Western Slope Conservation Center

VOLUNTEER WATER QUALITY MONITORING NETWORK

2001 to 2014 Data Report

Volunteer collecting a sample on the North Fork of the Gunnison River.

Western Slope Conservation Center
204 Poplar Ave
Paonia, CO 81428

Phone: (970) 527-5307
Mailing Address: PO Box 1612 Paonia CO 81428
Street Address: 204 Poplar Ave Paonia CO 81428
Phone: 970-527-5307
Email: info@theconservationcenter.org
www.westernslopeconservation.org

Contributors:

Julia Bowman
Barbara Galloway
Mike Galloway
Alex Johnson
Dawn Reeder
Teresa Shishim
Hannah Stevens

WSCC Volunteer Water Quality Monitoring Data Report

Table of Contents

TABLE OF FIGURES

TABLE OF TABLES

LIST OF ACRONYMS:

% EPT	Percent of ephemeroptera, plecoptera and trichoptera species
°C	Degrees Celsius
µg/L	Micrograms per Liter
CaCO3	Calcium Carbonate
CDPHE	Colorado Department of Public Health and Environment
CPW	Colorado Parks and Wildlife
cfs	Cubic feet per second
CSU	Colorado State University
DO	Dissolved Oxygen
E. coli	Escherichia coli
EPA	Environmental Protection Agency
H^+	Hydrogen ions
HBI	The Hilsenhoff Biotic Index
ISDS	Independent Sewage Disposal System
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
WSCC	Western Slope Conservation Center
PCS	Permit Compliance System
O_2	Oxygen
OH^-	Hydroxyl ion
ppb	Parts per billion
PO4	Phosphate
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SO4	Sulfate
SOPs	Standard Operating Procedures
TVS	Table Value Standard
USFS	US Forest Service
USGS	US Geological Survey
WS	Water Supply
WWTP	Wastewater Treatment Plant
WQCC	Colorado Water Quality Control Commission

Definitions

Acute standard — the concentration value of a contaminant or substance in water that will result in adverse effects either from a single exposure or from multiple exposures in a short period of time
Chronic standard — the concentration value of a contaminant or substance in water that is deemed to cause adverse effects as a result of long term exposure.
Dissolved solids — refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water. Concentrations of total dissolved solids are reflected in conductivity measurements.
Mode – The number that appears most often in a set of numbers.

1. INTRODUCTION

Western Slope Conservation Center

Established in 1977, the Western Slope Conservation Center (WSCC) is a 501(c)3 non-profit group that formed to disseminate information about regional energy development and its impacts on the region's natural resources. Today, our mission is to build an active and aware community to protect and enhance the lands, air, water and wildlife of the Lower Gunnison Watershed.

As a result of our work, in 35 years the communities of the Lower Gunnison Watershed will be characterized by intact and functioning ecosystems, clean and abundant water resources, well-managed lands with the highest level of protection they deserve, and informed and an engaged citizenry that understand the connection between the vitality of its ecological and social communities.

WSCC Mission:
To build an active and aware community to protect and enhance the lands, air, water and wildlife of the Lower Gunnison Watershed

In 2015, the Board of Directors affirmed our commitment to the following goal areas:

- Watershed Stewardship
- Advocacy for the Protection of Public Lands
- Education and Public Outreach

We distinguish ourselves by committing to four unique values.

- **Transparent, responsible, and ethical in our actions.** We strive for integrity in all of our efforts. We are accountable to our mission, membership, donors, partners, and the public.
- **Guided by science.** We use reliable, relevant, and the best-available scientific research to guide our decisions whenever possible.
- **Respect for the environment and diverse communities.** We strive to include the active involvement of the people and partners who are linked to the ecosystems we endeavor to protect. We consider the needs and values of our community. We build relationships based on trust and mutual benefit.
- **We seek tangible and enduring results.** We use informed debate and creative problem solving to develop locally appropriate solutions to complex conservation problems.

North Fork Volunteer Water Quality Monitoring Network

The North Fork Volunteer Water Quality Monitoring Network (the Network) was initiated in April 2001. The goal of the program is to obtain credible water quality information for the North Fork of the Gunnison watershed. This project is run entirely by local volunteers, with the donation of time and services from a variety of local businesses, educational institutions and state, local and federal organizations. It represents the efforts of dozens of volunteers, and thousands of hours spent preparing and analyzing samples. This report summarizes the results of water quality monitoring conducted from 2001 to 2014 at fifteen sites located along the North Fork of the Gunnison River and two in the Lower Gunnison watershed. The project monitors water quality parameters of concern, including fecal coliform, nutrients, sediment and metals.

Data gathered from the Network is provided to the U.S. Environmental Protection Agency (EPA), the State of Colorado, Colorado Data Sharing Network and Colorado River Watch for inclusion in their publicly available databases. It is hoped that the information collected will encourage informed decisionmaking by local citizens, government agencies, and local officials. The Network is intended to continue indefinitely and supply the people of the North Fork Valley with reliable information about the state of their watershed.

2. DESCRIPTION OF THE NORTH FORK WATERSHED

Figure 2-1: Headwaters of the North Fork

The North Fork of the Gunnison River (North Fork) is located in west-central Colorado, flowing through northwestern Gunnison and eastern Delta Counties. Flanked by the West Elk mountain range to the east, the peak elevation in the North Fork watershed is 13,687 feet. The headwaters of the North Fork are located in the Gunnison National Forest. The North Fork is formed by the confluence of Muddy Creek and Anthracite Creek downstream of the Paonia Reservoir Dam (Figure 2-2). The North Fork flows 33 miles in a southwesterly direction from this point to its junction with the Gunnison River at 4,553 ft elevation, approximately 8.5 miles west of the Town of Hotchkiss in Delta County. Terror, Hubbard, Minnesota, Roatcap, Cottonwood, and Leroux Creeks enter the North Fork between Paonia Reservoir and Hotchkiss. The North Fork watershed (HUC 14020004) drains a basin of approximately 986 square miles. Three communities line the banks of the North Fork as it flows west towards the Gunnison River: Somerset, Paonia, and Hotchkiss, and the small town of Lazear is near the river. Figure 2-2 shows the location and topographical relief of the North Fork watershed.

The North Fork Valley consists of multiple river terraces positioned laterally along a highly dissected broad valley with gentle down-valley elevation relief. The soils along the river are deep to moderately deep, nearly level to steep, well-drained gravelly loam and stony loam that formed in outwash alluvium derived from igneous rock. Upstream of Somerset, the North Fork Gunnison River is incised in the Mesa Verde Formation (sandstone, shale and coal), and downstream of Somerset, it is incised in the Mancos Shale. Near the USFWS National Fish Hatchery west of Hotchkiss, the river flows out of the Mancos Shale and is then incised in the Dakota Sandstone. Some of Leroux Creek and much of Cottonwood Creek is incised in the Mancos Shale. The vegetation is classified as northern desert scrub and consists primarily of juniper, sagebrush, western wheatgrass, muttongrass, fourwing saltbush, and bitterbrush.

Regional Map of the North Fork Watershed

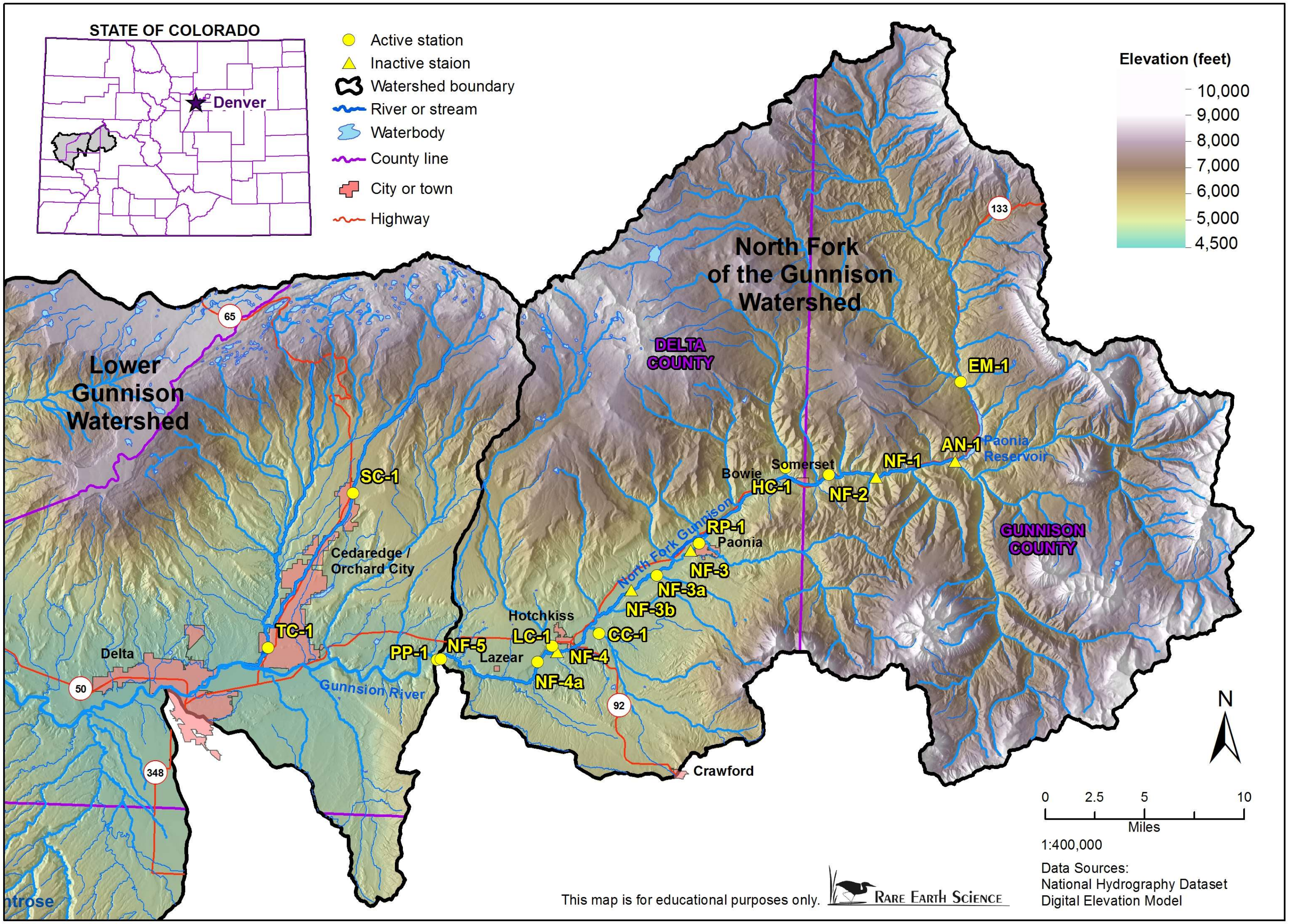


Figure 2-2: Location and Topography: North Fork Watershed

Land Use

Current land use in the study area is predominantly agricultural. Of the more than 1,000 parcels adjoining the river, 35 percent are classified as agricultural, consisting of cattle and sheep ranches, crop production and fruit orchards. Extractive industries include hard rock coal mining, and gravel mining. Tourism and outdoor recreation supplement the general economy. The majority of riverfront property is privately owned and used for residences, agriculture, recreation and gravel mining.

The land cover in the upper reaches of the watershed, above Somerset, is a mixture of aspen deciduous and coniferous forest. Much of this land is federally owned and managed by the US Forest Service and Bureau of Land Management. Beginning in Paonia and stretching downstream to the confluence with the Gunnison River, the land cover changes to agriculture and shrub/scrub. South West Regional Gap Project land cover data in the North Fork is illustrated in Figure 2-3.

Flow Data

The North Fork of the Gunnison River is a fourth order perennial stream, fed predominantly by snowmelt, with average bankfull widths of 100 to 200 feet. The average flow of the river near Somerset during spring runoff is approximately 3,000 cubic feet per second (cfs); irrigation diversions can reduce late summer flows to less than 20 cfs. The predominant alluvial landforms can produce high bedload and sediment concentrations, especially during spring runoff.

Major flooding may also occur during spring runoff months from rapid snowmelt that is sometimes augmented by rain. The Network does not manually collect flow data. The U.S. Geological Survey (USGS) and Colorado Division of Water Resources (DWR) both manage gaging stations along the North Fork of the Gunnison River and its tributaries. The gages provide real-time flow data that is electronically available. Table 1 summarizes the stream flow gaging stations utilized by the Network.

