences can be made

3. Site Selection

When practical, water quality monitoring sites will be co-located or situated to leverage information that can be gained in conjunction with other efforts including riparian, macroinvertebrate, and upland monitoring. Inference will therefore, be limited to the sample sites, but information collected in the water quality monitoring program can be used in multiple ways. The 64 sites recommended for water-quality monitoring in the NCPN are shown in Table 10. The basis for including each site was the value of the site in meeting NCPN Vital Signs monitoring goals, and for providing data to meet park resource-management needs. Where multiple sites were under consideration for a single water source, the site with the most extensive historical data record was given priority because this improves the ability to evaluate seasonal and long-term changes in water-quality conditions.

To ensure the sample design would be relevant and useful in the future, site recommendations were made irrespective of current NCPN funding and resources. As expected, the number of sites identified greatly exceeds NCPN's current ability to monitor them. To reduce the list to sites that could be practically monitored by the NCPN in the next few years, sites were assigned the following priority ranking as indicated in column 8 in Table 10

Priority 1 – Highest Priority. NCPN will monitor the site with planned network resources unless the site is otherwise receiving stable, long-term monitoring through other NPS or outside agency programs (32 sites).

Priority 2 – Less than Highest Priority Sites. These will not be monitored with NCPN resources in the near term unless additional funding support becomes available (32 sites).

There are 32 sites planned for monitoring by NPS and other agencies (i.e. Priority 1 sites). Of those, 16 require full NCPN support and 16 are currently monitored and supported by non-NCPN programs that will continue for the foreseeable future. The 16 sites NCPN will support are marked with an "X" in the "Planned NCPN Supported Site" column in Table 10. These include eight sites where some monitoring now occurs, but it is less than satisfactory because it is less frequent than desired, supported only by soft funding, or includes only a very limited suite of parameters. The other seven Priority 1 sites have no current monitoring. Of the 32 Priority 2 sites included in Table 10 one is adequately monitored, 22 have limited monitoring and 9 are not monitored.

Table 10. Water-quality vital signs monitoring sites for NCPN with other significant monitored sites.

Site Name	NCPN Site No	NCPN Database Site No	STOR ET Site ID	Latitude, Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups**	Considerations
ARCHES NATIONAL PARK												
Courthouse Wash near Moab, UT	M-0	225	599524	383646N, 1093445W	L	1	NPS Coop w/ UT - Rotating	X		12/yr	CP, MI, Nut, T, TSS, FIB	Bact, Status and trends. Expand from rotation to continuous long-term
Salt Wash at Wolfe Ranch Road	M-1	263	599522	384414N, 1093109W	L	1	NPS Coop w/ UT - Rotating	X		12/yr	CP, MI, Nut, T, TSS, FIB	Status and trends. Expand from rotation to continuous long-term
Freshwater Spring	M-42		599520	384429N, 1093141W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	
Sleepy Hollow	M-43		599525	384024N, 1093821W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	
Willow Spring	M-44		599527	384160N, 1093743W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	
Lost Spring	M-45		599529	384813N, 1093050W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	
Upper Courthouse Wash	M-2		5995245	384117N, 1093915W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	

Site Name	NCPN Site No	NCPN Database Site No	STOR ET Site ID	Latitude, Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
BLACK CANYON OF THE GUNNISON NATIONAL PARK												
Gunnison River below Gunnison Tunnel	M-3	570		383145N, 1073854W	L	1	NPS - Project Funding		09128000	12/yr	CP, MI, Nut, T	Status and trends
Red Rock Canyon near NPS Boundary, Near Montrose, CO	M-4			383418N, 1074714W	L	1	NPS - Project Funding	X		7/yr	CP, MI, Nut, T	Se, unionized ammonia, irrigation return flow
BRYCE CANYON NATIONAL PARK												
Sheep Creek below Spring	M-5		4951855	373417N, 1121201W	L	1	NPS Coop w/ UT - Rotating	X		12/yr	CP, MI, Nut, T, FIB, Tu	Water source for hikers, grazing/wildlife
Yellow Creek below Spring	M-6		4951857	373428N, 1120825W	P	1	NPS Coop w/ UT - Rotating	X		12/yr	CP, MI, Nut, T, FIB, Tu	Water source for hikers, grazing/wildlife
MOSSY CAVE SPRING NW OF TROPIC			4951915	373948N, 1120654W	P	1	NPS Coop w/ UT - Rotating	X		12/yr	CP, MI, Nut, T, FIB, Tu	Water source for hikers, grazing/wildlife
Tropic Ditch at Mossy Cave			None	373952N, 1120651W	P	1	NPS	X		12/yr	Flow and core params only	Flow and core params related to Mossy Cave
CANYONLANDS NATIONAL PARK												
Colorado River above	M-7	1039	495240	381133N, 1095302W	L	1	NPS Coop w/ UT		09180500	10-12/yr	MI, Nut, T, TSS,	Se, P, Status and trends

Site Name	NCPN Site No	NCPN Database Site No	STOR ET Site ID	Latitude, Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
Green River											FIB	
Green River above Colorado River	M-8	1055	493001	381124N, 1095321W	L	1	NPS Coop w/ UT		09315000	10-12/yr	MI, Nut, T, TSS, FIB	Se, Status and trends
Green river at Mineral Bottom	M-46		4930150	383119N, 1095955W	L	1	NPS Coop w/ UT		09315000	10-12/yr	MI, Nut, T, TSS, FIB	Status and trends
Colorado River at Potash Boat Ramp	M-47		495629	383020N, 1093932W	L	1	NPS Coop w/ UT		09180500	10-12/yr	MI, Nut, T, TSS, FIB	Status and trends
Colorado River at Big Drop 3	M-48		495238	380829N, 1095544W	L	1	NPS Coop w/ UT		09180500, 09315000	10-12/yr	MI, Nut, T, TSS, FIB	Status and trends
Salt Creek at Crescent	M-9	1083	599515	380506N, 1094559W	R	1	NPS Coop w/ UT	X		12/yr	MI, Nut, T, TSS, FIB	Status and trends
Salt Creek - Peekaboo	M-49		599516	380708N, 1094501W	R	2	NPS Coop w/ UT			12/yr	MI, Nut, T, TSS, FIB	Status and trends
Little Spring Canyon	M-10	1072	599512	381103N, 1094759W	R	2	NPS Coop w/ UT			12/yr	MI, Nut, T, TSS, FIB	Se, Status and trends
Cave Spring	M-50		599505	380924N, 1095412W	R	2	NPS Coop w/ UT			12/yr	MI, Nut, T, TSS, FIB	Status and trends
2.4 mile Loop Spring	M-51		599502	380832N, 1094845W	R	2	NPS Coop w/ UT			12/yr	MI, Nut, T, TSS, FIB	Status and trends

Site Name	NCPN Site No	NCPN Database Site No	STOR ET Site ID	Latitude Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
Maze Overlook	M-52		599550	381342 1095943	R	2	NPS Coop w/ UT			12/yr	MI, Nut, T, TSS, FIB	Status and trends
Chocolate Drops	M-53		599542	381329 1100009	R	2	NPS Coop w/ UT			12/yr	MI, Nut, T, TSS, FIB	Status and trends
Horseshoe Canyon	M-54		5995540	382742 1101157	R	2	NPS Coop w/ UT			12/yr	MI, Nut, T, TSS, FIB	Status and trends
CAPITOL REEF NATIONAL PARK												
Fremont River at U12 crossing			4954390	381612 1112229	R	2	UTDEQ			12/yr	MI, Nut, T	Phosphorus
Fremont River at Hickman Bridge	M-11	1423	495433	381719 1111403	L	1	UTDEQ			12/yr	MI, Nut, T	Phosphorus
Pleasant Creek South of Sleeping Rainbow Ranch	M-14	1473	495478	381048 1111050	R	2	None			12/yr	MI, Nut, T, TSS, FIB	Total Phosphorus, ammonia, pH, BACT.
Oak Creek above Diversion	M-13	1461	495497	380457 1110812	R	1	None			12/yr	MI, Nut, T, TSS, FIB	Bact, few data, status and trends
Halls Creek below the narrows	M-12	1450	495481 2	373654 1105215	R	1	NPS Coop w/ UT - Rotating	X		12/yr	CP, MI, Nut, T, TSS, FIB	few data, BACT., hiker impact, nutrients
SULPHUR CK BL ROAD			495477 5	381807	R	1	NPS Coop w/ UT - Rotating	X		12/yr	MI, Nut, T, FIB	Bact. , Nutrients and

Site Name	NCPN Site No	NCPN Database Site No	STORET Site ID	Latitude, Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
TO GOOSENECKS OVERLOOK IN CRNP				1111831								TSS
Sulphur Creek at Mouth at Fruita, UT	M-15	1481	495477	381733N, 1111543W	R	2	None			12/yr	MI, Nut, T, FIB	Bact. , Nutrients and TSS
CEDAR BREAKS NATIONAL MONUMENT							None					Only perennial stream is very difficult to access.
COLORADO NATIONAL MONUMENT							None					Little perennial streamflow
CURECANTI NATIONAL RECREATION AREA												
Blue Mesa Res. above Soap Creek	M-16	2362		382831N, 1072600W	L	1	NPS - Project Funding	X		7/yr	CP, MI, Nut, T, Secchi	Status and trends
Crystal Reservoir near Dam	M-18	2402		382924N, 1073523W	L	1	NPS - Project Funding			7/yr	MI, Nut, T, Secchi	Trophic status, Status and trends
Gunnison River at 32 Road	M-19	2492		383103N, 1065942W	L	1	USGS			7/yr	MI, Nut, T	Status and trends
Cebolla Creek at Powderhorn	M-20	2436		381633N, 1070547W	R	1	NPS - Project Funding		09122000	7/yr	CP, MI, Nut, T	Status and trends
Cimarron River below Squaw Creek	M-17	2446		382647N, 1073318W	R	1	NPS - Project Funding	X	09126500	7/yr	MI, Nut, T	Ag and silviculture, status and

Site Name	NCPN Site No	NCPN Database Site No	STOR ET Site ID	Latitude, Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
												trends
Lake Fork Gunnison River below Gateview	M-21	2509		381934N, 1073350W	R	1	NPS - Project Funding			7/yr	CP, MI, Nut, T	Status and trends
West Elk Creek below Forest Boundary	M-23	2550		383028N, 1071622W	R	1	NPS - Project Funding	X		7/yr	MI, Nut, T	Status and trends
Steuben Creek near Mouth	M-22	2547		383137N, 1071836W	R	1	None			7/yr	CP, MI, Nut, T	Status and trends
Blue Creek at Hwy 50	M-24	2349		382418N, 1072426W	R	2	None			7/yr	MI, Nut, T	Trophic status, Status and trends
Blue Mesa Reservoir above Cebolla Creek	M-25	2361		382829N, 1071222W	R	2	None			7/yr	MI, Nut, T, Secchi	Trophic status, Status and trends
Curecanti Creek near Sapinero	M-26	2466		382916N, 1072452W	R	2	None			7/yr	MI, Nut, T	Status and trends
Morrow Point Reservoir near Dam	M-27	2518		382702N, 1073154W	R	2	None			7/yr	MI, Nut, T, Secchi	Trophic status, Status and trends
Soap Creek above Chance Creek	M-28	2540		383137N, 1071836W	R	2	None			7/yr	MI, Nut, T	Status and trends
DINOSAUR NATIONAL MONUMENT												
Green River	M-29	3341	493790	402434N, 1072426W	L	1	USGS &		0926100	6/yr	MI, Nut,	Status and

Site Name	NCPN Site No	NCPN Database Site No	STORET Site ID	Latitude/ Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
near Jensen				1091405			UTDEQ		0		T	trends
Yampa River at Deerlodge Park	M-30	3478		402706N, 1083128W	L	1	USGS 4x/year	X	09260050	8/yr	CP, MI, Nut, T, TSS	Increasing pH & nutrients effects on biota. NCPN expand frequency to 8/yr by USGS
Green River above Gates of Lodore	M-31	3369		404417N, 1085249W	R	1	USGS 6x/year	X		8-12/yr	CP, MI, Nut, T	Status and trends
Jones Hole Creek below Fish hatchery	M-32	3416		403515N, 1090324W	R	1	UT DWQ		09260500	8/12/yr	CP, MI, Nut, T, FIB, Tu	Effects of fish hatchery upstream on creek, nutrients.
Cub Creek at Mouth	M-33	3326		402513N, 1091428W	R	2	None			8-12/yr	MI, Nut, T	Status and trends
FOSSIL BUTTE NATIONAL MONUMENT							None					Need Inventory of 4 sites. No NCPN sites due to remote location.
GOLDEN SPIKE NATIONAL HISTORIC SITE							None					No priority surface water sources in park. Blue Creek monitored adequately by

Site Name	NCPN Site No	NCPN Database Site No	STOR ET Site ID	Latitude/ Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
												UTDEQ
HOVENWEEP NATIONAL MONUMENT												
Cajon Spring	M-55		599571	371758N, 1091101W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
Square Tower Sp.	M-56		599570	372309N, 1090452W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
Hackberry Spring 1	M-57		599572	372428N, 1090130W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
Hackberry Spring 2	M-58			372428N, 1090129W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
Horseshoe Spring	M-59		5995540	372431N, 1090148W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
Goodman Point	M-60				R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
Sipapu Bridge Spring	M-61		599533	383109N, 1095942W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
NATURAL BRIDGES NATIONAL MONUMENT												
Armstrong Canyon near Kachina Bridge	M-62		599531	373549N, 1100149W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
Owachomo Bridge Sp.	M-63		599532	373454N, 1100048W	R	2	NPS Coop w/ UT - Rotating			12/yr	MI, Nut, T, TSS, FIB	Springs are priority water source
PIPE	M-64						None				Springs	

Site Name	NCPN Site No	NCPN Database Site No	STORET Site ID	Latitude/ Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
SPRING NATIONAL MONUMENT											are priority water source	
TIMPANAGOS CAVE NATIONAL MONUMENT												
HANSEN CAVE SPRING IN TIMPANAGO S CAVE NM	M-34		4994970		L	1	NPS Coop w/ UT - Rotating	X		12/yr	Critical resource.	
Hidden cave lake			none		L	1	NPS - Project Funding	X		4/yr	Organics	Contributing watershed influences
ZION NATIONAL PARK												
North Fork Virgin River at North Fork Road	M-36	4511	4951260	372325; 1124929	L	1	NPS Coop w/ UT - Rotating	X		12/yr Discontinued July 2008	CP, MI, Nut, T, Tu	BACT., source tracking, trends
Nth Fk Virgin R ab scenic narrows			4951261	372325; 1124929	L	1	NPS Coop w/ UT - Rotating	X		12/yr Discontinued July 2008	Duplicate to match 4951260	
N FK VIRGIN R AT WSA BNDRY			4951265	372214: 1125255	L	1	NPS Coop w/ UT - Rotating	x		12/yr Began July 2008	CP, MI, Nut, T, Tu	BACT., source tracking, trends
N FK VIRGIN R AB CNFL/BAPTIST			4951266	372214: 1125255	L	1	NPS Coop w/ UT - Rotating	x		12/yr Began July	Duplicate to match	

Site Name	NCPN Site No	NCPN Database Site No	STORET Site ID	Latitude/ Longitude (DMS)	Panel: Long-Term Continuous or Rotation*	Priority**	Current Monitoring	Planned NCPN Supported Site	Stream flow Gage	Sample Frequency	Sample Parameter Groups***	Considerations
SM RIVER										2008		
North Fork Virgin River above Confluence	M-35	4493	495095	370948N, 1130044W	L	1	UTDEQ		09405500	12/yr	MI, Nut, T, Tu	Total Phosphorus
La Verkin Creek at Lee Pass Trail	M-38	4476	4950800	372426N, 1131030W	R	1	NPS Coop w/ UT - Rotating	X		12/yr	CP, MI, Nut, T	Total Phosphorus, Ammonia
North Creek at planned gage in Park	M-39	4486	4950920	371540N, 1130620W	R	1	NPS Coop w/ UT - Rotating	X	Planned NPS/UD WR	12/yr	CP, MI, Nut, T	Total Phosphorus
East Fork Virgin River at Confluence	M-37	4454	495140	370947N, 1130038W	R	1	UTDEQ		09404900	12/yr	MI, Nut, T, Tu	Total phosphorus, source tracking, trends
East Fork Virgin River, Upper Park Boundary	M-40		Best access point	371054N, 1125148W	R	2	None			12/yr	MI, Nut, T, Tu	Source tracking, trends. Access very difficult.
North Creek above confluence	M-41	4485	495089	371209N, 1131031W	R	2	UTDEQ			12/yr	MI, Nut, T	TDS TMDL

* Panel: Long-Term Continuous or Rotation indicates whether each site will be sampled continuously (as indicated by an 'L' for long-term continuous sampling) or an 'R' for rotational sampling which occurs monthly for two years, then off for two years

** Priority 1 = Highest Priority. NCPN will monitor the site with planned network resources unless the site is otherwise receiving stable, long-term monitoring through other NPS or outside agency programs (32 sites). Priority 2 = Less than Highest Priority Sites. These will not be monitored with NCPN resources in the near term unless additional funding support becomes available (32 sites).

***CP=Core field parameters, MI= Major ions, N=Nutrients, T= Trace elements, TU= Turbidity, TSS= Total suspended solids, FIB= Fecal Indicator Bacteria, SD = Secchi depth

4. Revisit design

Sampling implementation will use a split-panel design, where some sites are visited at every sampling event, while others are sampled in rotation. The split panel design balances the need to sample every site with budget constraints that limit the number of sites that can be sampled in each year. In Table 10, the “Panel” column indicates whether each site will be sampled continuously (as indicated by an ‘L’ for long-term continuous sampling or an ‘R’ for rotational sampling, which occurs monthly when possible for two years, then off for two years). Of the 15 sites planned for NCPN monitoring, 8 are long-term and 7 are rotation sites. Once activated, each rotation site should be sampled for at least 2 consecutive years with the goal of collecting data representative of a broad range of hydrologic and other environmental conditions. Site rotation will be managed to ensure each site is sampled within 3 years of sample-design implementation to ensure some data are collected for each site within a reasonable time frame.

To balance the requirement to minimize the annual cost of the program with the need for repeated collection of data at each site, recommended sample frequencies range from 7-12 samples per year, depending on site characteristics, known water-quality conditions/issues, and other site-specific considerations. To use the UDEQ laboratory for no-cost analytical work, all sites in Utah must be sampled monthly. However, it is understood that some sites are not accessible year-round.

The following implementation schedule (Table 11) accounts for long-term monitoring by others, and represents the current plan to monitor all 15 sites requiring NCPN support within 3 years.

Table 11. Site implementation schedule through first complete round of sampling.

Schedule	Rotation Panel (NCPN Site ID M-x)	Long Term Panel (NCPN Site ID M-x)
2006	9 ^a , 12 ^b , 17 ^c , 23 ^c , 38 ^b , 39 ^b	0 ^a , 1 ^a , 4 ^c , 5 ^b , 6 ^b , 16 ^c , 30 ^d , 31 ^d , 36 ^b
2007	9 ^a , 12 ^b , 17 ^c , 23 ^c , 38 ^b , 39 ^b	
2008	13 ^b , 14 ^b , 15 ^b	
2009	13 ^b , 14 ^b , 15 ^b	
2010	Restart rotation	

^a Sites sampled by SEUG staff

^b Sites sampled by NCPN staff

^c Sites sampled by BLCA/CURE staff

^d Sites sampled by USGS

5. Site locations

Sampling site locations are presented in Figures 3-10. The sites displayed in the maps correspond to NCPN site identification in Table 10.

Zion

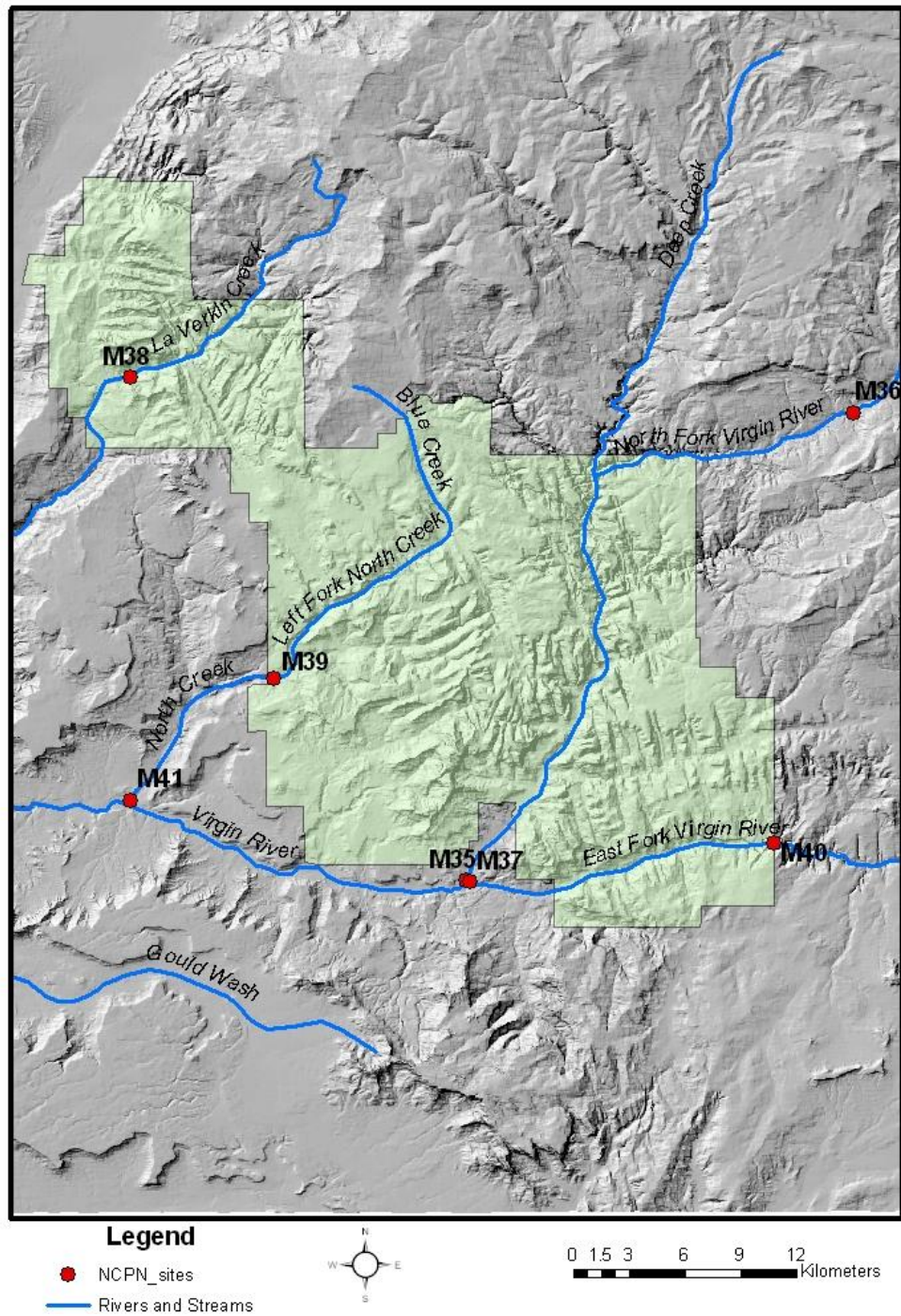


Figure 4. Map of sampling locations in Zion National Park.