USGS/DWR Gaging Stations in the North Fork Watershed			
USGS Gage Number	**DWR Gage Name**	**Period of Record Used for this Report**	**Location**
9131490	MUDAPRCO	2001-2014	Muddy Creek above Paonia Reservoir
--	MUDBPRCO	2001-2014	Muddy Creek below Paonia Reservoir
9132960	HUBBOWCO	2001-2013	Hubbard Creek at Highway 133 at Mouth near Bowie
9132500	NFGSOMCO	2001-2014	North Fork near Somerset
9134100	NFGPANCO	2001-2014	North Fork below Paonia
9136100	--	2009-2014	North Fork Gunnison River above mouth near Lazear
9143500	SURACECO	2001-2014	Surface Creek at Cedaredge

Table 1: USGS Gaging Stations in the North Fork Watershed

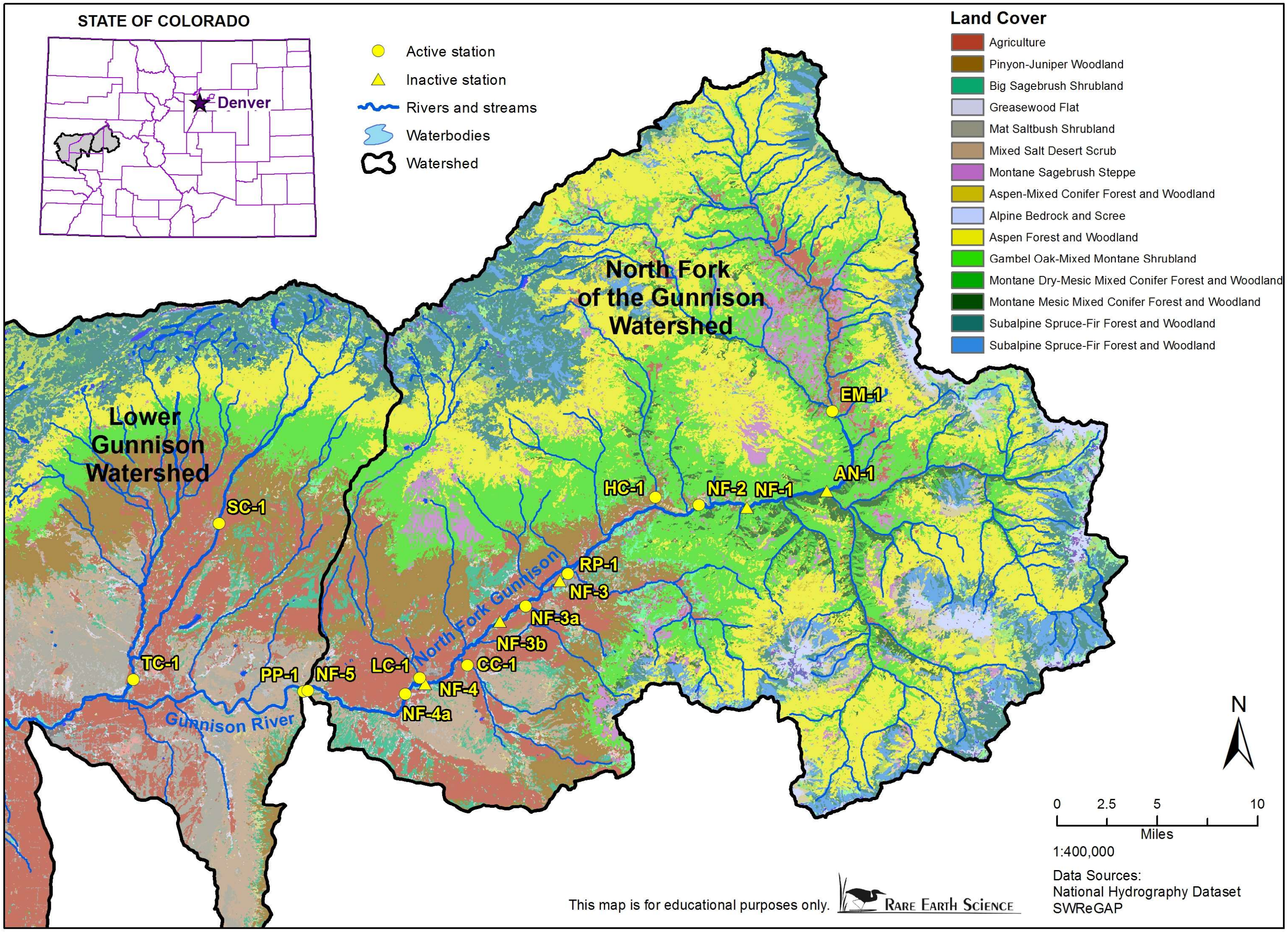


Figure 2-3: Land Cover: North Fork and Lower Gunnison Watershed

Point Sources

There are twenty discharge facilities in the North Fork watershed documented by the CDPHE. Table 2 lists all the currently permitted dischargers in the North Fork watershed. There are three permitted wastewater treatment plants (WWTPs) within the watershed: Town of Somerset, Town of Paonia and Town of Hotchkiss. All other towns, businesses and private residences in the area utilize independent sewage disposal systems (ISDS).

National Pollution Discharge Elimination System Facilities in the North Fork Watershed	
4D Gravel Pit Paonia	SH 92 Stengels Hill
Anderson Pit	Sheep Gas Gathering System
Bowie No 2 Mine	Somerset Central WTF
Hotchkiss Water Storage Facility	Spaulding Peak Production System
Hotchkiss WWTF	Town of Hotchkiss Drain Seep Line
Janet Pit	Tri County Pit
Lemoine Gravel Pit	West Elk Mine
Paonia WWTF	Williams Construction

Table 2: List of NPDES Discharge Facilities

Water Quality Pollution Risks

In addition to natural sources of pollutants, potential anthropogenic pollution sources exist in the North Fork Watershed, including, but not limited to:

- cattle and sheep ranches
- irrigation return flows
- independent sewage disposal systems
- municipal wastewater treatment discharges
- the annual bulldozing of in-stream diversion structures
- sand and gravel mining
- coal mining operations.

Other Water Quality Monitoring Efforts

The North Fork Volunteer Water Quality Monitoring Project, in conjunction with Colorado River Watch, is the only active comprehensive water quality data collection program in the North Fork watershed. The Colorado Department of Public Health and Environment (CDPHE) typically collects samples in the watershed every five years near the Town of Lazear. Other agencies, such as U.S. Geological Survey, the local mining companies and Colorado Parks and Wildlife (CPW) have collected limited water quality samples.

3. Water Quality Standards

Report Analysis Rating and Standards

This report evaluates stream health based on ratings that are dependent on conductivity and the presence and health of macroinvertebrates. These variables were used because they are good indicators of river health both independently and combined. Ratings for the two variables may not be the same for each at a particular location. Conductivity varies seasonally, so the conductivity rating typically varies seasonally.

The ratings are as follows:

Excellent -
Macroinvertebrates: No major differences in community structure and abundance between stations, high percentage of collectors and scrapers
Conductivity: 0 – 800 µS/cm

Good –

Macroinvertebrates: Some differences in community structure and abundance between stations, adequate percentage of collectors and scrapers
Conductivity: 800 – 1,200 µS/cm

Moderate -
Macroinvertebrates: Differences in community structure and abundance between stations, median percentage of collectors and scrapers
Conductivity: 1,200 – 1,800 µS/cm

Poor -
Macroinvertebrates: Major differences in community structure and abundance between stations, low percentage of collectors and scrapers
Conductivity: > 1,800 µS/cm

Stream Segment Classifications and Standards

The Colorado Water Quality Control Commission (WQCC) created a regulatory framework called Basic Standards and Methodologies for Surface Water, or Regulation 31, to protect water quality in Colorado. Excerpts of these standards are provided in Appendix B. Water quality standards are dependent on current and desired future beneficial uses and are applied on a segment-by-segment basis. The official designated uses for the North Forkwatershed include Aquatic Life Cold 1 (for water bodies supporting salmonid species), Aquatic Life Cold 2, Recreation E (existing primary contact use, such as swimming and boating), Recreation P (potential primary contact use, but uncertain until studied further), Water Supply and Agriculture.

The WQCC most recently modified designated uses and segmentation of the Gunnison River basin in 2016.

Table 4 shows the updated stream segments, or water body identification (WBIDs) from Regulation 35 Classifications and Numeric Standards for Gunnison and Lower Dolores River Basins that are sampled by the North Fork Volunteer Water Quality Monitoring Project and the state's applicable water quality standards for those segments.Table 3 shows a summary of stream segment (and subsequent station) classification. The WBID segments are also displayed in Figure 3-1. Excerpts from Regulation 35 can be found in Appendix C.

Every two years, CDPHE is required to prepare a list of impaired streams not meeting water quality standards called the 303(d) Impaired Waters List, as well as the regulatory precursor to the 303(d) list, the Monitoring and Evaluation List (M&E List). The M&E List identifies waters of questionable water quality that may be on their way to the 303(d) List. Regulation 93 lists segments in the Upper and Lower Gunnison basins (5 CCR 1002-94). The stream segments sampled by the North Fork Monitoring Network can be found in Table 5.

		CLASSIFICATION					
Stream Segment	Station	Water Supply	Agriculture	Aq Life Cold 1	Aq Life Warm 2	Recreation E	Recreation P
COGUNFO2	NF-2, NF-1	X	X	X		X	
COGUNFO3	RP-1, NF-3, NF-3a, NF-3b, NF-4, NF-4a, NF-5	X	X	X		X	X
COGUNFO4	EM-1, AN-1	X	X	X		X	
COGUNFO5A	HC-1, LC-1	X	X	X			X
COGUNFO6A			X		X		X
COGULGO7B	CC-1	X	X	X			X

Table 3: Stream Segment Classification Summary

Table 4: Stream Segments and Water Quality Standards

2. Mainstem of North Fork of the Gunnison River from its inception at the confluence of Muddy Creek and Coal Creek to the Black Bridge (41.75 Drive) above Paonia.

COGUNF02	Classifications
Designation	Agriculture
Reviewable	Aq Life Cold 1
	Recreation E
	Water Supply
Qualifiers:	
Other:	

Temporary Modification(s):
Arsenic(chronic) = hybrid
Expiration Date of 12/31/2021

Physical and Biological	DM	MWAT
Temperature °C	CS-II	CS-II
	acute	chronic
D.O. (mg/L)	—	6.0
D.O. (spawning)	—	7.0
pH	6.5 - 9.0	—
chlorophyll a (mg/m^2)	—	—
E. Coli (per 100 mL)	—	126

Inorganic (mg/L)	acute	chronic
Ammonia	TVS	TVS
Boron	—	0.75
Chloride	—	250
Chlorine	0.019	0.011
Cyanide	0.005	—
Nitrate	10	—
Nitrite	—	0.05
Phosphorus	—	—
Sulfate	—	WS
Sulfide	—	0.002

Metals (ug/L)	acute	chronic
Aluminum	—	—
Arsenic	340	0.02(T)
Beryllium	—	—
Cadmium	TVS(tr)	TVS
Chromium III	50(T)	TVS
Chromium VI	TVS	TVS
Copper	TVS	TVS
Iron	—	WS
Iron	—	1000(T)
Lead	TVS	TVS
Manganese	TVS	TVS
Manganese	—	WS
Mercury	—	0.01(t)
Molybdenum	—	160(T)
Nickel	TVS	TVS
Selenium	TVS	TVS
Silver	TVS	TVS(tr)
Uranium	—	—
Zinc	TVS	TVS
Zinc	—	TVS(sc)

3. Mainstem of North Fork of the Gunnison River from the Black Bridge (41.75 Drive) above Paonia to the confluence with the Gunnison River.