Bryce

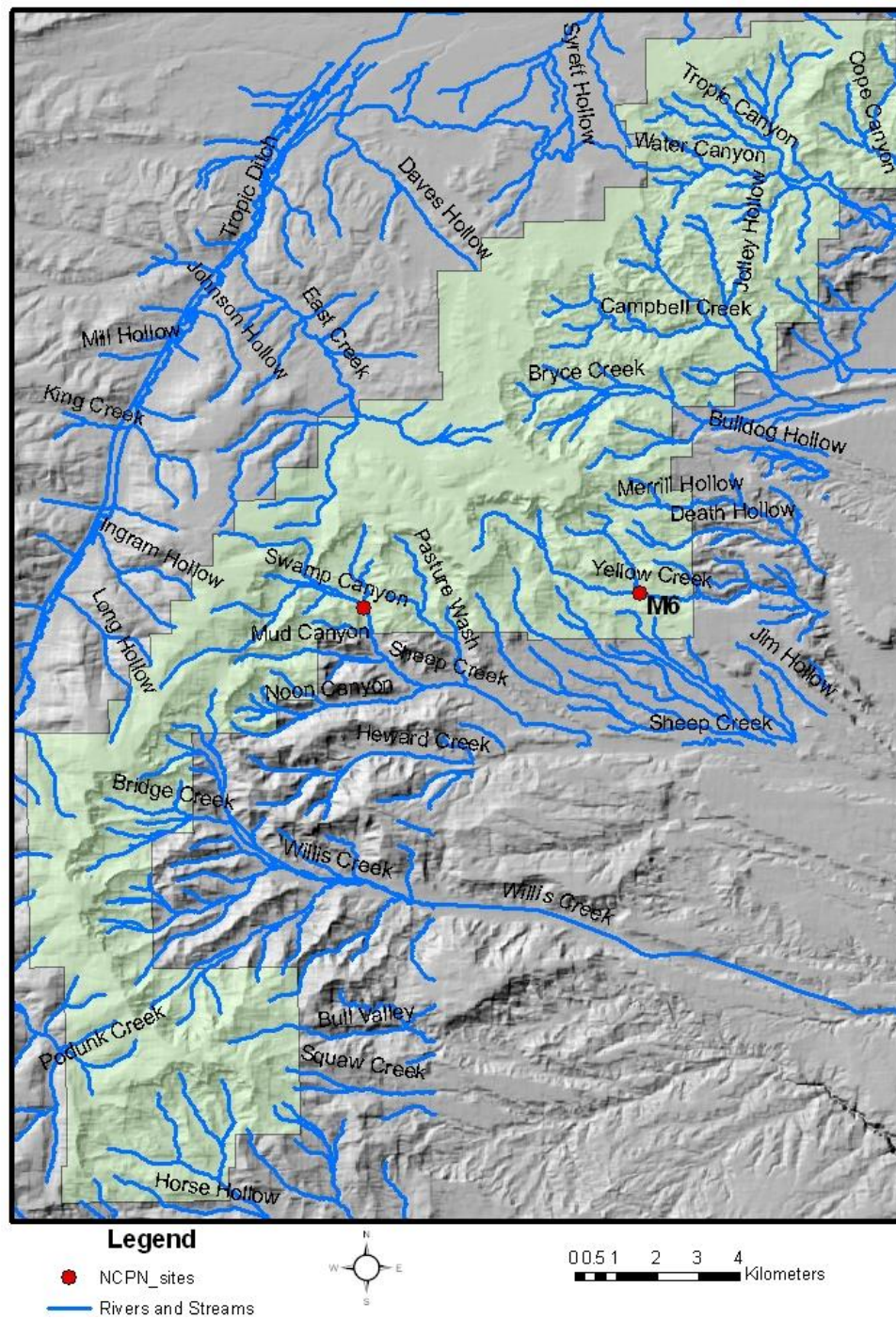


Figure 5. Map of sampling locations in Bryce Canyon National Park.

Capitol Reef

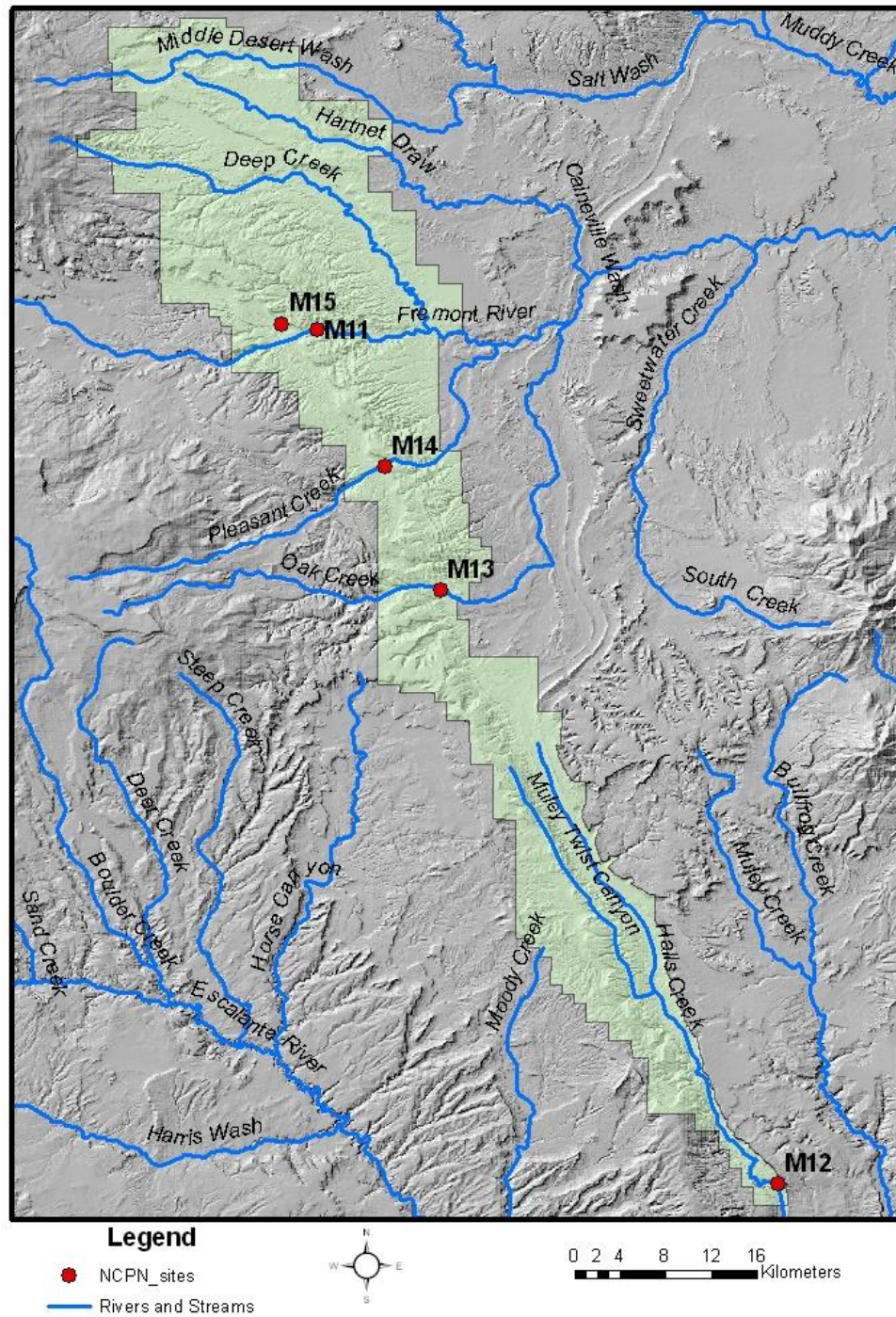


Figure 6. Map of sampling locations in Capitol Reef National Park.

Canyonlands

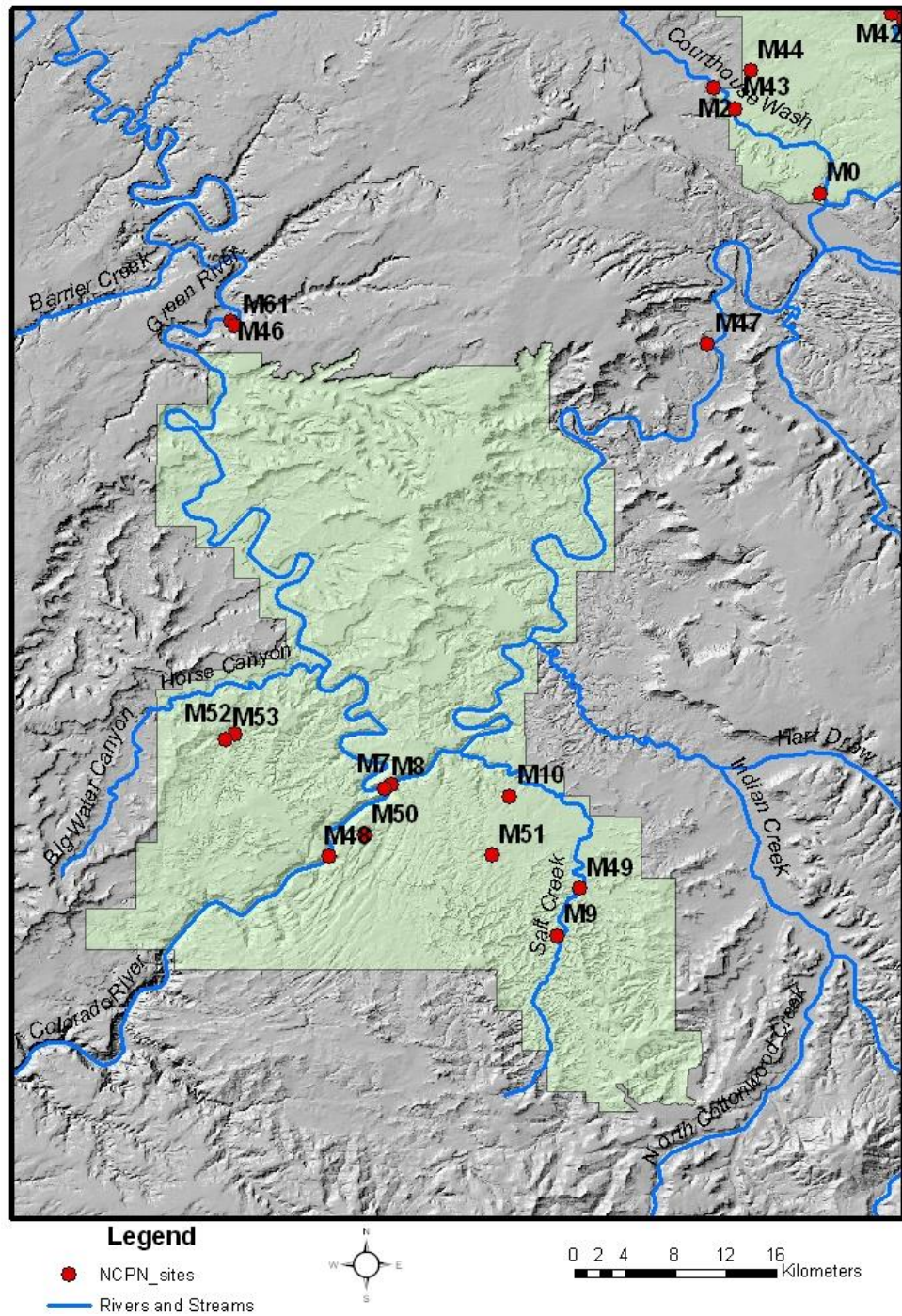


Figure 7. Map of sampling locations in Canyonlands National Park.

Arches

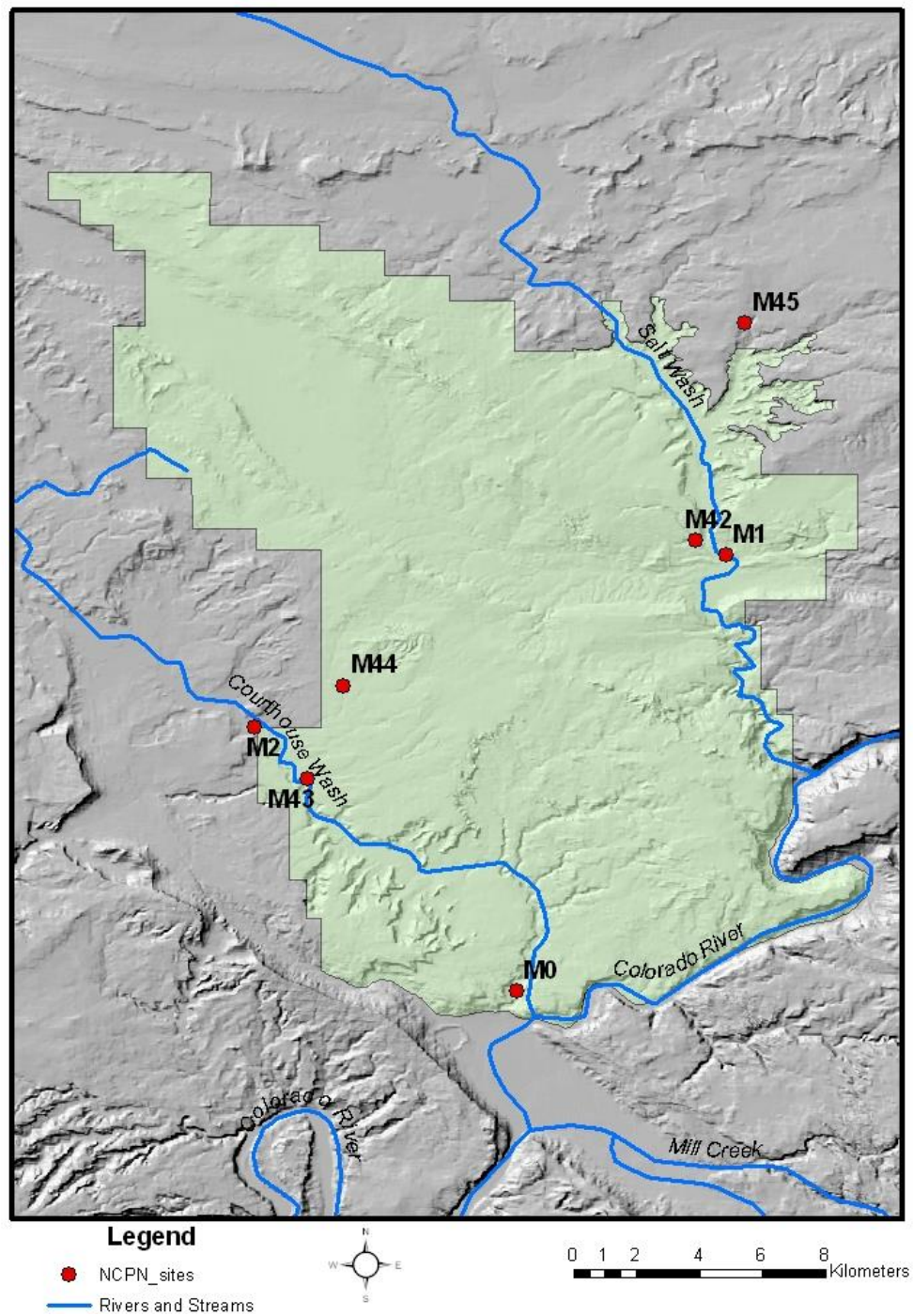


Figure 8. Map of sampling locations in Arches National Park.

Natural Bridges and Hovenweep

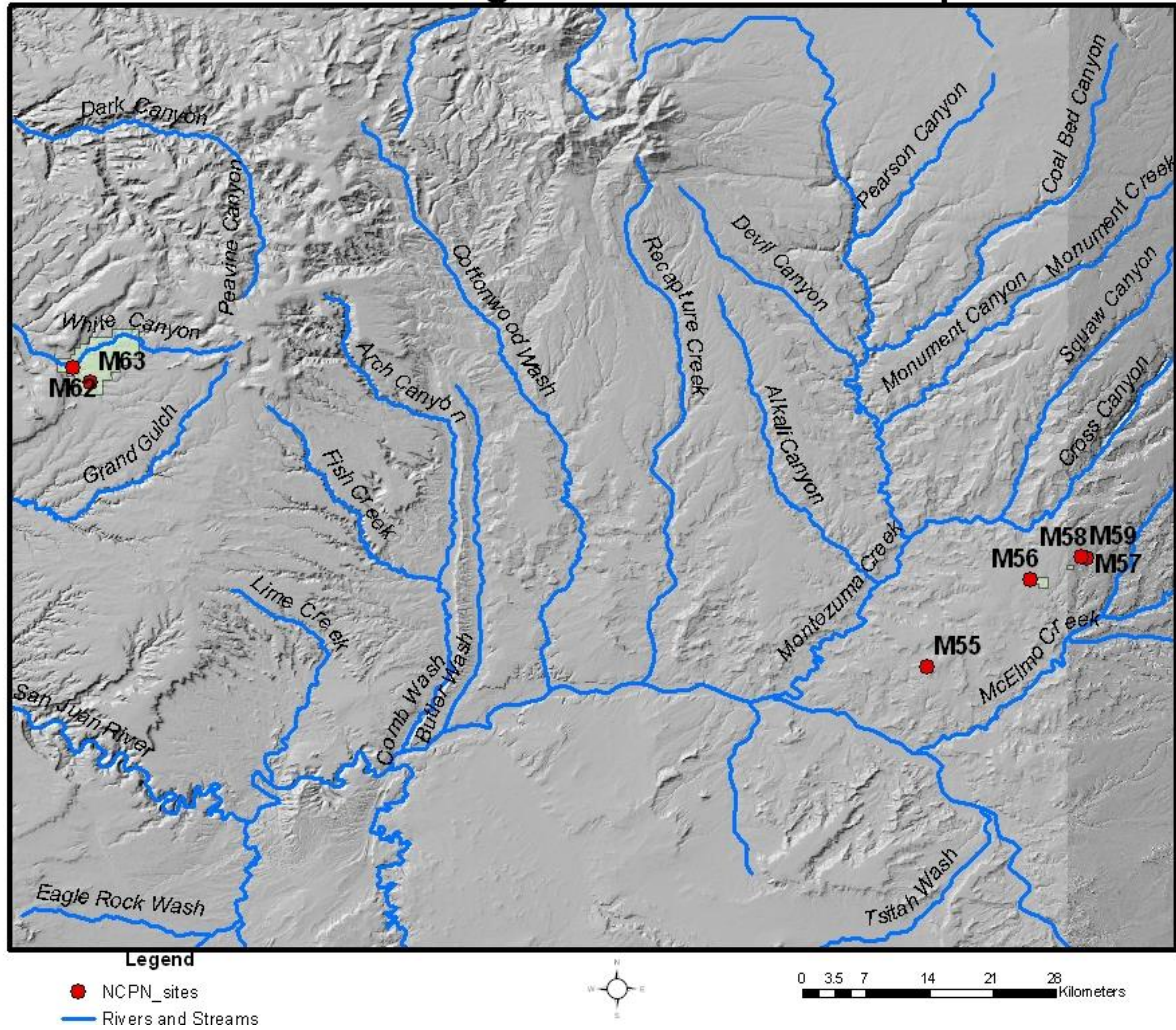


Figure 9. Map of sampling locations in Natural Bridges and Hovenweep National Monuments.

Black Canyon of the Gunnison and Currecanti National Recreation Area

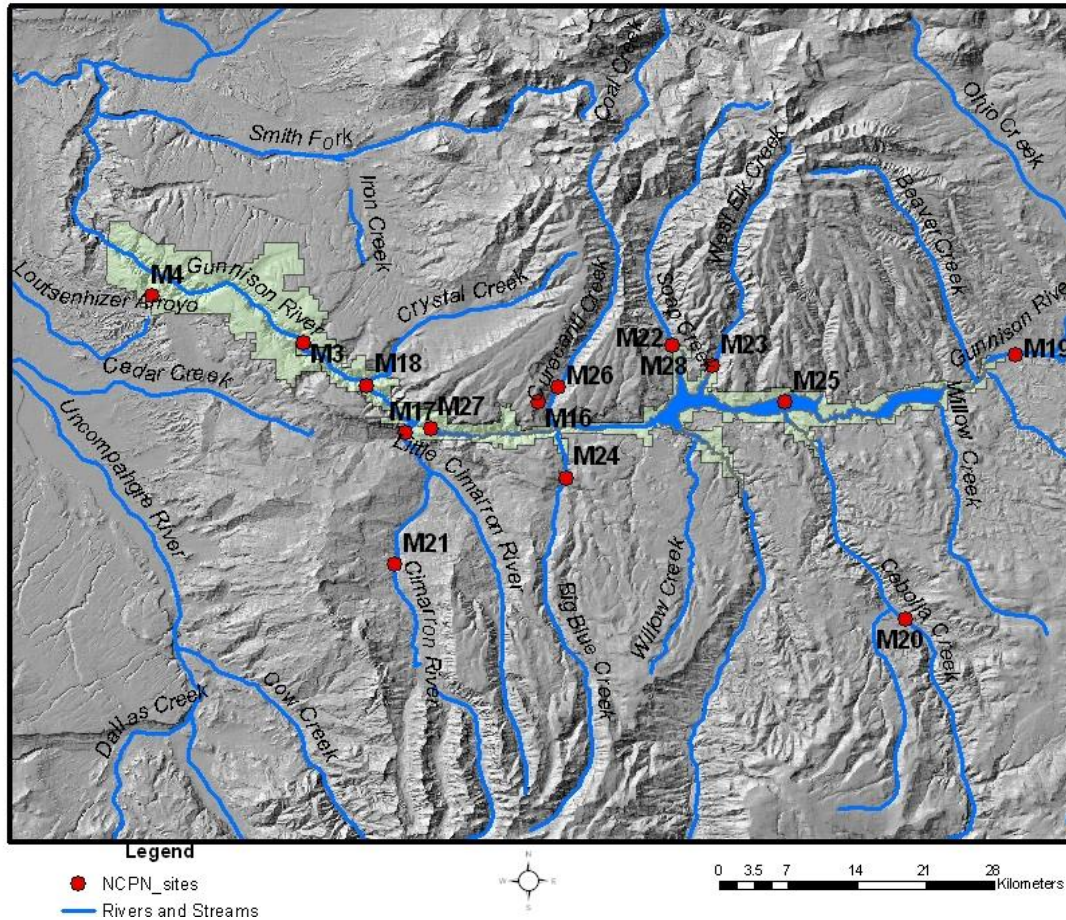


Figure 10. Map of sampling locations in Currecanti National Recreation Area and Black Canyon of the Gunnison National Park.

Dinosaur National Monument

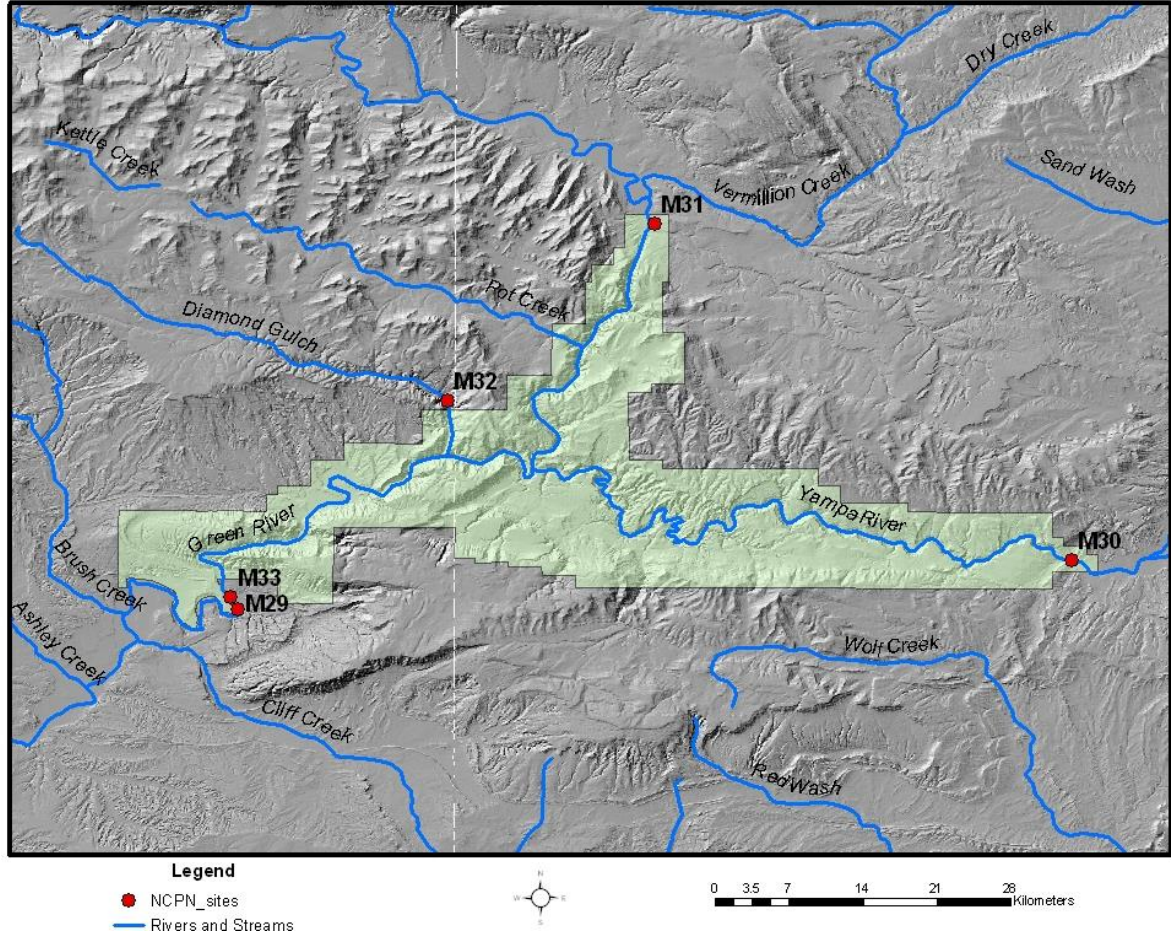


Figure 11. Map of sampling locations in Dinosaur National Monument.