COGUNF03	Classifications	
Designation	Agriculture	
Reviewable	Aq Life Cold 1	
	Recreation E	4/1 - 9/30
	Recreation P	10/1 - 3/31
	Water Supply	
Qualifiers:		
Other:		

Physical and Biological		DM	MWAT
Temperature °C		CS-II	CS-II
		acute	chronic
D.O. (mg/L)		—	6.0
D.O. (spawning)		—	7.0
pH		6.5 - 9.0	—
chlorophyll a (mg/m^2)		—	—
E. Coli (per 100 mL)	4/1 - 9/30	—	126
E. Coli (per 100 mL)	10/1 - 3/31	—	205

Inorganic (mg/L)	acute	chronic
Ammonia	TVS	TVS
Boron	—	0.75
Chloride	—	250
Chlorine	0.019	0.011
Cyanide	0.005	—
Nitrate	10	—
Nitrite	—	0.05
Phosphorus	—	—
Sulfate	—	WS
Sulfide	—	0.002

Metals (ug/L)	acute	chronic
Aluminum	—	—
Arsenic	340	0.02(T)
Beryllium	—	—
Cadmium	TVS(tr)	TVS
Chromium III	50(T)	TVS
Chromium VI	TVS	TVS
Copper	TVS	TVS
Iron	—	WS
Iron	—	1000(T)
Lead	TVS	TVS
Manganese	TVS	TVS
Manganese	—	WS
Mercury	—	0.01(t)
Molybdenum	—	160(T)
Nickel	TVS	TVS
Selenium	TVS	TVS
Silver	TVS	TVS(tr)
Uranium	—	—
Zinc	TVS	TVS

4. Muddy Creek, including all tributaries and wetlands, from the source to the confluence with Coal Creek. Coal Creek, including all tributaries and wetlands, from the source to the confluence with Muddy Creek, All tributaries to the North Fork of the Gunnison from its inception at the confluence of Muddy Creek and Coal Creek to the confluence with the Gunnison River within national forest boundaries, except for the specific listing in Segment 1.

COGUNF04	Classifications
Designation	Agriculture
Reviewable	Aq Life Cold 1
	Recreation E
	Water Supply
Qualifiers:	
Other:	
Temporary Modification(s): Arsenic(chronic) = hybrid Expiration Date of 12/31/2021	

Physical and Biological		
	DM	MWAT
Temperature °C	CS-I	CS-I
	acute	chronic
D.O. (mg/L)	—	6.0
D.O. (spawning)	—	7.0
pH	6.5 - 9.0	—
chlorophyll a (mg/m^2)	—	—
E. Coli (per 100 mL)	—	126

Inorganic (mg/L)		
	acute	chronic
Ammonia	TVS	TVS
Boron	—	0.75
Chloride	—	250
Chlorine	0.019	0.011
Cyanide	0.005	—
Nitrate	10	—
Nitrite	—	0.05
Phosphorus	—	—
Sulfate	—	WS
Sulfide	—	0.002

Metals (ug/L)		
	acute	chronic
Aluminum	—	—
Arsenic	340	0.02(T)
Beryllium	—	—
Cadmium	TVS(tr)	TVS
Chromium III	50(T)	TVS
Chromium VI	TVS	TVS
Copper	TVS	TVS
Iron	—	WS
Iron	—	1000(T)
Lead	TVS	TVS
Manganese	TVS	TVS
Manganese	—	WS
Mercury	—	0.01(t)
Molybdenum	—	160(T)
Nickel	TVS	TVS
Selenium	TVS	TVS
Silver	TVS	TVS(tr)
Uranium	—	—
Zinc	TVS	TVS
Zinc	—	TVS(sc)

5a. Mainstems of Hubbard Creek, Terror Creek, Minnesota Creek, and Leroux Creek from the national forest boundary to their confluences with the North Fork of the Gunnison River; mainstem of Jay Creek from its source to its confluence with the North Fork of the Gunnison River.

COGUNF05A	Classifications
Designation	Agriculture
Reviewable	Aq Life Cold 1
	Recreation P
	Water Supply
Qualifiers:	
Other:	
Temporary Modification(s): Arsenic(chronic) = hybrid Expiration Date of 12/31/2021	

Physical and Biological		
	DM	MWAT
Temperature °C	CS-I	CS-I
	acute	chronic
D.O. (mg/L)	---	6.0
D.O. (spawning)	---	7.0
pH	6.5 - 9.0	---
chlorophyll a (mg/m^2)	---	---
E. Coli (per 100 mL)	---	205

Inorganic (mg/L)		
	acute	chronic
Ammonia	TVS	TVS
Boron	---	0.75
Chloride	---	250
Chlorine	0.019	0.011
Cyanide	0.005	---
Nitrate	10	---
Nitrite	---	0.05
Phosphorus	---	---
Sulfate	---	WS
Sulfide	---	0.002

Metals (ug/L)		
	acute	chronic
Aluminum	---	---
Arsenic	340	0.02(T)
Beryllium	---	---
Cadmium	TVS(tr)	TVS
Chromium III	50(T)	TVS
Chromium VI	TVS	TVS
Copper	TVS	TVS
Iron	---	WS
Iron	---	1000(T)
Lead	TVS	TVS
Manganese	TVS	TVS
Manganese	---	WS
Mercury	---	0.01(t)
Molybdenum	---	160(T)
Nickel	TVS	TVS
Selenium	TVS	TVS
Silver	TVS	TVS(tr)
Uranium	---	---
Zinc	TVS	TVS
Zinc	---	TVS(sc)

6a. All tributaries, including wetlands, to the North Fork of the Gunnison River from its inception at the confluence of Muddy Creek and Coal Creek to the confluence with the Gunnison River, and not within national forest boundaries, except for the specific listings in Segments 5a, 5b, and 6b.

COGUNF06A	Classifications
Designation	Agriculture
Reviewable	Aq Life Warm 2
	Recreation P
Qualifiers:	
Other:	

Physical and Biological	DM	MWAT
Temperature °C	WS-II	WS-II
	acute	chronic
D.O. (mg/L)	—	5.0
pH	6.5 - 9.0	—
chlorophyll a (mg/m^2)	—	—
E. Coli (per 100 mL)	—	205

Inorganic (mg/L)	acute	chronic
Ammonia	TVS	TVS
Boron	—	0.75
Chloride	—	—
Chlorine	0.019	0.011
Cyanide	0.005	—
Nitrate	100	—
Nitrite	—	0.05
Phosphorus	—	—
Sulfate	—	—
Sulfide	—	0.002

Metals (ug/L)	acute	chronic
Aluminum	—	—
Arsenic	340	100(T)
Beryllium	—	—
Cadmium	TVS	TVS
Chromium III	TVS	TVS
Chromium III	—	100(T)
Chromium VI	TVS	TVS
Copper	TVS	TVS
Iron	—	1000(T)
Lead	TVS	TVS
Manganese	TVS	TVS
Mercury	—	0.01(t)
Molybdenum	—	160(T)
Nickel	TVS	TVS
Selenium	TVS	TVS
Silver	TVS	TVS
Uranium	—	—
Zinc	TVS	TVS

7b. Mainstem of Surface Creek from the point of diversion of water supply to the confluence with Tongue Creek; mainstem of Tongue Creek from its inception at the confluence of Ward Creek and Dirty George Creek to the confluence with the Gunnison River; mainstem of Youngs Creek from the national forest boundary to the confluence with Kiser Creek; mainstem of Kiser Creek from the national forest boundary to the confluence with Youngs Creek.

COGULG07B	Classifications
Designation	Agriculture
Reviewable	Aq Life Cold 1
	Recreation P
	Water Supply
Qualifiers:	
Other:	

Physical and Biological	DM	MWAT
Temperature °C	CS-II	CS-II
	acute	chronic
D.O. (mg/L)	---	6.0
D.O. (spawning)	---	7.0
pH	6.5 - 9.0	---
chlorophyll a (mg/m^2)	---	---
E. Coli (per 100 mL)	---	205

Inorganic (mg/L)	acute	chronic
Ammonia	TVS	TVS
Boron	---	0.75
Chloride	---	250
Chlorine	0.019	0.011
Cyanide	0.005	---
Nitrate	10	---
Nitrite	---	0.05
Phosphorus	---	---
Sulfate	---	WS
Sulfide	---	0.002

Metals (ug/L)	acute	chronic
Aluminum	---	---
Arsenic	340	0.02(T)
Beryllium	---	---
Cadmium	TVS(tr)	TVS
Chromium III	50(T)	TVS
Chromium VI	TVS	TVS
Copper	TVS	TVS
Iron	---	WS
Iron	---	1000(T)
Lead	TVS	TVS
Manganese	TVS	TVS
Manganese	---	WS
Mercury	---	0.01(t)
Molybdenum	---	160(T)
Nickel	TVS	TVS
Selenium	TVS	TVS
Silver	TVS	TVS(tr)
Uranium	---	---
Zinc	TVS	TVS
Zinc	---	TVS(sc)

All metals are dissolved unless otherwise noted.

T = total recoverable
t = total
tr = trout
sc = sculpin
D.O. = dissolved oxygen

DM = daily maximum
MWAT = maximum weekly average temperature
WS = Water Supply
TVS = Table Value Standard

Table Value Standards (TVS) for ammonia are based on temperature and pH and for metals it is based on hardness
See WQCC Regulation 31 for details on TVS, TVS(tr), TVS(sc), WS, temperature standards

Table 5: Impaired Segments on the 303(d) List and Monitoring and Evaluation List

Water Body ID (WBID)	**Sampling Station**	**Segment Description**	**Portion**	**Colorado's Monitoring & Evaluation Parameter(s)**	**Clean Water Act Section 303(d) Impairment**	**303(d) Priority**
COGUNF04	EM-1, AN-1	Muddy Creek and all tributaries, Coal Creek and all tributaries; all tributaries to the North Fork of the Gunnison within the national forest boundary	East Muddy Creek	Lead, Selenium	Iron (Trec)	High
			Muddy Creek	E. coli (May-Oct)		
			Ruby Anthracite Creek		Arsenic	Low
COGUNF06b	CC-1	Bear Creek, Reynolds Creek, Bell Creek, McDonald Creek, Cottonwood Creek, Love Gulch, Cow Creek, Dever Creek, German Creek, Miller Creek, Stevens Gulch, Big Gulch, Stingley Gulch and Alum Gulch not on national forest lands from the source to the North Fork of the Gunnison River	Cottonwood Creek	Iron (Trec), Manganese, Sulfate		
COGULG07b	TC-1, SC-1	Surface Creek from the diversion of water supply to Tongue Creek; Tongue Creek to the Gunnison River; Youngs Creek from USFS boundary to Kiser Creek; Kiser Creek from the USFS boundary to the confluence with Youngs Creek	Tongue Creek		Selenium, Iron (Trec)	Medium

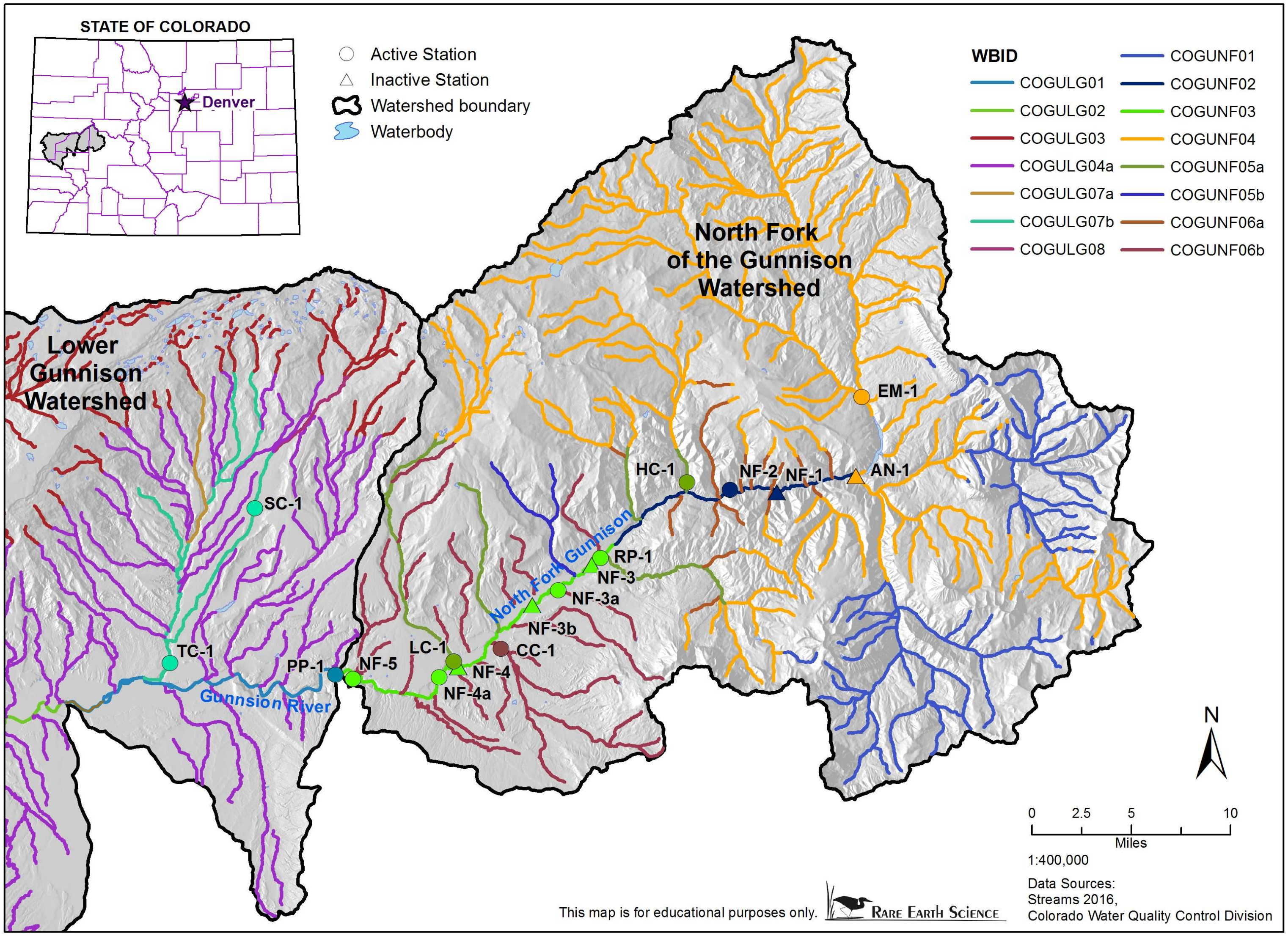


Figure 3-1: WBID Segments in the North Fork and Lower Gunnison Basin

Total Phosphorus and Total Nitrogen Standards

Both Total Phosphorus and Total Nitrogren standards are evaluated by the interim values outlined in the tables below.

Interim Total Phosphorus Values	
Lakes and Reservoirs, cold, >25 acres	25 µg/L [1]
Lakes and Reservoirs, warm > 25 acres	83 µg/L [1]
Lakes and Reservoirs, <=25 acres	RESERVED
Rivers and Streams – cold	110 µg/L [2]
Rivers and Streams - warm	170 µg/L [2]
[1] summer (July 1-September 30) average Total Phosphorus (µg/L) in the mixed layer of lakes (median of multiple depths), allowable exceedance frequency 1-in-5 years. [2] annual median Total Phosphorus (µg/L), allowable exceedance frequency 1-in-5 years.	

Table 6: Interim Total Phosphorus Values

Interim Total Nitrogen Values (Effective May 31, 2017)	
Lakes and Reservoirs, cold, >25 acres	426 µg/L [1]
Lakes and Reservoirs, warm, > 25 acres	910 µg/L [1]
Lakes and Reservoirs, <=25 acres	RESERVED
Rivers and Streams – cold	1,250 µg/L [2]
Rivers and Streams - warm	2,010 µg/L [2]
[1] summer (July 1–September 30) average Total Nitrogen (µg/L) in the mixed layer of lakes (median of multiple depths), allowable exceedance frequency 1-in-5 years. [2] annual median Total Nitrogen (µg/L), allowable exceedance frequency 1-in-5 years.	

Table 7: Interim Total Nitrogen Values

Temperature standards are based on the use of the river and the aquatic life it supports. They are included in the table below.

Site(s)	Classification	*Warm Season Maximum Weekly Average Temperature Standard(MWAT) (Deg C)	Warm Season Daily Maximum Temperature Standard (DM) (Deg C)	*Cold Season MWAT (Deg C)	Cold Season DM (Deg C)
EM-1, AN-1, HC-1, LC-1	Cold Stream I	17.0	21.7	9	13
NF-1, NF-2, NF-3, NF-3a, NF-3b, NF-4, NF-4a, NF-5, SC-1, TC-1	Cold Stream II	18.3	23.9	9	13
CC-1	Warm Stream II	27.5	28.6	13.8	14.3
*Warm and Cold season month designations vary for each standard.					

Table 8: Stream Segments Temperature Standards.

E. coli Standards

E. coli standards used in this report are based on the regulatory standard (235 organisms/mL) outlined by the CDPHE Water Quality Control Division (WQCD) for natural swimming areas.

4. NORTH FORK VOLUNTEER MONITORING NETWORK

Introductions

Since April 2001, Network volunteers have been collecting water quality samples in the North Fork Valley. As part of this joint project, coordinated by the Western Slope Conservation Center (WSCC) and Colorado River Watch, volunteers receive lab and field training on EPA-approved water sampling procedures. Volunteers travel once a month to sample different sites throughout the watershed. Stations start as high as East Muddy Creek and proceed down the North Fork of the Gunnison River as far as the confluence with the main stem of the Gunnison River. Two additional sites were adopted by the Network in 2004 in the Lower Gunnison Watershed on Tongue and Surface Creeks and are monitored every other month. The Network began sampling Hubbard Creek, Cottonwood Creek and Leroux Creek tributaries in 2011, and they are now monitored monthly.

Samples are collected for analysis of temperature, dissolved oxygen, alkalinity, conductivity, hardness, pH, metals, nutrients, other inorganic parameters, macroinvertebrates and bacteria. The majority of samples collected and analyzed by the Network are done in conjunction with Colorado River Watch (River Watch). River Watch is a state-wide volunteer monitoring program that focuses on collecting baseline water quality data. River Watch provides volunteer groups like WSCC with training, water monitoring equipment, chemicals for analysis of field parameters and lab analysis for metals, nutrients and other inorganic parameters. All River Watch data are publicly available on the River Watch website.

The Network bacteria monitoring program commenced in 2001 in partnership with the Environmental Protection Agency (EPA) after water quality standards in segments in the North Fork were upgraded to reflect recreational uses. Bacteria samples are not collected for regulatory or compliance purposes. Rather, these data (total coliforms and *E. Coli*) provide a screening-level assessment of bacterial concentrations.

The following sections explain the specifics of the Network's water sampling program, including the location of the water quality monitoring stations, parameters analyzed and the volunteer training program.

Water Quality Monitoring Stations

The North Fork Volunteer Monitoring Network has collected water quality data at fifteen locations throughout the North Fork watershed and two stations in the Lower Gunnison watershed. Table 9 outlines the location, description and active period for each station. The stations are strategically located to provide baseline coverage of the watershed stretching from the headwaters downstream. Monitoring locations and frequencies have changed over the years to reflect changing priorities. Figure 2-2 shows a map of all active Network monitoring stations.

Table 9: Network Water Monitoring Stations

Station Name	Station #	Lat	Long	Date Started	Date ended	Station Description	WBID
AN-1	645	38.93995	-107.35796	Apr-2001	May-02	**Anthracite Creek:** Turn right on CR 135 to Kebler Pass. After bridge over Muddy Creek, access along Crystal Meadows Ranch fence, use USBOR access to Anthracite Creek.	COGUN04
EM-1	644	38.997075	-107.35712	Apr-2001	on-going	**Muddy Creek:** 1/2 mile north of Paonia State Park entrance on HWY 133, just below confluence of East and West Muddy Creeks.	COGUN04
NF-1	646	38.92595	-107.43372	Apr-2001	on-going	**North Fork of Gunnison:** USGS Gauging Station accessed off HWY 133, 2/10 of mile above entrance to West Elk Mine.	COGUN02
NF-2	649	38.927316	-107.47828	Apr-2001	on-going	**North Fork of Gunnison:** Along HWY 133, west of the town of Somerset, just below the Fire Mountain Canal irrigation diversion.	COGUN02
NF-3	238	38.8688	-107.60461	Apr-2001	Jun-08	**North Fork of Gunnison:** Off HWY 133, turn south onto the Samuel Wade Rd into Paonia. Sample just downstream of the "County Road Bridge".	COGUN03
NF-3a	875	38.8508	-107.6359	Jun-2002	on-going	**North Fork of Gunnison:** From Old River Road between Paonia and Hotchkiss, turn north on N-25 Road and then immediately left. Take this road until is crosses the railroad tracks, and then turn right into the first driveway. Follow the private road down toward the river.	COGUN03
NF-3b	272	38.83738253	-107.658315	Jul-2008	on-going	**North Fork of Gunnison:** In Hotchkiss, from the intersection of Hwy 92 and Hwy 133, travel northeast on Hwy 133, 4.9 miles to Campbell Road. Turn right on Campbell road and continue .4 miles, continue south on private road .2 miles. Park before gate. Walk .2 miles south.	COGUN03
NF-4	269	38.792	-107.72628	Apr-2001	May-02	**North Fork of Gunnison:** From downtown Hotchkiss, turn south onto Cedar Drive (3400 Rd). Follow road to bridge, turn right just before bridge, sample next to red gate.	COGUN03
NF-4a	876	38.78312	-107.74386	Jun-2002	on-going	**North Fork of Gunnison:** From downtown Hotchkiss, turn south onto Cedar Drive (3400 Rd). Follow this road across bridge, and then turn right onto River Park Road. Follow this dirt road thru gate, and then take the right fork down to the river.	COGUN03
NF-5	650	38.7839	-107.8346	Apr-2001	on-going	**North Fork of Gunnison:** From HWY 133, turnoff at the Pleasure Park entrance, follow road to river. At bottom, turn left into BLM parking area. Trails to river.	COGUN03
CC-1	10425	38.806141	-107.6878	Jan-2011	on-going	**Cottonwood Creek:** From downtown Hotchkiss, head southeast on HWY 92 and then turn left on Back River Road. Site is across from the turnoff to K-50 Ln. Sample just downstream of the culvert.	COGUNF06a
LC-1	893	38.795449	-107.731000	Jan-2011	on-going	**Leroux Creek:** From Hwy 92 in Hotchkiss, turn south on Pinion Drive. Go strait through stop sign, turn right and then quickly angle left onto Hotchkiss Ave/Riverside Dr. Turn left at 461 Riverside Dr opposite the Hotchkiss brick barn. Drive past the house and workshop on the left. Park and walk straight back to through tree line to the creek.	COGUNF05a
HC-1	892	38.927208	-107.517526	Jan-2011	on-going	**Hubbard Creek:** Head north on Hwy 133 from Paonia and turn left at Bowie Road at Industrial Building. Pass the mine, go down the hill with the North Fork River is on your right. Park on the left at cottone, go to the left of the garage, turn right down to the river.	COGUNF05a
SC-1	260	38.90159438	-107.921243	Apr-2005	on-going	**Surface Creek:** Proceed up HWY 65 to Cedaredge NE 4th Street. Turn right and pass fenced pond on left to next driveway (310 NE 4th Street). Walk over lawn down stairs to path to creek.	COGULG07b
TC-1	262	38.7877898	-107.995277	Apr-2005	on-going	**Tongue Creek:** From HWY 92 turn right at HWY 65 (toward Cedaredge). Left on Fairview Drive for ¼ mile - creek is at bottom of grade. Walk blocked road to locked barbed wire fence and go thru fence to creek.	COGULG07b

Water Quality Parameters Monitored

The Network's water quality monitoring program collects information on the chemistry, biology and physical habitat of the North Fork River. During the 2001 to 2014 sample period, Network volunteers collected monthly field parameter, metal, metals, nutrient and other inorganic parameter samples and bacteria samples. Macroinvertebrate/physical habitat analyses were conducted annually. Table 10 lists the water quality parameters the Network monitors, and Table 11 provides a brief description of each parameter.

Parameters Monitored by the Network			
Field Parameters	**Nutrients and Other Inorganics**	**Metals***	**Biological**
pH Temperature Conductivity Alkalinity Hardness Dissolved Oxygen Flow	Total suspended solids (TSS) Sulfate Chloride Total Phosphorus Nitrate+nitrite Ammonia	Aluminum Arsenic Cadmium Calcium Copper Iron Lead Magnesium Manganese Selenium Zinc ****Total and dissolved***	Total coliforms *E. Coli* Macroinvertebrates Physical Habitat

Table 10: Parameters Monitored by the River Watch Volunteer Water Qualty Monitoring Network

Where Are Samples Analyzed?