6. Strengths and Limitations of Monitoring Design

The approach selected provides several benefits to the NCPN, parks and regulatory agencies. It will create a long-term record with consistent methodologies and thus provide high quality information for some of the key water resources. This record will be valuable for understanding long-term trends and identifying both chronic contamination and the extent of natural variability. It can document some larger scale year-to-year changes and smaller scale changes that show some consistency or periodicity over periods of several years. By following state-accepted protocols, it will be effective in determining compliance with state water quality standards (except bacteria, which require a higher sampling frequency). It will contrast with data from short-term studies and many monitoring efforts that end after a few years that make analysis of long-term trends problematic.

The sampling frequency (8-12 samples per year) will capture conditions that occur over relatively long periods, such as base flow, spring runoff, warm season and cool season

conditions. It will be somewhat less effective for capturing individual episodic events such as flood conditions that occur several times a year but are relatively short duration.

Primary among the limitations of the program is that it is not nearly comprehensive. The number of water sources is a small portion of the total and biased toward perennial streams. Additionally, the waters sampled are represented by a single sample location, so drawing conclusions about the larger water system requires some assumptions about spatial consistency.

Water quality characteristics that fluctuate diurnally or otherwise change rapidly will not be well-characterized. The monthly measure of water chemistry, while useful for comparison against standards, will not fully characterize the patterns of parameters. Stream discharge measurements will be useful primarily for understanding hydrologic conditions at the time of sampling, which is necessary to interpret laboratory data. Springs,, which have more consistent flow, will be well–represented. For some springs, the discharge measurements made under this program will be the only flow data available. For bacterial monitoring, the frequency will be sufficient for a “screening” level of analysis, but will not be sufficient as a basis for regulatory action. Winter conditions will be missed at sites with poor winter access.

Importantly, this monitoring is not expected to capture short-duration episodic events such as spills or floods. It will, however, provide a well documented baseline of background conditions.

7. Field and Laboratory Methods

7.1. Standard Operating Procedures

Field and laboratory methods will employ standard methods of water quality sampling and analysis. Standard operating procedures (SOPs) cover field season preparations and equipment, sequence of events in the field, details of taking measurements (including field forms and electronic data entry), post-collection processing of samples, lab analysis, data verification and end-of-season procedures. A Quality Assurance Project Plan (QAPP) describes Quality Assurance (QA) and Quality Control (QC) Procedures.

Procedures described in the SOPs are developed from several sources, primarily:

- Utah Division of Water Quality, Manual for Water Quality Monitoring 1993
- Standard Methods for the Examination for Water and Wastewater, 20th ed., Clesceri, 1998
- USGS National Field Manual for the Collection of Water-Quality Data, variously dated U.S.
- Manuals provided by equipment manufacturers

Monitoring is subdivided into 17 categories, for which a detailed Standard Operating Procedure (SOP) details activities. Table 12 provides a brief overview of SOP’s used in this monitoring program.

Table 12. Standard Operating Procedures (SOPs) for water quality monitoring.

SOP #	Title	Description
SOP 1	Safety	Each NPS employee performing field inventory and monitoring activities in the NCPN will, in conjunction with their supervisor (and, if appropriate, other knowledgeable persons), develop a Job Hazard Analysis of the task to be performed. This is consistent with Director's Order #50B and Reference Manual #50B, Occupational Safety and Health Program. The Job Hazard Analysis will identify real and potential hazards associated with inventory and monitoring activities, and develop approaches that minimize or eliminate the hazards.
SOP 2	Staff Training, Colorado Units	Annual training will be provided by NPS staff that has attended USGS training in water quality field techniques. As a partner, USGS will provide quality reviews of NPS field and laboratory techniques.
SOP 3	Staff Training, Utah Units	Annual training is conducted by the state and required for all field staff. If staff is available, back-up staff will also attend this training. If new staff come on board outside of the regular training season (spring) arrangements will be made with UDEQ for a special training session.
SOP 4	Sample Site Selection and Documentation	A description of the criteria used to select sample sites. A process for documenting each site as part of the permanent record. In addition to location information, this will include access information such as road conditions and land ownership, known hazards, park contacts, special equipment requirements, the source of streamflow data, and parameters and parameter groups to be measured.
SOP 5	Preparations and Equipment Calibration, Handling, & Storage, All Units	This SOP will follow guidelines provided by the manufactures (e.g., Oakton, In-SITU, Inc., Marsh-McBirney, Rickly Hydrologic, etc.) for equipment operation and maintenance as well as common sense. This includes calibration methods and frequency, cleaning, changing pH electrodes, and D.O. membranes. An equipment log will be established for each major piece of equipment where calibrations, servicing, problems and other notable events are recorded. In addition, a field equipment checklist is included in the protocol. This lists all required and optional equipment and supplies to be carried with the field crew (or in the field vehicle) at all times. The checklist is provided for review before leaving the base park/office for each sampling event.
SOP 6	Quality Assurance Project Plan (QAPP), all Units	Following guidance from Irwin (2004), the QAPP or QC SOP includes 1) QC objectives for measurement certainty (detection limits such as MDL (method detection limit) and ML (minimum quantitation limit), 2)QC objectives for measurement precision, 3) QC objectives for measurement systematic error (bias as percent recovery), 4)QC objectives for data completeness (including adequacy of planned sample sizes and statistical power), and 5) QC objectives for blank controls for lab measurements. Individual SOPs for parameters also include discussion related to data comparability and selection of laboratories and protocols. SOP is detailed (e.g., indicating how many duplicate samples will be collected for QC) so that other agencies can determine whether they can utilize NCPN data in conjunction with their own data.

SOP 8	Field Methods for Core Parameters, Turbidity and Discharge, All Units	This focuses primarily on the use of multiparameter probes for measuring basic physical and chemical characteristics of the water. Several alternative methods for measuring discharge are presented. The particular method used will vary by site and depend on the quantity of flow, channel characteristics, and accessibility. For moderate to large streams, the preferred method is to use a nearby stream gage as a source of flow data. Colorado - Specifically, the Hydrolab Minisonde 4a with a Surveyor 4 display will be used for determining dissolved oxygen concentration and percent saturation, specific conductance, pH and temperature in CO units. Details of this field SOP will focus on the actual in-situ measurement (e.g., location of probe within sample site, location of probe in water column, proximity to streambank, differences in measurement techniques in pools versus riffles.) Utah - Same except for use of TROLL 9000 with a Rugged Reader display. The Hach 2100 P Turbidimeter will be used to measure turbidity.
SOP 9	Field Sample Collection and Sample Processing for Water Chemistry and Nutrients, Colorado Units	This field SOP focuses on the actual in-situ collection of samples (e.g., clean and sterile technique to avoid contaminating a sample, location of sample in the water column, proximity to streambank, and the use of composite samples). Details of sample bottle labeling, storage, and transport to laboratories (including chain of custody forms) are discussed. Laboratory methods are also discussed.
SOP 10	Field Sample Collection and Sample Processing for Water Chemistry, Nutrients and TSS, Utah Units	Similar to SOP 9, except specific to coordination with the Utah State Laboratory and UDWQ protocols.
SOP 11	Field and Laboratory Methods for Bacteria, All Units	Sampling frequency is at a screening level (monthly) as opposed to an enforcement level, such as for swimming beaches (5 samples/month).
SOP 12	Laboratory Analysis, Colorado Parks	Describes USGS National Water Quality Laboratory protocols. Lists EPA Method number and reporting limit for each parameter.
SOP 13	Laboratory Analysis, Utah Parks	Describes UDEQ laboratory protocols. Lists EPA Method number and reporting limit for each parameter.
SOP 14	Data Management	Discusses the handling of data from multiple sources and repositories of data. Includes discussion of NPS-WRD requirement for use of WRD-STORET and cooperators requirement for storage in STORET (Utah) and NWIS (USGS).
SOP 15	Data Analysis and Reporting	Describes techniques for annual reporting of results including notable hydrologic events, exceedances, and recommendations on modifications to the sampling Network or Protocols.

SOP 16	Revising the Protocol Narrative and SOPs	Describes the procedure for updating this protocol narrative and the SOP's to maintain a relevant reference source that serves to maintain high integrity in data collection and archive. Older versions of SOP's are kept on file so that in the future changes in the program can be tracked.
SOP 17	Annual Project Review	An annual review of procedures and needs. Will provide a schedule and list of what will be reviewed, including: Annual maintenance and upkeep Equipment maintenance Supplies and consumables Review safety contact numbers Review and update field folders Update field forms Equipment list / ownership / location / loan

7.2. Measurable attributes

The water quality attributes measured or sampled at each site are grouped by sample type (Table 13) for convenience in discussion and reporting. Core parameters are required by WRD as the minimum suite of parameter measurements that could be used as indicators of water quality and they are closely related to the speciation and concentration of other water quality constituents as well as determinants of biological activity. Major ions are used to determine alkalinity, and are useful in toxicity and transport models. Sulfate can drive mercury methylation to very high levels and is a good general indicator of water quality in small western streams. Some of these ions are nutrients and trace elements necessary for biological activity and may be correlated with other water quality parameters.

Table 13. Water-quality attributes grouped by sample type.

Sample type	Attributes
Core Field Parameters (CP)	discharge, water temperature, dissolved oxygen, specific conductance, pH, turbidity*, Secchi depth*
Major Ion (MI)	alkalinity, bicarbonate, calcium, CO ₂ , carbonate, chloride, hardness, hydroxide*, magnesium, potassium, sodium, sulfate, and total dissolved solids
Nutrients (Nut)	Ammonia*, unionized ammonia* (calculated), nitrite, nitrate, organic nitrogen*, total phosphorus
Trace Elements (T)	aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, selenium, silver and zinc
Fecal Indicator Bacteria (FIB)	fecal coliform, E. coli in selected samples

* these parameters will not be measured at every site either due to site type (stream or lake) or depending on laboratory which receives samples (CO or UT laboratories).

7.3. Site specific attributes and protocols

Management issues and receiving laboratory determine which sample types are reported for each site. Table 14 summarizes the sampling done at each NCPN site and the personnel who will collect the data and protocols they will follow.

Table 14. Target waters, parameters to be monitored and protocols to be used.

Site Name	NCPN Site ID	Parameter Groups	Sample Frequency	Field Personnel	Protocols
Courthouse Wash near Moab, UT	M-1	CP, MI, Nut, T, TSS, FIB	12/yr	SEUG	Utah State Protocols
Salt Wash at Wolfe Ranch Road	M-2	CP, MI, Nut, T, TSS, FIB	12/yr	SEUG	Utah State Protocols
Red Rock Canyon near NPS Boundary	M-4	CP, MI, Nut, T	7/yr	BLCA/CURE Aquatic Biologist	National Field Manual (USGS, variously dated)
Sheep Creek below Spring	M-5	CP, MI, Nut, T, FIB, Tu	8-12/yr ¹	NCPN Hydrologist (BRCA)	Utah State Protocols
Yellow Creek below Spring	M-6	CP, MI, Nut, T, FIB, Tu	8-12/yr ¹	NCPN Hydrologist (BRCA)	Utah State Protocols
Halls Creek below the narrows	M-15	CP, MI, Nut, T, TSS, FIB	12/yr	NCPN Hydrologist (BRCA)	Utah State Protocols
Blue Mesa Res. above Soap Creek	M-17	CP, MI, Nut, T, Secchi	7/yr	BLCA/CURE Aquatic Biologist	National Field Manual (USGS, variously dated)
Cimarron River below Squaw Creek	M-21	MI, Nut, T	7/yr	BLCA/CURE Aquatic Biologist	National Field Manual (USGS, variously dated)
West Elk Creek below Forest Boundary	M-23	MI, Nut, T	7/yr	BLCA/CURE Aquatic Biologist	National Field Manual (USGS, variously dated)
Yampa River at Deerlodge Park	M-31	CP, MI, Nut, T, TSS	8-12/yr	USGS	National Field Manual (USGS, variously dated)
Green River above Gates of Lodore	M-32	CP, MI, Nut, T	8-12/yr ¹	USFS or USFWS	Utah State Protocols
Jones Hole Creek below fish hatchery	M-33	CP, MI, Nut, T, FIB, Tu	8-12/yr ¹	USFS or USFWS	Utah State Protocols

Site Name	NCPN Site ID	Parameter Groups	Sample Frequency	Field Personnel	Protocols
North Fork Virgin River at North Fork Road	M-36	CP, MI, Nut, T, Tu	10-12/yr ¹	NCPN Hydrologist (BRCA or ZION)	Utah State Protocols
La Verkin Creek at Lee Pass Trail	M-38	CP, MI, Nut, T	10-12/yr ¹	NCPN Hydrologist (BRCA or ZION)	Utah State Protocols
North Creek at planned gage in Park	M-39	CP, MI, Nut, T	12/yr	NCPN Hydrologist (BRCA or ZION)	Utah State Protocols
Total Number of NCPN Samples per year			136-148		

¹ Collection of 12 samples per year will be attempted, but it is recognized that this site will be inaccessible during some periods due to snow or muddy roads or trails.

8. Data Management

The custody requirements of the organizations involved in water quality monitoring result in NCPN data ‘temporarily’ being distributed among several water quality data bases. Data acquired by USGS cooperators resides permanently in the NWIS data base. Data acquired through state of Utah resides in EPA-STORET, and field data collected by NCPN staff resides in the MS-Access database (NCPN H2O) that consolidates water quality data collected in and near the 16 NCPN park units. Although data initially resides in disparate databases, they are reconciled periodically such that all data from NCPN activities eventually makes its way to WRD STORET to conform to the water quality component of the Natural Resource Challenge that requires networks archive all water quality data collected as part of the monitoring program in a STORET (STORage and RETrieval) database maintained by the NPS Water Resources Division (WRD). The relationships between sample collection activities and these databases and their linkages are presented in Figure 12. Flow chart of data management activities..

These databases have been developed by water data specialists to document the multiple layers of attributes describing each datum (i.e. the sample was filtered or not, was acid stabilized or not, was at the limit of detection, or documents the specific laboratory method used). NCPN data will be most useful to a wider audience when it is included in these national data bases.

The WRD-STORET and EPA-STORET data bases are reconciled regularly by the NPS-WRD. The transfer of data to the STORET system will occur by 2 pathways, one for parks where the NCPN partners with the State of Utah, and another for Colorado Parks where the data is handled internally by the hydrologist at CURE/BLCA. For a few monitoring sites, data will be developed by the USGS and stored initially in their NWIS database, with later transfer to the WRD-STORET database. It will be the responsibility of the NCPN hydrologist and data manager to ensure this data transfer occurs on an annual basis.

NCPN H₂O has built in water quality standards assessment tools that allow comparisons of historical and current data with applicable state standards. NCPN will maintain this database and integrate new data so it can serve as an ongoing tool for the network's long-term water quality monitoring and analysis needs. On an annual basis, the NCPN will compile and format new water quality data from NCPN H₂O into an electronic data deliverable (EDD) that is compatible with WRD-STORET. The templates developed for NPSTORET will be used or serve as a guide in developing the EDD to ensure all required metadata is captured. WRD will ensure that content is transferred to the EPA STORET.

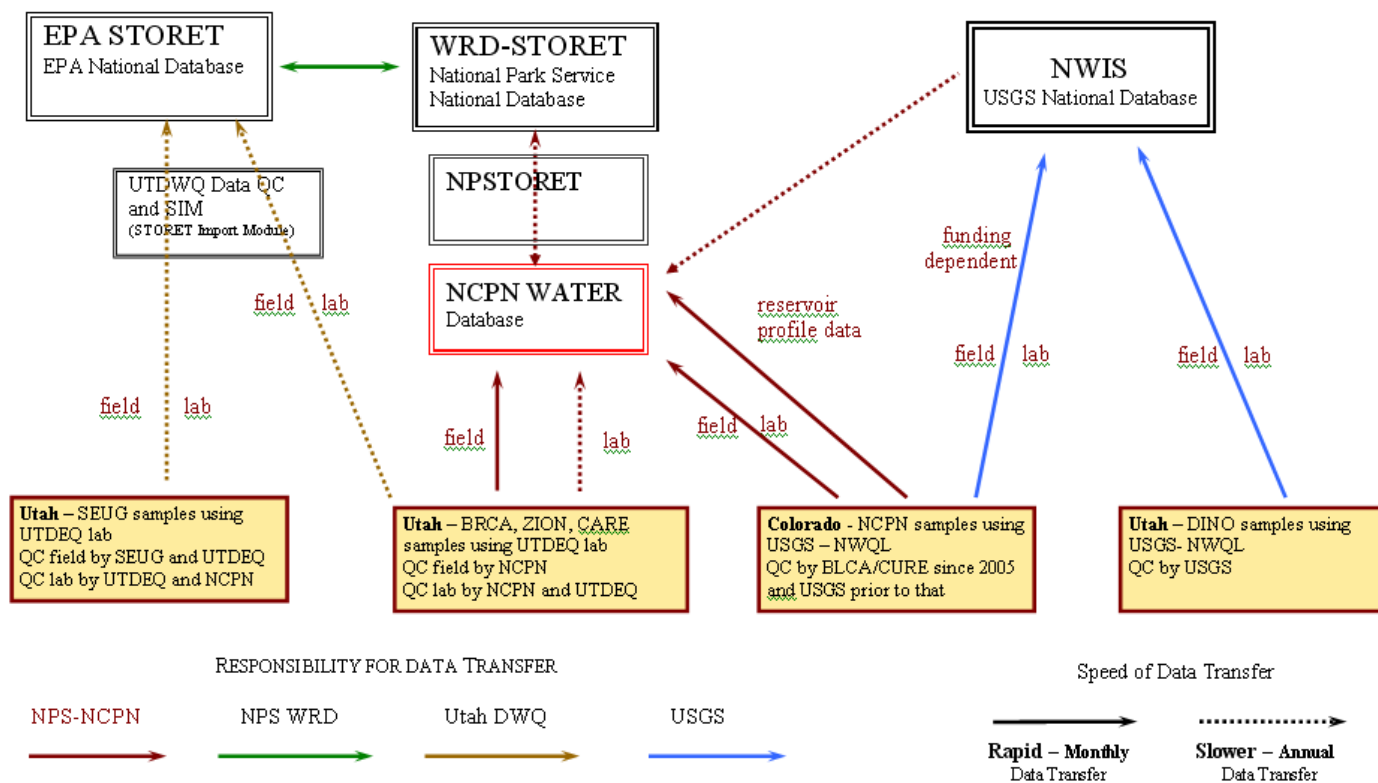


Figure 12. Flow chart of data management activities.

Table 15. Elements of Data Management for each Approach to Water Quality Vital Signs Monitoring in the NCPN.

Method of Sample Collection and Partner	Elements of Method	Parks Affected	Number of Sites Affected	Data Management
Partnership with UDWQ	Sample Collection by NPS Staff Analysis done by UDWQ UDWQ enters Data into Local STORET and uploads to National STORET UDWQ passes data to NCPN, NCPN uploads to NCPNH20 and WRD-STORET semiannually	ARCH, BRCA, CARE, CANY, HOVE, NABR, ZION	15	UDWQ uploads data to EPA-STORET and NCPN uploads to WRD-STORET 1 to 2 times each year. UDWQ reviews lab results as soon as possible and request reruns if necessary. Data are transferred to NPS staff annually for upload to NCPN H2O.
Colorado Parks	Sample Collection by NPS Staff Analysis done by USGS NPS enters Data into NP-STORET, annual update to WRD-STORET USGS data entered into NWIS QC Checks by BLCA/CURE hydrologist	BLCA, CURE	5	NCPN pulls from NWIS to upload to NCPN H2O NCPN pulls from NP-STORET and uploads to NCPN H2O
Agreement with USGS (NPS pays for greater sample frequency)	Sample Collection by USGS Staff Analysis done by USGS USGS enters Data into NWIS QC Checks by USGS	DINO	2	NCPN pulls from NWIS to upload to NCPN H2O

8.1. Data Management in Utah Parks in partnership with UDWQ

For parks in Utah, samples will be collected by NPS staff, and sent to the State Water Quality Laboratory for Analysis. Field measurements and notes will be electronically transferred to the state using their template described in SOP 10 section 8.4. At least annually, NPS data will be separated from non-NPS data using the STORET Report function and electronically transferred to WRD-STORET on an annual basis by the NCPN hydrologist. The transfer will involve two steps, (1) establishing station ID and a data framework in WRD-STORET (this should generally only need to be done once for each station), and (2) Assembling the data for those stations and transferring. Staff at WRD would have to confirm that the transfer was completed successfully. UDWQ can

also respond to special requests for data and for expedited laboratory analysis on a case-by-case basis.

8.2. Data Management in Colorado NCPN Parks

Data management in Colorado parks will be primarily the responsibility of the CURE hydrologist. Field data will be uploaded to NWIS electronically by the CURE hydrologist using the Personal Computer Field Forms (PCFF) developed and maintained by the USGS. Laboratory data will be electronically uploaded to NWIS by the National Water Quality Laboratory staff. The data will be quality checked soon after receipt by the CURE hydrologist (2 to 3 weeks) so that laboratory re-runs or clarification can be requested. This data will be transferred to the WRD-STORET database annually by the CURE hydrologist. At the same time it will be transferred to the NCPN H2O data base with receipt verified by the NCPN hydrologist.

8.3. Data Management for Sites with a USGS Partner

Field and laboratory data from DINO sites monitored by USGS through a cooperative agreement with NCPN will be managed as USGS data and be entered in the NWIS Database. At least once annually, NCPN will request a data transfer of the park specific data from Colorado USGS to WRD-STORET and NCPN H₂O. As with other transfers this will involve two steps, (1) establishing station ID and a data framework in WRD-STORET (this should generally only need to be done once for each station), and (2) Assembling the data for those stations and transferring. Staff at WRD and NCPN would have to confirm that the transfer was completed successfully.

9. Data Analysis and Reporting

Analyzing the information gained through water quality monitoring and reporting is essential for the short and long-term utility of the monitoring program. It will permit network staff to assess the condition of the resources, and share that information with other interested parties. Specifically, it will permit the NCPN to meet its monitoring objectives stated in section 2.5 and will:

- Provide written documentation of the condition of water resources in a form that can be shared with others,
- Identify areas of water quality concern,
- Present supporting information (metadata) essential for the understanding and utility of the data,
- Document accomplishments of the monitoring program, and
- Assess and document the effectiveness of the monitoring program and recommend improvements.

Two types of formal reports will be prepared regularly, annual summaries and triennial reports of water quality conditions. Additionally, annual coordination meetings will be conducted with NCPN staff and cooperators.