- Field Parameters: in field and at local River Watch laboratory
- Metals: River Watch/CPW Laboratory, Fort Collins, Colorado
- Nutrients: River Watch/CPW Laboratory, Fort Collins, Colorado
- Bacteria: EPA Region 8 Laboratory, Golden, Colorado
- Macroinvertebrates: River Watch contract laboratory in Ft. Collins, Colorado

Parameters Monitored by the Network	
Parameter	Description/Relationships Field Parameters
pH	Measure of hydrogen ion (H+) concentration. Water with a pH below 7.0 is acidic; a pH above 7.0 is alkaline.
Temperature	Varies seasonally, fish and aquatic life require specific temperatures to reproduce and thrive.
Total Alkalinity, as CaCO3	Measure of carbonate (HCO3-) and bicarbonate (CO3-) anions present. Reflects the river's buffering capacity.
Total Hardness, as CaCO3	The amount of dissolved calcium and magnesium in water. Mitigates metals toxicity for fish.
Dissolved Oxygen	Amount of oxygen in the water in its dissolved form. DO varies with temperature and flow and is indirectly related to temperature.
Nutrients and Other Inorganic Parameters	
Total suspended solids	Minerals and soil particles suspended in the water column. In slow or low flows, this material can be deposited in the streambed.
Sulfate	This form of sulfur (SO4) is most common in the oxidizing conditions of flowing waters.
Chloride	Can originate from natural sources, but also associated with evaporation, road salts or water treatment plants.
Total phosphorus	Common constituent in soil and some fertilizers.
N, Nitrate+nitrite	Nitrates and nitrites are oxidized forms of nitrogen commonly found in flowing water.
N, Ammonia	Ammonia is a common component of organic wastes (e.g., sewage) and fertilizers. Can be toxic to fish in high concentrations.
Bacteria	
Total Coliform	A family of microorganisms that originate in the intestines of humans and other warm-blooded animals. Not always pathogenic (disease-causing), although high concentrations indicate risk.
Escherichia Coli (E. Coli)	Bacteria associated with water-borne diseases such as dysentery and cholera. Many *E. Coli* bacteria cause no health problems, others may be highly pathogenic.
Metals	
Aluminum	Most abundant naturally occurring metal in the earth's surface.
Arsenic	Naturally occurring element in the earth's crust and mineral deposits. May enter the soil from natural or manmade sources. Can cause cancer and skin lesions. It has also been associated with developmental effects, cardiovascular disease, neurotoxicity and diabetes.
Cadmium	Naturally occurring, the largest source of cadmium is often burning of fossil fuels and incineration of municipal waste. Chronic exposure can cause kidney, bone and lung disease.
Calcium	The most abundant cation in the world's rivers and a common constituent of local soils. Important contributor to hardness. A major component of hardness.
Copper	Found in mineralized ore deposits. Rarely found in pristine source water, may reflect mining impacts.
Iron	Second most abundant metallic element in earth's crust. Excessive amounts may cause staining of plumbing fixtures and laundry.
Lead	Naturally occurring, highly toxic; can accumulate in fish and human tissue with negative health effects.
Magnesium	A major component of hardness and is primarily derived from the weathering of rocks.

Manganese	Essential element in plant and animal metabolism.
Selenium	A naturally occurring metal common in the Mancos shale. Leaches from soils via irrigation. Can be toxic to fish and wildlife.
Zinc	Zinc is relatively abundant but may be released to the environment by coal burning, mining, and other industrial activities.
Macroinvertebrates	
The presence of a diverse range of macroinvertebrate species serve as "bioindicators" and are a sign of adequate habitat and a healthy river ecosystem. The presence of pollution-sensitive species is a sign that pollution is absent in a stream.	

Table 11: Parameters Monitored by the Network

Sample Collection and Analytical Procedures

The majority of Network samples are collected using the grab sample technique. Grab samples are collected by volunteers wading into the stream and collecting water using a clean, large bucket. Water from this bucket is used to fill all subsequent sample bottles. When river water levels permit, volunteers may collect composite samples. Composite samples are collected at multiple locations moving across a stream channel. Sampling and analysis procedures utilized by the Network follow Standard Methods and/or EPA approved methods. Table 12 lists the sample method code and laboratory reporting limits for each parameter monitored.

Methods and Reporting Limits				
Parameters	**Unit**	**Method**	**Source**	**Reporting Limit**
Aluminum	µg/L	200.7	USEPA	15
Ammonia	mg/L	350.1	USEPA	.01
Arsenic	µg/L	200.7	USEPA	15
Cadmium	µg/L	200.7	USEPA	.15
Calcium	µg/L	200.7	USEPA	100
Chloride	mg/L	375.4	USEPA	1.0
Copper	µg/L	200.7	USEPA	1
DO	mg/L	421 B	SM	.5
E. coli	MPN/100 mL	9223b 24hr		1
Iron	µg/L	200.7	USEPA	10
Lead	µg/L	200.7	USEPA	3
Magnesium	µg/L	200.7	USEPA	100
Manganese	µg/L	200.7	USEPA	5
Nitrate + Nitrite	mg/L	353.2	USEPA	.02
pH	SU			.01
Potassium	µg/L	200.7	USEPA	100
Selenium	µg/L	200.7	USEPA	5
Sodium	µg/L	200.7	USEPA	100
Sulfate	mg/L	375.4	USEPA	.5
Temperature	Deg C			
Total Alkalinity	mg/L	310.1	USEPA	2
Total Coliforms	MPN/100 mL	9223b 24hr		1
Total Hardness	mg/L	314	SM	2
Total Nitrogen	mg/L	353.2	USEPA	0.02
Total Phosphorus	µg/L	365.1	USEPA	5
Total Suspended Solids	mg/L	160.2	USEPA	4
Zinc	µg/L	200.7	USEPA	3

Table 12: Methods and Reporting Limits

Volunteer Training and Certification

All volunteers must attend a River Watch training workshop before they can join the Network. The River Watch training provides in-depth instruction on all aspects of water monitoring: sample preparation, collection, analyses, shipping, data management and Quality Assurance & Quality Control (QA/QC) procedures.

The WSCC Technical Advisor accompanies volunteers on the first several sampling runs until satisfied that the volunteers can complete the sampling procedures independently. Volunteers between the ages of 10 and 18 can be trained and work alongside at least one adult in the field and lab. Figure 4-1 shows Network volunteers collecting samples and processing them in the lab.

Figure 4-1: Volunteers collecting and processing water quality samples

Quality Control/Quality Assurance Measures

Quality control measures both in the field and in the lab are detailed in Quality Assurance Project Plans (QAPPs) developed in 2001. For this project three separate QAPPs were created, one each for nutrients and other inorganic parameters, bacteria and metals. The QAPP documents are available for inspection at the WSCC office in Paonia. The River Watch Program follows the CDPHE QAPP and is updated as the CDPHE QAPP is updated.

As part of the River Watch program, the Network participates in a rigorous annual QA/QC regime. Network QA/QC controls include twenty percent duplicate and blank samples, analysis of unknown samples twice per year and an annual site visit from a River Watch staff member. The QA/QC measures evaluate techniques, chemicals and equipment. Chains-of-custody forms accompany all shippedsamples.

Data Reporting

Volunteers use standardized reporting forms developed by River Watch for every sample collection event. Hard copies documenting sample location, date, time, field conditions and field parameters are stored at the ERO Resources office in Hotchkiss and the River Watch office in Denver. Digital copies are on file at the WSCC office in Paonia. Information from the data sheets is validated and then entered into the online River Watch database (except for bacteria data), where it is eventually combined with metals, nutrients and other inorganics results. Bacteria data are stored with the EPA. The River Watch data are publicly available online at: http://wildlife.state.co.us/riverwatch/. River Watch data are also uploaded to the Colorado Data Sharing Network (www.codsnstoret.com) and EPA's STORET electronic data system (www.epa.gov/storet).

Project Sponsors

The North Fork Volunteer Water Quality Monitoring Project would not be possible without the support of many different State, Federal, and local organizations. Each group provides critical support, either in the form of technical assistance, lab equipment, or volunteer recruitment. The following is a list of the project partners:

- **Western Slope Conservation Center** is responsible for water quality data management, volunteer recruitment and training, report creation and technical support to the project. In addition, WSCC advertises the project to the local community, initiates fundraising efforts and assists with map and report creation efforts.
- **River Watch Program**, co-sponsored by the *Colorado Watershed Assembly* and the *Colorado Division of Wildlife* was instrumental for the start-up of this program. The Colorado Watershed Assembly helps supply critical training, technical support, equipment, and encouragement to get activities started. They also help link this project with the numerous other volunteer water monitoring projects throughout the State.
- **U.S. Environmental Protection Agency** Region 8 provides all bacteriological sample analysis for this project, as well as significant technical assistance. They provide crucial high quality data for this key parameter of concern in the North Fork watershed.
- **ERO Resources Corporation** provides use of their facility for laboratory space in Hotchkiss, Colorado.
- **Colorado Parks and Wildlife** Aquatic Biologist Barb Horn conducts annual site visits and provides technical advice.
- **Paonia Farm and Home** provides donation to help with shipping costs.
- **Hardin's Natural Foods** provided snacks to volunteers everymonth.
- **Bureau of Reclamation** provided a WaterSMART Cooperative Watershed Management Program Grant that has helped fund the compilation and analysis of data in this report.

5. FIELD DATA

WSCC field parameters consist of those sampled and analyzed "in house" by the Network. Field parameters include: total hardness, total alkalinity, phenolphthalein alkalinity, conductivity, pH, temperature (air and stream temperature measured at the site) and dissolved oxygen. Samples are collected and analyzed by project volunteers in a laboratory at the ERO Resources Corporation building in Hotchkiss. The following section summarizes the results from 2001 to 2014. Many of the graphs in the sub-sections below illustrate values from selected stations. A complete water quality dataset can be found online or by contacting the Conservation Center. For more information, refer to Appendix A. Please refer to Figure 2-2 for a map of all water quality monitoring stations.

Hardness

Hardness is a measure of the most prevalent polyvalent cations (ions with a positive charge greater than +1) in water: calcium (Ca^{2+}) and magnesium (Mg^{2+}). Hardness is measured in mg/L of calcium carbonate ($CaCO_3$).

The ions contributing to the hardness of water are often derived from the drainage of calcareous (calcite-rich) sediments such as limestone, dolomite or gypsum. The dissolution of calcium, magnesium and other polyvalent cations, such as iron and manganese, from rocks and soils can also contribute to hardness in natural systems. Mine drainage, certain industrial processes, sewage outflow and irrigation can artificially increase hardness in waterways.

Waters with high hardness values are referred to as "hard," while those with low hardness values are "soft." Table 4-1 shows EPA's defined hardness ranges. Hard water can prevent soap from producing lather, leaves behind undesirable films or scum on hair, fabrics and glassware, and can form scale when used in boilers and water heaters. Water softeners can make hard water functional for household purposes by replacing calcium (Ca^{2+}) and magnesium (Mg^{2+}) with sodium (Na^{+}) and potassium (K^{+}) ions.

EPA Hardness Ranges	
	Hardness Concentration (mg/L $CaCO_3$)
Soft	0-75
Moderate	75-150
Hard	150-300
Very Hard	300+

Table 13: EPA Hardness Ranges

Hardness is advantageous in aquatic systems because it can mitigate the toxic effects of metals. While the exact mechanism is unknown, Ca^{2+}, Mg^{2+} and other polyvalent cations prevent fish from absorbing metals such as lead, arsenic and cadmium into their bloodstream through their gills. The greater the hardness, the more difficult it is for toxic metals to be absorbed through the gills. Therefore, hardness is inversely related to metals toxicity. For this reason, many metals standards are calculated based on hardness results.

Figure 5-1, Figure 5-2, and Figure 5-3 show total hardness data from 2001 to 2014. Overall, stations in the upper reaches of the watershed (EM-1 and NF-1) exhibit hardness values in the "soft to "moderate" hardness range. Station EM-1 occasionally yielded maximum values in the "hard" range. Lower stations had higher hardness concentrations. High hardness concentrations are due to calcium and magnesium in soils developed from the Mancos shale (Liebermann 1989). The high hardness values at the lower stations may also be due to irrigation return flows that have absorbed calcium and magnesium en route from fields to the monitored streams (FAO 2003).