9.1. Annual Summary Report

An Annual Summary Report will be prepared that will include an accounting of the number of samples taken and analyses conducted, observations of notable events, and a listing of exceedances. The target audiences will be park managers, resource managers in the park and network, and state water quality managers. An explanation of the significance of the results will be provided along with recommendations for changes in park operations or state actions where warranted, for modifications in the monitoring program, and where special studies are indicated.

The Annual Reports will involve monthly data review including quality assurance and control; identify anomalous values indicating need for reanalyzing samples; censor values below method detection limits; flag values exceeding state standards and report to parks. Additionally, the annual report will include annual summary status that summarizes site data by season and tabulates values exceeding, and approaching exceedance of standards (20% or less below the applicable standard); summary tables, histograms, and box and whisker plots to show frequency distribution, median and interquartile ranges (for non-normally distributed data), mean and standard deviation (for normally distributed data), and 95% confidence intervals for means and medians of parameters at each site.

The Annual Summary report will be prepared in geographic sections as shown in Table 16, and compiled by the NCPN hydrologist stationed in BRCA.

Table 16. Annual Reporting Responsibilities.

Monitoring in these Parks	Responsibility
BLCA, CURE	CURE RM Staff
ARCH, CANY, HOVE, NABR	SEUG RM Staff
BRCA, CARE, DINO, ZION	NCPN staff in BRCA
Responsible for compiling Combined Report	NCPN staff in BRCA

9.2. Triennial Report

A triennial report will summarize longer term trends but will otherwise have a similar layout to the annual report and will include comprehensive analysis and synthesis of site level trends adjusted for season and flow for individual constituents. Statistical tests include Seasonal Kendall tests for monotonic trends and Seasonal Rank Sum tests for step trends.

10. Coordination Meetings

Water quality planning meetings will be held annually to discuss the results of water quality monitoring and to provide a forum for discussing recent developments and concerns in water quality issues. Participants will include NCPN water resources and data management staff, park water resources managers, NCPN management, and WRD staff. These meetings will also provide an opportunity to receive suggestions on refining protocols. NCPN water quality staff will also participate in annual meetings with cooperators.

11. Roles and Responsibilities

The water quality program leader will be the Network Hydrologist stationed at BRCA. The individual will be responsible for conducting field work, QA/QC measures, data management (in conjunction with the network Data Manager), data analysis, and reporting and will be supervised by the Network coordinator. Additional field staff with position titles including aquatic ecologist, biologist, and hydrologist will conduct fieldwork for groups of parks within the network, and be stationed at central locations for accessing those parks (Table 17). At this time these locations are the Southeast Utah Group office in Moab, Utah, and CURE in Gunnison, Colorado. Their responsibilities will parallel those of the water quality program leader with the exception of program oversight and the preparation of consolidated reports.

Table 17. Areas of responsibility for staff involved in NCPN water quality monitoring. The level or responsibility is indicated by specific park(s), “group” of parks serviced by that water quality specialist, or “NCPN” for all network parks.

Location of Water Quality Field Staff	Area of Responsibility								
	Field Sampling in:	Data Entry	Verification of Laboratory Results	Coordination with Partners	Data Analysis	Annual report for	Consolidated Annual Report	Data Management	Budget and Program Administration
BRCA	BRCA, CARE, ZION	Group	Group + DINO	Group + DINO	Group + DINO	Group + DINO	NCPN	NCPN and Group	NCPN and Group
SEUG	ARCH, CANY, HOVE, NABR	Group	Group	Group	Group	Group		Group	Group
CURE	BLCA, CURE	Group	Group	Group	Group	Group		Group	Group
TBA	DINO	DINO	TBA						
Other NCPN Staff									
Network Coordinator				NCPN					NCPN
Data Manager								NCPN	

The location of these personnel is based on the location of existing personnel with expertise in water quality sampling and suitable facilities.

12. Operational Requirements

12.1. Annual workload and Field Schedule

The fieldwork load will be somewhat heavier in summer when more sites are accessible. Year-round monitoring is planned in Utah parks, though it is recognized that some sites will not be accessible in the winter due to mud or snow. Sampling in Colorado parks is planned for 7 months per year, excluding the winter and early spring. Data entry and validation checks will be ongoing. The time commitment per site will vary with accessibility, from Halls Creek in CARE which may require 1½ to 2 days, to more accessible sites where two or three sites can be sampled in a day. On average, each sample is estimated to require 0.5 day for preparation, 1.0 day for access, sample collection and processing, and 0.5 day for data management for a total of 2.0 work-days per sample.

12.2. Facility and Equipment Needs

The large geographic area covered by the NCPN requires that monitoring personnel and equipment be at multiple dispersed locations referred to here as nodes. These will be at CURE, SEUG, and BRCA. Each node will need laboratory facilities and the equipment listed in Table 18.

Table 18. Equipment requirements for each sampling node.

Activity	Equipment Required	CURE	SEUG	BRCA	Backup
Discharge Measurement	Pryce AA or Mini flow meter, Wading rod and associated equip.	X	X	X	O
	Optional-Aquacalc	X	-	X	-
	Optional-Portable Flume	-	-	X	-
Sample Collection	Compositing Churn	X	-	-	-
Field Parameters	Multi-parameter Meter for pH, water Temp, Specific Conductance, Dissolved Oxygen.	X	X	X	O
	Optional- Turbidity Meter	Lab	-	Field	-
Sample Processing	Peristaltic Pump and Tubing	X	X	X	O
Bacteria Enumeration	Membrane Filtration Apparatus or IDEXX system and Incubator	X	X	X	-
		X	X	X	-
Laboratory Operations and calibration	DI Water Generation or Storage	X	X	X	X
	Acid storage	X	X	X	-
	Sink and Counter Space	X	X	X	-
	Supply Storage	X	X	X	-
Transpiration	Vehicle	X	X	X	-

X = Equipment Serviceable

- = Equipment not present & not needed

O = Equipment not present, need to acquire

12.3. Startup Costs and Budget Considerations

12.3.1. Approximate Costs of Sample Collection and Analysis

Categorized annual program costs are estimated in Table 19. A per site visit cost estimate of \$720 to \$780 per sample is derived by dividing total program budget (FY05) by estimated sample number (136 to 148 samples per year contingent on access). This includes supplies and equipment, field sampling, NPS laboratory analysis, outside laboratory analysis, data validation, data management, report preparation and coordination with other park and NCPN activities. This represents an underestimate of actual costs because some equipment and supplies were already purchased by parks and by the NCPN in previous years. Some support is provided to cooperating parks (SEUG) where staff helps with water sample collection and data handling. Average sample costs for parks in Utah will be somewhat lower than for parks in Colorado, typically \$200 to \$300, because UDEQ is contributing laboratory analysis costs.

Table 19. Projected Annual Budget for NCPN Water Quality Monitoring.

Program Item	Estimated Annual Expense	Sub Totals
Personnel		\$ 59,500
Hydrologist GS-11, ½-time	\$ 52,000	
Technician at SEUG	\$ 7,500	
Equipment and Supplies		\$ 10,000
Field & Lab Equipment and Supplies	\$ 5,000	
Major Equip. Replacement and Service	\$ 5,000	
Park and Other Agency Support for WQ		\$ 28,500
Facility Support to BRCA	\$ 2,000	
Laboratory Analysis (CO parks)	\$ 7,500	
IA cooperation for Sampling at DINO	\$ 19,000	
Travel and Transportation	\$ 5,500	\$ 5,500
Maintain IT Hardware/Software	\$ 1,000	\$ 1,000
General supplies and Misc.	\$ 2,000	\$ 2,000
Total	\$106,500	\$106,500

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14. Appendix A: Protected Uses for Northern Colorado Plateau Parks in Utah, Wyoming, Arizona and Colorado

The following tables summarize protected uses as identified by the states of Utah, Wyoming, Arizona, and Colorado for Northern Colorado Plateau Parks. Numeric standards for water quality are specific to these protected uses.

Prepared by: Dave Sharrow, NPS Zion National Park November 2003(corrected 3-2009)

Table A-1. Protected uses designated for Northern Colorado Plateau Parks in Utah.

Utah Park Unit	Waters in Park	Reference to State Segment	Utah High Quality Cat. 2 ¹	Utah Protected Uses (See Table A-5 for Definitions of Use Codes)						
				1C	2B	3A	3B	3C	3D	4
Hovenweep NM	See Table D-4 below	San Juan River								
Bryce Canyon NP	East	Paria River								
	West	East Fork Sevier River, Annabelle Diversion to headwaters and Tropic Res.								
Zion NP	Kolob Area (Taylor Creek, Camp Creek)	Ash Creek above Ash Creek Res.								
	North Fork Virgin River and tributaries.	North Fork Virgin River confluence w/ E. Fork to headwaters								
	East Fork Virgin River	East Fork Virgin River confluence w/ N. Fork to headwaters								
	Kolob Creek	Kolob Creek, confluence with N. Fork V. R. to headwaters								
	Kolob Reservoir & Navajo Lake (both outside Park)	Kolob Reservoir and Navajo Lake								

Utah Park Unit	Waters in Park	Reference to State Segment	Utah High Quality Cat. 2 ¹	Utah Protected Uses (See Table A-5 for Definitions of Use Codes)						
				1C	2B	3A	3B	3C	3D	4
Zion NP	North Creek, Coalpits Wash	Virgin River upstream of Quail Creek Diversion								
	LaVerkin Creek	Virgin River below Quail Creek Diversion								
Cedar Breaks NM	West Slope	Coal Creek and tributaries								
	East Slope	Duck Creek and tributaries								
Timpanogos Cave NM	All	American Fork River								
Dinosaur NM	See Table D-4 below									
Natural Bridges NM	All (White Canyon)	Lake Powell and all tributaries								
Golden Spike NHS	Blue Creek	Blue Creek from Great Salt Lake to Blue Cr. Res.								
Capitol Reef NP	Fremont R. Downstream of CARE (Harnet Draw, Sandy & Oak Cr. in park)	Fremont River and tributaries from the confluence with Muddy Cr. To CARE								
	Fremont River in CARE and upstream	Fremont River and tributaries through CARE to Headwaters								
	Pleasant Creek inside CARE	Pleasant Cr. and tributaries from east boundary of Capitol Reef to headwaters								
	Pleasant Cr. upstream of CARE (outside of Park)	Pleasant Cr. and tributaries from east boundary of Capitol Reef to headwaters								
	Halls Creek (Bitter Cr. Divide South in park)	All tributaries to Lake Powell except as listed separately								
	Southwestern Margin of park	Escalante River and tributaries, from Lake Powell to confluence with Boulder Creek								
Arches NP	All	Colorado R. and tributaries from Lake Powell to state line								

Utah Park Unit	Waters in Park	Reference to State Segment	Utah High Quality Cat. 2 ¹	Utah Protected Uses (See Table A-5 for Definitions of Use Codes)						
				1C	2B	3A	3B	3C	3D	4
Canyonlands NP	Most of park	Colorado R. and tributaries from Lake Powell to state line, and Green River and tributaries from confluence with Colorado R. to State Line								
	Immediate vicinity of Indian Cr. confluence and southeastern-most margin of park.	Indian Creek and tributaries from confluence with Colorado R. to Newspaper Rock State Park								
	Southwestern-most margin of park	All Tributaries to Lake Powell except as listed separately								

¹ High Quality category 2 designation in Utah does not carry with it specific numeric criteria at this time.

Table A-2. Protected uses designated for Northern Colorado Plateau Parks in Wyoming.

Wyoming				
Park	Waters in Park	Reference to State Segment	Use Code ¹	Protected Uses
Fossil Butte NM	Chicken Creek Watershed and North East Slopes draining to North Fork Twin Cr.	Chicken Creek, tributary to Twin Creek and North Fork of Twin Creek in Lincoln County	3B	Scenic Value, Industry, Agriculture, Wildlife, Recreation, Other Aquatic Life (NOT Protected are: Drinking Water, Game Fish, Non-Game Fish, and Fish Consumption)
	Western slopes draining to Rock Creek. Southern slopes draining to Twin Creek, including Smallpox Cr.	Rock Creek, tributary to Twin Creek Twin Creek, tributary to Bear River	2AB	All (Drinking Water, Game Fish, Non-Game Fish, and Fish Consumption, Other Aquatic Life, Recreation, Wildlife, Agriculture, Industry, and Scenic)

¹See table A-5 for definitions of Class

Table A-3. Protected uses designated for Northern Colorado Plateau Parks in Arizona.