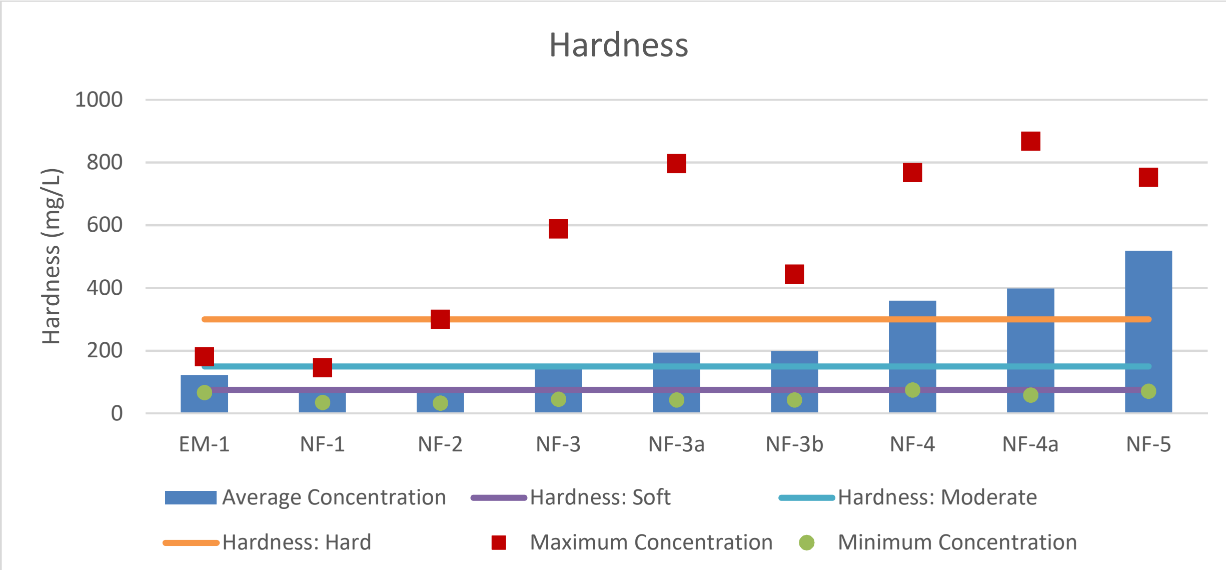


Figure 5-1: Average, maximum, and minimum total hardess concentrations for East Muddy Creek and the North Fork Gunnison River.

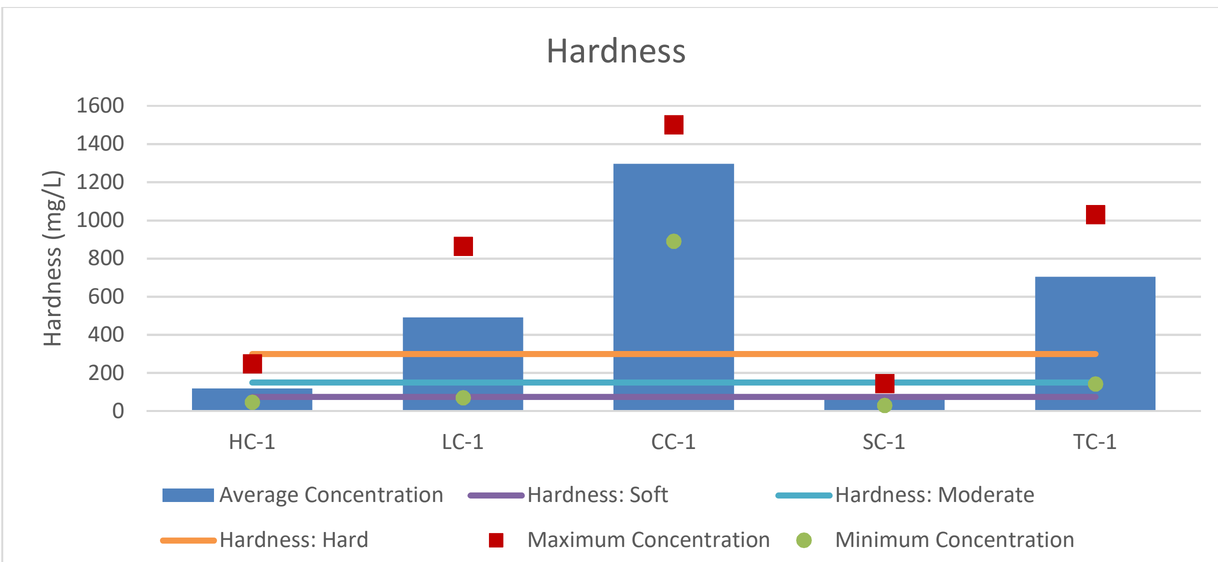


Figure 5-2: Average, maximum, and minimum total hardness values for tributaries to the North Fork Gunnison and Gunnison Rivers.

The highest hardness concentrations typically occured between the months of July and September during low stream flow. The lowest hardness concentrations at the lower stations occurred between March and June. At high flows during snowmelt runoff, calcium and magnesium concentrations in the river and tributaries are lower due to dilution.

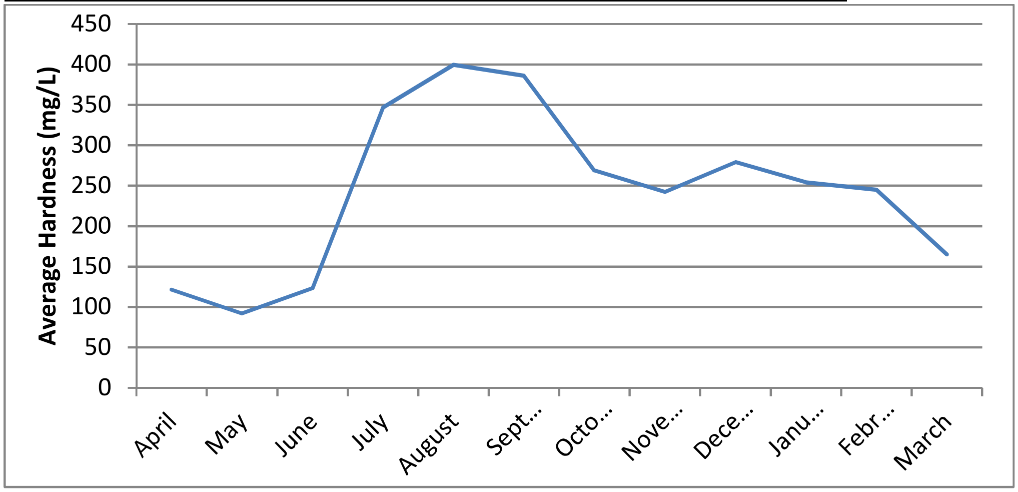


Figure 5-3: Seasonal total hardness (average of all stations by month)

Alkalinity

Alkalinity is a measure of buffering capacity, or the ability of water to resist change in pH when an acid or base is added. It represents the balance of carbon dioxide in water and is reported as mg/L CaCO3, but is actually a measure of the amount of HCO3 (bicarbonates) and CO32- (carbonates) anions that are present. The presence of buffering materials such as carbonates, bicarbonates, and occasionally hydroxide (OH-), help neutralize acids as they are added to water.

Moderate alkalinity concentrations are desirable in aquatic systems because it can limit, or buffer, the effects of acid mine drainage or acid rain. Waters with low alkalinity (below 10 mg/L) are poorly buffered and very susceptible to changes in pH. Systems with alkalinity concentrations above 100 mg/L are able to resist major shifts in pH. The North Fork drainage basin consists of Tertiary igneous rocks (as individual laccoliths) and sedimentary rocks in the headwaters, and Cretaceous sandstones, coal measures, and calcareous marine shales at the lower elevations. Alkalinity typically increases downstream as the geology changes from igneous rocks and carbonate-poor soils in the headwaters to limestone, sedimentary rock and carbonate-rich soils in lower portions of the watershed. Alkalinity is also beneficial because it can mitigate the toxic impacts of dissolved metals. Carbonate and bicarbonate ions bind with dissolved metals such as lead, arsenic and cadmium, causing them to precipitate out of solution and become unavailable for aquatic life.

The highest recorded alkalinity concentration at NF-4 was 852 mg $CaCO_3$/L, which was measured in January 2008. There was one recorded instance of “poor” buffering capacity (below 10 mg $CaCO_3$/L) at NF-1 in July 2010.

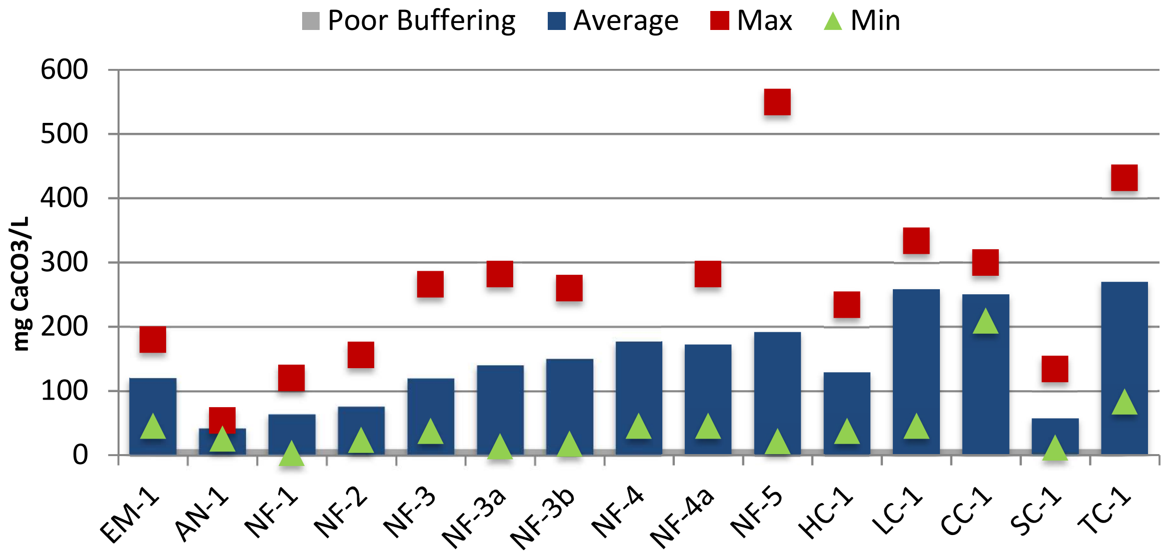


Figure 5-4: Average, maximum and minimum total alkalinity values at all stations

Like hardness, alkalinity is inversely related to flow. Highest concentrations in the lower stations occurred during low flow conditions between June and August and lowest alkalinity concentrations were measured between April and June during peak flow conditions. Alkalinity at the lower stations and EM-1 is generally adequate to buffer against changes in pH.

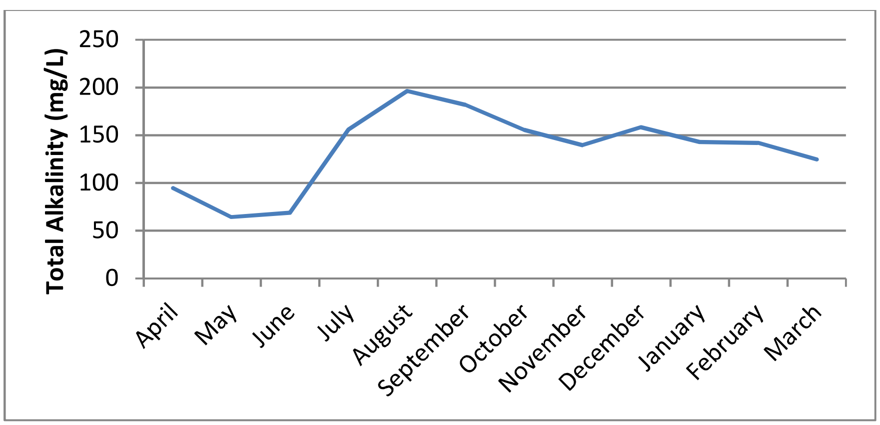


Figure 5-5 Seasonal alkalinity (average of stations by month)

pH

pH measures the acidity of a solution. It is determined by the relative concentration of hydrogen (H+) and hydroxide (OH-) ions. The pH scale is negatively logarithmic and ranges from 0 to 14. Solutions with low pH values, below 7, are acidic and have more H+ than OH-. Basic solutions have high pH values, above 7, and have more OH- than H+. A neutral solution has a pH of 7 and equal concentrations of H+ and OH-. Aquatic ecosystems have adapted to tolerate a narrow range of pH, but most prefer pH values between 6.5 and 8.0. If the pH becomes too high or too low, it can lead to problems in reproduction and even death.

pH can also influence the state of metals in water. Low pH concentrations can liberate toxic metals from rocks or sediments in a stream, which can affect fish metabolism and lead to death in juvenile fish. The WQCC has set a standard of 6.5 to 9 for pH in natural waters.