Arizona			
PARK	WATERS IN PARK	REFERENCE TO STATE SEGMENT	Protected Uses
Pipe Spring NM	All	Kanab Creek	Aquatic and Wildlife warm water, Full-body Contact, Domestic Water Source, Fish Consumption, Agricultural Irrigation

Table A-4. Protected uses designated for Northern Colorado Plateau Parks in Colorado (including portions of Dinosaur and Hovenweep National Monuments in Utah).

Segment Description1	Water Body Identification Code (305b Water Body Identification Code) 2	Miles (In Park)	Shoreline Miles 3	Acres (In Park)	State-Designated Uses Applied to this Segment (See Table D-5 for Definitions of Use Codes)									
					Colorado						Utah			
					AG	ALCW1	ALWM1	ALWM2	DWS	RPC	RSC	1C	2B	3A
Dinosaur National Monument														
CO Region 11, LY/G Basin, Segment 2 Mainstem of the Yampa River from a point immediately above the confluence with Lay Creek to the confluence with the Green River.	COLCLY02 (COLCLY02_8100)	48.23		2.92										
CO Region 11, LY/G Basin, Segment 14 All Tributaries to the Yampa River, including all wetlands, lakes and reservoirs from a point immediately below the confluence with Lay Creek to a point immediately below the confluence with the Little Snake River.	COLCLY14 (COLCLY14_8100)	230.98												
CO Region 11, LY/G Basin, Segment 19 Mainstem of the Green River within Colorado (Moffatt County)	COLCLY19 (COLCLY19_7800)	25.32		48.65										
CO Region 11, LY/G Basin, Segment 20 All tributaries to the Green River in Colorado, including all wetlands, lakes and reservoirs, except for the specific listings in segments 21 and 22; all tributaries of the Yampa River from a point immediately below the confluence with the Green River, except for the specific listings in segments 15 through 18.	COLCLY20 (COLCLY20_7800)	74.28												

Segment Description1	Water Body Identification Code (305b Water Body Identification Code) 2	Miles (In Park)	Shoreline Miles 3	Acres (In Park)	State-Designated Uses Applied to this Segment (See Table D-5 for Definitions of Use Codes)											
					Colorado							Utah				
					AG	ALCW1	ALWW1	ALWW2	DWS	RPC	RSC	1C	2B	3A	3B	4
CO Region 11, White R. Basin, Segment 22 All Tributaries to the White River, including all wetlands, lakes and reservoirs, from a point immediately above the confluence with Douglas Creek to the Colorado/Utah border, except for the specific listing in Segment 23.	COLCWH22 (COLCWH22_8500)	0.99														
Dinosaur National Monument - Utah Portions																
Green River and tributaries from the confluence with Colorado River to State Line, except for the two segments listed below.	UT-R-GREEN-0001 (UT14060001-001_00)	140.18	0.5	4.68												
Big Brush Creek and tributaries from confluence with Green River to Tyzack (Red Fleet) Dam.	UT-R-GREEN-0034 (UT14060002-003_00)	0.95														
Jones Hole Creek and tributaries from confluence with Green River to headwaters. Utah as High Quality Category 2, which provides narrative standards for antidegradation.	UT-R-GREEN-0036 (UT14060001-002_00)	6.33														
Black Canyon of the Gunnison National Park																
CO Region 10, Basin – Lower Gunnison R., Segment 1. Mainstem of the Gunnison River from the outlet of Crystal Reservoir to a point immediately above the confluence with the Uncompahgre River	COGULG01 (COGULG01_6800)	11.93														

Segment Description1	Water Body Identification Code (305b Water Body Identification Code) 2	Miles (In Park)	Shoreline Miles 3	Acres (In Park)	State-Designated Uses Applied to this Segment (See Table D-5 for Definitions of Use Codes)											
					Colorado							Utah				
					AG	ALCW1	ALWW1	ALWW2	DWS	RPC	RSC	1C	2B	3A	3B	4
CO Region 10, Basin – Lower Gunnison R., Segment 4a. All tributaries to the Gunnison River, including all wetlands which are not on national forest lands, from the outlet of Crystal Reservoir to the confluence with the Colorado River.	COGULG04A (COGULG04_6800)	16.15														
Curecanti National Recreation Area																
CO Region 10, Basin – Lower Gunnison R., Segment 1. Mainstem of the Gunnison River from the outlet of Crystal Reservoir to a point immediately above the confluence with the Uncompahgre River	COGULG01 (COGULG01_6800)	2.26														
CO Region 10, Basin – Lower Gunnison R., Segment 4a. All tributaries to the Gunnison River, including all wetlands which are not on national forest lands, from the outlet of Crystal Reservoir to the confluence with the Colorado River.	COGULG04A (COGULG04A_6800)	0.60														
CO Region 10, Basin – Upper Gunnison R., Segment 14. Mainstem of the Gunnison River from the confluence of the East and Taylor Rivers to the inlet of Blue Mesa Reservoir.	COGUUG14 (COGUUG14_6800)	4.61	5.34	169.10												

Segment Description1	Water Body Identification Code (305b Water Body Identification Code) 2	Miles (In Park)	Shoreline Miles 3	Acres (In Park)	State-Designated Uses Applied to this Segment (See Table D-5 for Definitions of Use Codes)											
					Colorado							Utah				
					AG	ALCW1	ALWM1	ALWM2	DWS	RPC	RSC	1C	2B	3A	3B	4
CO Region 10, Basin – Upper Gunnison R., Segment 25. Blue Mesa, Morrow Point and Crystal Reservoirs and those segments of the Gunnison River which inter-connect reservoirs.	COGUUG25 (COGUUG25_6800)	64.05	100.30	9421.83												
CO Region 10, Basin – Upper Gunnison R., Segment 26. All tributaries, from the source, to those waters described in segment 25 including all lakes, reservoirs and wetlands which are on Gunnison and Uncompahgre National Forest lands, or which flow into or are present within Curecanti National Recreation Area with the exception of Segments 14, and 29.	COGUUG26 (COGUUG26_6800)	19.88	3.90	67.27												
CO Region 10, Basin – Upper Gunnison R., Segment 29. Mainstem of Lake Fork of the Gunnison including all tributaries, lakes, reservoirs and wetlands from the source to Blue Mesa Reservoir.	COGUUG29 (COGUUG29_6800)	9.68	16.01	533.58												

Segment Description ¹	Water Body Identification Code (305b Water Body Identification Code) 2	Miles (In Park)	Shoreline Miles 3	Acres (In Park)	State-Designated Uses Applied to this Segment (See Table D-5 for Definitions of Use Codes)									
					Colorado						Utah			
					AG	ALCW1	ALWW1	ALWW2	DWS	RPC	RSC	1C	2B	3A
Colorado National Monument														
CO Region 11, Basin – Lower Colorado River, Segment 13a: All Tributaries to the Colorado River, including all wetlands, lakes and reservoirs, from a point immediately below the confluence of Parachute Creek to the Colorado/Utah border except for the specific listings in segments 13b through 19. (13b is a temporary standard for streams NE of park boundary, other exceptions are N/A)	COLCLC13A (COLCLC13A_6500)	54.46												
Hovenweep National Monument														
CO Region 9, Basin -La Plata R., Mancos R. McElmo Cr., and San Juan R. in Montezuma County and Delores County, Segment 7a: Mainstem of McElmo Creek from the source to the Colorado/Utah Border. Mainstem of Yellow Jacket Creek, including all tributaries, wetlands, lakes and reservoirs from the source to the confluence with McElmo Creek.														
Utah Units – all San Juan River and its tributaries														

¹ Segment Descriptions are taken verbatim from the State of Colorado Stream Classifications and Water Quality Standards except that references to exceptions that do not pertain to the park have been deleted. (e.g. where the description says “except for the specific listings for segments 3a to 6,” this text has been deleted if segments 3a to 6 are not located in or near the park.)

² The Water Body Identification Code is a state-assigned identifier for each reach. The Water Body Identification Codes used in 303d reports may include more than one WBID, or may include only a part of one WBID.

³ Shoreline Miles applies to adjacent lakes/ponds, seas/oceans, swamps/marshes, reservoirs or estuaries.

Table A-5. Definitions of Colorado and Utah designated protected uses.

State-Designated Use Codes	State-Designated Use	Definition
Colorado		
AG	Agriculture	These surface waters are suitable or intended to become suitable for irrigation of crops usually grown in Colorado and which are not hazardous as drinking water for livestock.
ALCW1	Aquatic Life Cold Water-Class 1	These are waters that (1) currently are capable of sustaining a wide variety of cold water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of abundance and diversity of species.
ALWW1	Aquatic Life Warm Water-Class 1	These are waters that (1) currently are capable of sustaining a wide variety of warm water biota, including sensitive species, or (2) could sustain such biota but for correctable water quality conditions. Waters shall be considered capable of sustaining such biota where physical habitat, water flows or levels, and water quality conditions result in no substantial impairment of abundance and diversity of species.
ALWW2	Aquatic Life Warm Water-Class 2	These waters are not capable of sustaining a wide variety of warm water biota, including sensitive species, due to physical habitat, water flows or levels, or uncorrectable water quality conditions that result in substantial impairment of the abundance and diversity of species.
DWS	Water Supply	These surface waters are suitable or intended to become suitable for potable water supplies. After receiving standard treatment (defined as coagulation, flocculation, sedimentation, filtration and disinfection with chlorine or its equivalent) these waters will meet Colorado drinking water regulations and any revisions, amendments or supplements thereto.
RPC	Recreation 1 - Primary Contact	These surface waters are suitable or intended to become suitable for recreational uses in or on the water when the ingestion of small quantities of water is likely to occur. Such waters include but are not limited to those used for swimming, rafting, kayaking and water-skiing.
RSC	Recreation 2 - Secondary Contact	These surface waters are suitable or intended to become suitable for recreational uses on or about the water which are not included in the primary contact subcategory, including but not limited to fishing and other streamside or lakeside recreation.

State-Designated Use Codes	State-Designated Use	Definition
Utah		
1C	Drinking Water Supply	Protected for domestic purposes with prior treatment by processes as required by the Utah Department of Health.
2A	Primary Contact (Recreation)	Protected for primary contact recreation such as swimming.
2B	Secondary Contact (Recreation)	Protected for secondary contact recreation such as boating, wading, or similar uses.
3A	Cold Water Game Fish	Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
3B	Warm Water Game Fish	Protected for warm water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
3C	Nongame Fish	Protected for nongame fish and other aquatic life, including the necessary aquatic organisms in their food chain.
3D	Waterfowl	Protected for waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain.
3E	Severely Habitat Limited	Severely habitat limited waters. Narrative standards will be applied to protect these waters for aquatic wildlife.
4	Agriculture	Protected for agricultural uses including crop irrigation and stock watering.
5	Great Salt Lake	Protected for primary and secondary contact recreation, aquatic wildlife, and mineral extraction.

State-Designated Use Codes	State-Designated Use	Definition
Wyoming		
2AB	Spawning fish	Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold water or warm water species present. All Class 2AB waters are designated as cold water game fisheries unless identified as a warm water game fishery by a "ww" notation in the "Wyoming Surface Water Classification List". Unless it is shown otherwise, these waters are presumed to have both sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, aquatic life other than fish, primary contact recreation, wildlife, industry, agriculture and scenic value uses.
3B	Intermittent streams	Class 3B waters are tributary waters including adjacent wetlands that are not known to support fish populations or drinking water supplies and where those uses are not attainable. Class 3B waters are intermittent and ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life including invertebrates, amphibians, or other flora and fauna which inhabit waters of the state at some stage of their life cycles. In general, 3B waters are characterized by frequent linear wetland occurrences or impoundments within or adjacent to the stream channel over its entire length.

Sources: Adapted from National Park Service 2003a, 2003b, 2003c, and 2003d, which used Environmental Protection Agency WQSDB (Version 3), and State of Utah, 1997 as primary sources and State of Wyoming 2000.

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