Figure 5-6 displays the maximum, average and minimum pH values of for all stations. The pH of the North Fork is slightly basic. The majority of pH values are between 8.0 and 8.5. The highest pH value exceeds the standard and occurred at station NF-1 (9.1) in August 2004. The lowest recorded pH value was 7.0 at station NF-1 in December 2005.

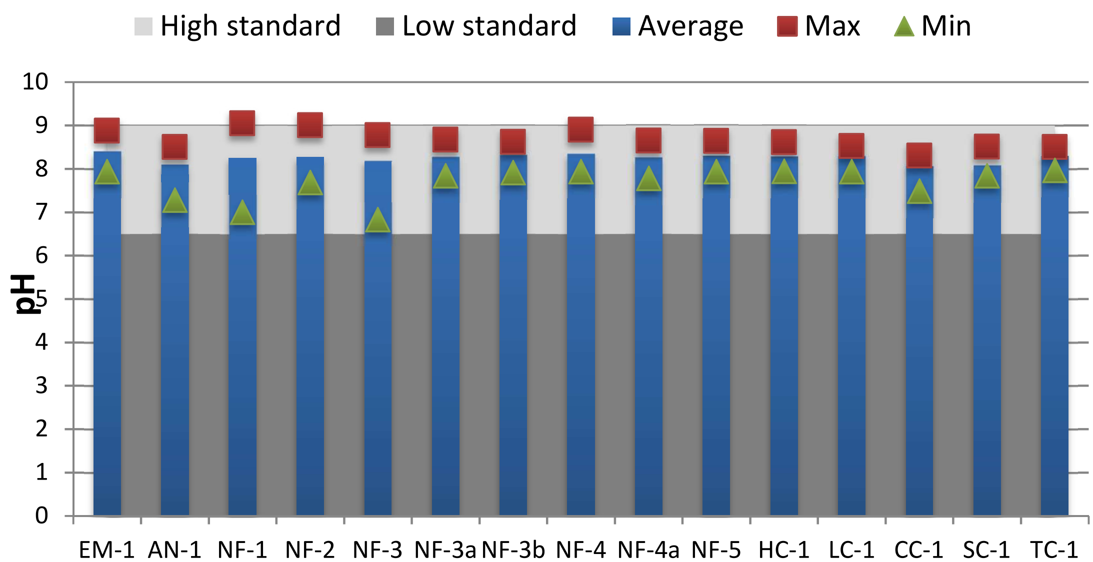


Figure 5-6 Average, maximum and minimum pH values at all stations

Conductivity

A plot of conductivity measurements from the North Fork Gunnison River sites that were sampled frequently for conductivity since 2010 (Figure 5-7) shows the progression of water quality changes that occur along the reach of the river from just downstream of Somerset (NF-2) to Pleasure Park (NF-5). Because conductivity is an analog for total dissolved solids (TDS), this method provides a good indicator as to how dissolved constituents change in the river, both seasonally and from upstream to downstream. TDS is typically 55 to 75 percent of conductivity (Hem 1992), depending on the site-specific chemistry. For the purposes of this report, a midway conversion of 60 percent was used (and then the resulting TDS concentration rounded), given that River Watch does not have TDS measurements for comparison. River Watch measures and reports conductivity in micro mhos per cm, but the current practice is to use micro Siemens per cm (µS/cm), which is equivalent.

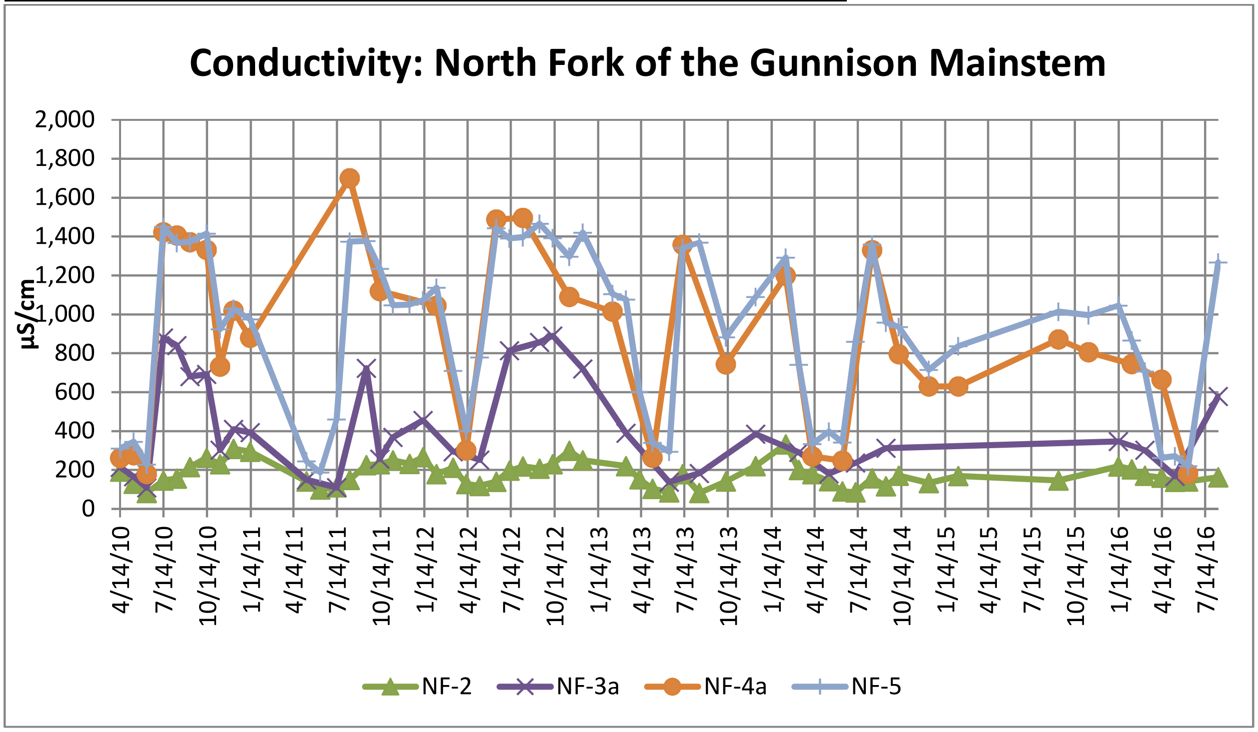


Figure 5-7: Conductivity: North Fork of the Gunnison Mainstem

The primary observation is that conductivity, and therefore TDS concentrations, vary seasonally depending on the dominant source of water to the river (see Figure 5-8). During the spring runoff/snowmelt season, conductivity values were at their lowest, increasing through the summer as runoff decreased and ground water and irrigation return flows become the dominant source of water to the river. All of the sites show this seasonal pattern, but the frequency of sampling at individual sites provide either more detail, such as at NF-2, or less detail, such as at NF-4a. In other words, apparent variance from the seasonal pattern is likely an artifact of the frequency of measurements.

Other general observations include the progression or increase in conductivity (and TDS) from upstream to downstream and the lack of any apparent long-term trend within the 2001 to 2014 period of record.

The upstream-most site (NF-2) showed a relatively small range of conductivity values (82-333 µmhos/cm, or 50-200 mg/L TDS) seasonally. NF-2 had the smallest range and lowest measured conductivity compared to the other River Watch sites on the North Fork. Both the range and magnitude of the conductivity measurements increased downstream, with the highest values at the NF-4a and NF-5 locations. The small range and low conductivity values at NF-2 reflects the geology, in that NF-2 is located very near to the contact between the Mancos Shale and the Mesa Verde Formation. Downstream of NF-2 the river is incised in Mancos Shale. The higher conductivities that started at NF-3a and were observed at NF-4a and NF-5 in the post runoff season reflect ground water and surface water contributions from areas of Mancos Shale. During spring runoff, all sites had relatively low conductivity (and, therefore, low TDS concentrations), typical of a snowmelt dominated flow system.

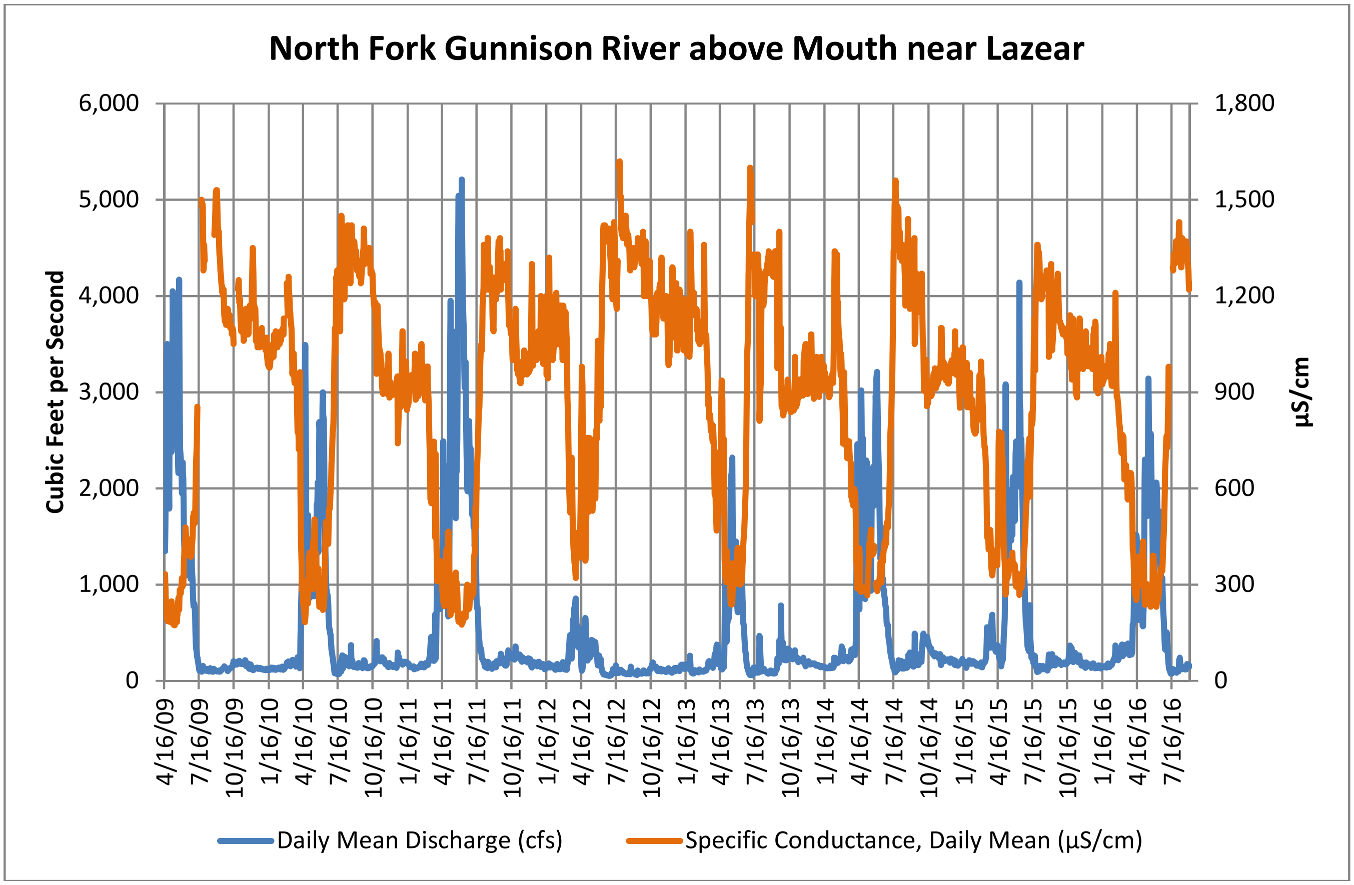


Figure 5-8: Specific Conductivity and Flow (data collected by USGS at gage 09136100)

The range of conductivity measurements (135-400 µmhos/cm, or80-240 mg/L TDS) from East Muddy Creek (EM-1) are similar, but slightly higher, than those observed at the upstream-most site NF-2 on the North Fork (Table 14). Other tributaries to the North Fork, such as Cottonwood Creek and Leroux Creek, contribute water with very high TDS concentrations (as measured by conductivity) to the North Fork, particularly right after the spring runoff period. Even during spring runoff, Cottonwood Creek contributes water to the North Fork with TDS concentrations of nearly 1,000 mg/L. This is a result of surface runoff from areas of Mancos Shale and ground water discharge to the creek from the Mancos Shale. Irrigation return flows from areas of Mancos shale likely also contribute water with high TDS concentrations to Cottonwood Creek, Leroux Creek, and the North Fork. These high conductivity measurements in the tributaries are reflected in the high conductivity measured at NF-4a and NF-5.

SampleLocation	Measured Conductivity Range (µmhos/cm)	Calculated TDS Range (mg/L)
NF-2	82-333	50-200
NF-3a	109-890	65-530
NF-4a	179-1700	110-1020
NF-5	188-1466	110-880
EM-1	135-400	80-240
HC-1	51-610	30-360
CC-1	1609-3510	965-2100
LC-1	159-1354	95-810

Table 14: Range of Measured Conductivities at Sampled Locations (2010-2014)

USGS Continuous Conductivity Measurements

The USGS has continuously measured conductivity (as well as flow and temperature) at a site very near NF-5 since April 2009 (Figure 5-8). The conductivity range measured at this site is comparable to the range measured at NF-5. The USGS data also show the same seasonal pattern in conductivity observed by River Watch. It is clear that the lowest conductivity occurs when the flow is the highest, and conductivity is highest when flow is the lowest. Because the USGS data were recorded continuously, the data provide significantly more detail concerning the seasonal conductivity pattern (and thus TDS concentration pattern) along the river than the monthly measurements.

Dissolved Oxygen and Temperature

Dissolved oxygen (DO) is the amount of oxygen (O_2) dissolved in water. It is an important indicator of a water body's ability to support life because most aquatic organisms require oxygen to breathe. The WQCC standard for DO for most stations is 6.0 mg/L or greater except during spawning, when it is 7.0 mg/L or greater. Cottonwood Creek (CC-1) is the exception, with a chronic standard of 5.0 mg/L or greater. Low DO concentrations are common in late summer/early fall due to low stream flow, warm water temperatures and the increased oxygen uptake of aquatic plants.

Water becomes oxygenated directly from the atmosphere and by photosynthesis of aquatic plants and algae. Oxygen is removed from the water by respiration and decomposition of organic matter. Dissolved oxygen concentrations vary with water temperature, altitude, salinity, depth and flow. Dissolved oxygen concentrations typically exhibit diurnal patterns due to cycles of photosynthesis/respiration.

Dissolved oxygen concentrations are illustrated below in Figure 5-9, Figure 5-10 and Figure 5-11.

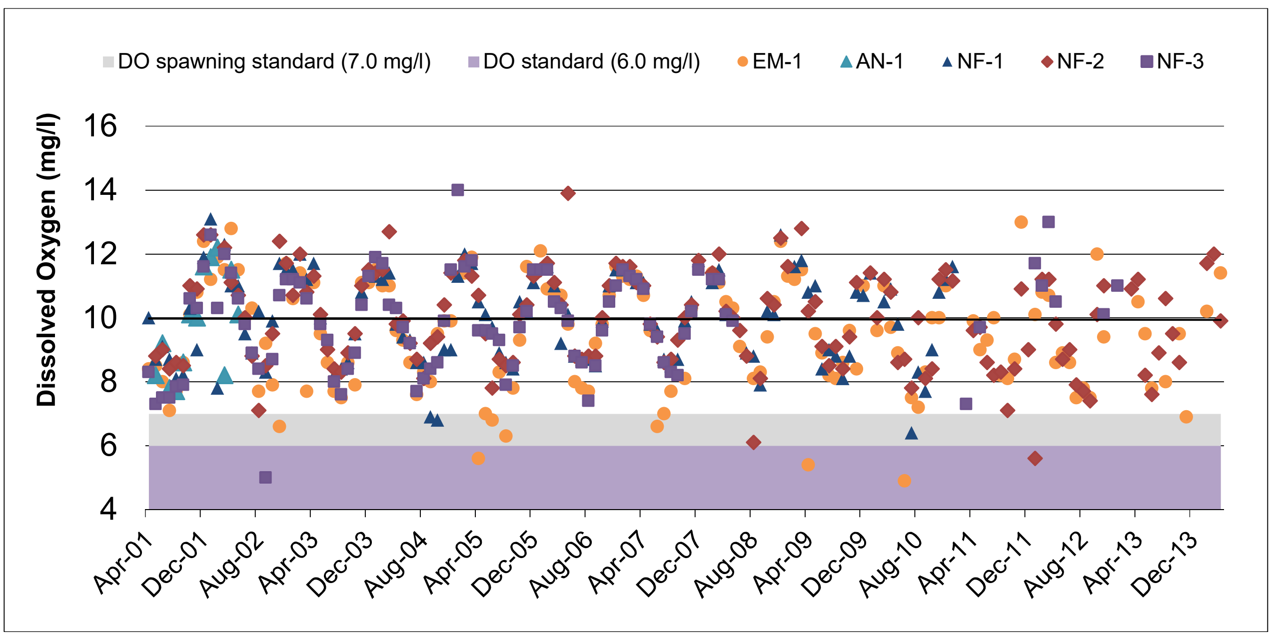


Figure 5-9 Dissolved Oxygen in the Upper North Fork and Tributaries
Note: A result of less than the state standard is an exceedance of the standard

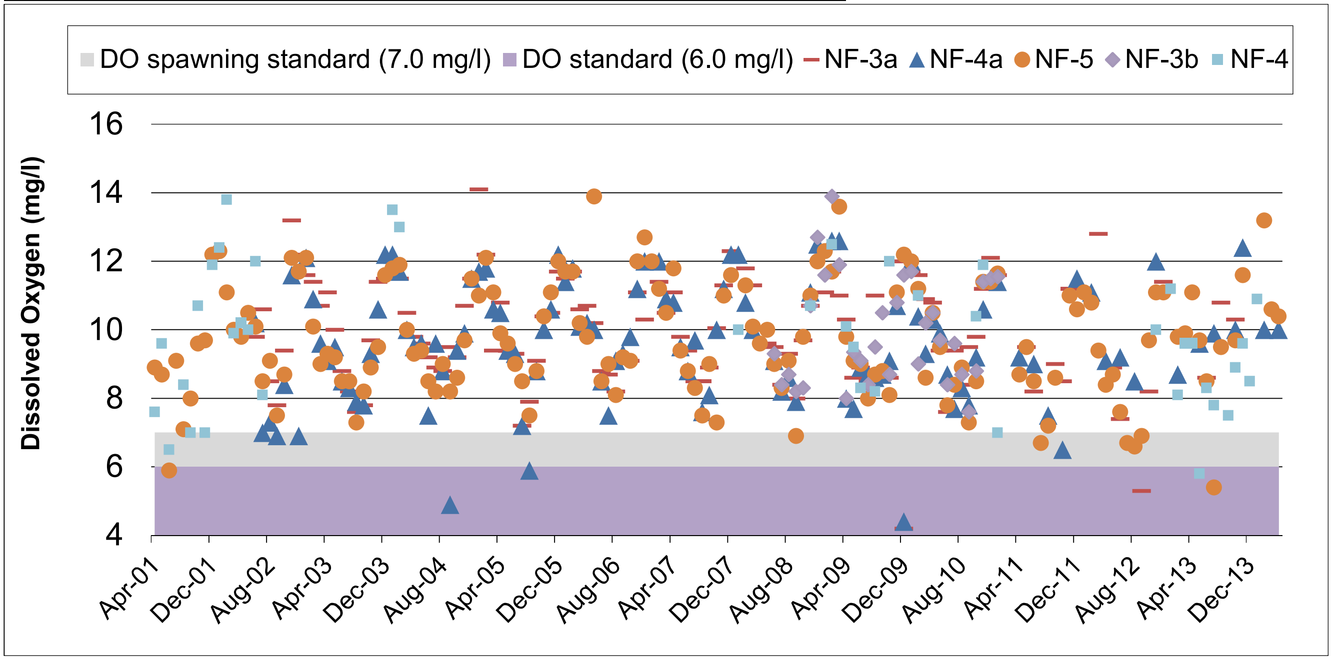


Figure 5-10 Dissolved Oxygen in the Upper North Fork

Note: A result of less than the state standard is an exceedance of the standard

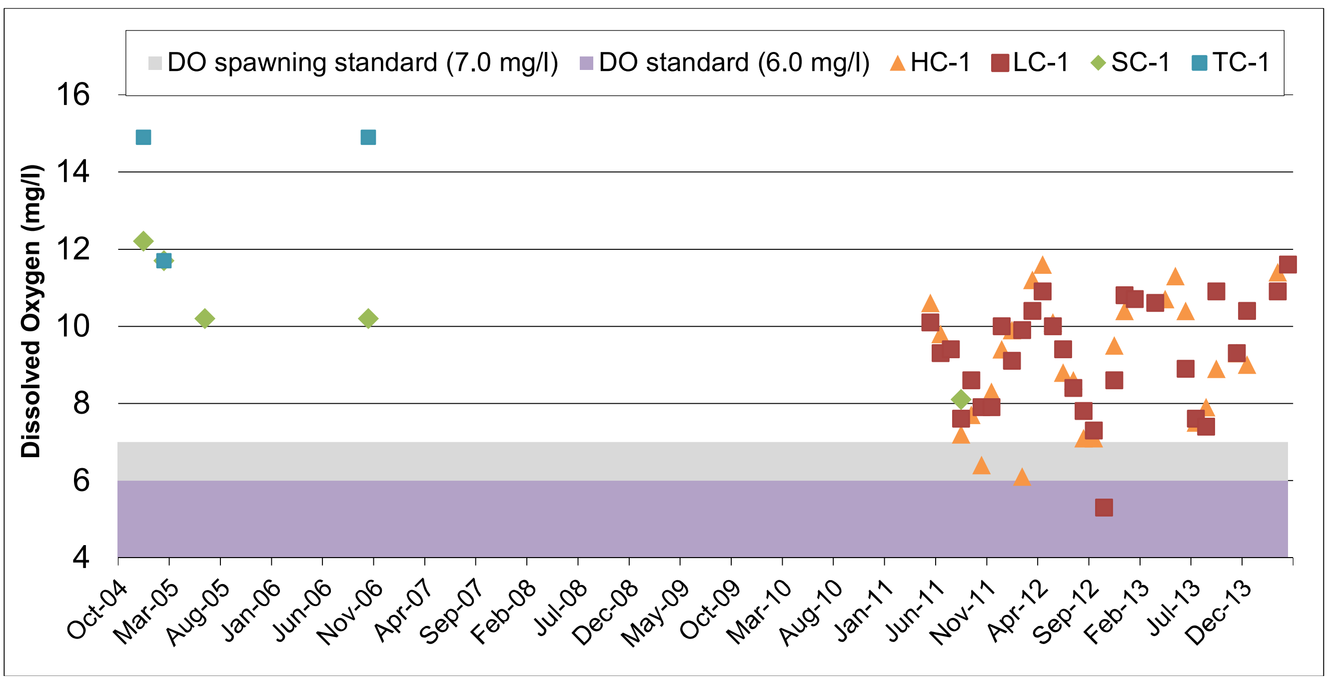


Figure 5-11 Dissolved Oxygen in Lower Tributaries

Note: A result of less than the state standard is an exceedance of the standard

Seasonal trends also occur because of the relationship between oxygen and temperature. Cold water has the ability to hold more oxygen. As a general rule, dissolved oxygen is inversely related to temperature. The dissolved oxygen and temperature relationship at station NF-3a is illustrated in Figure 5-12.

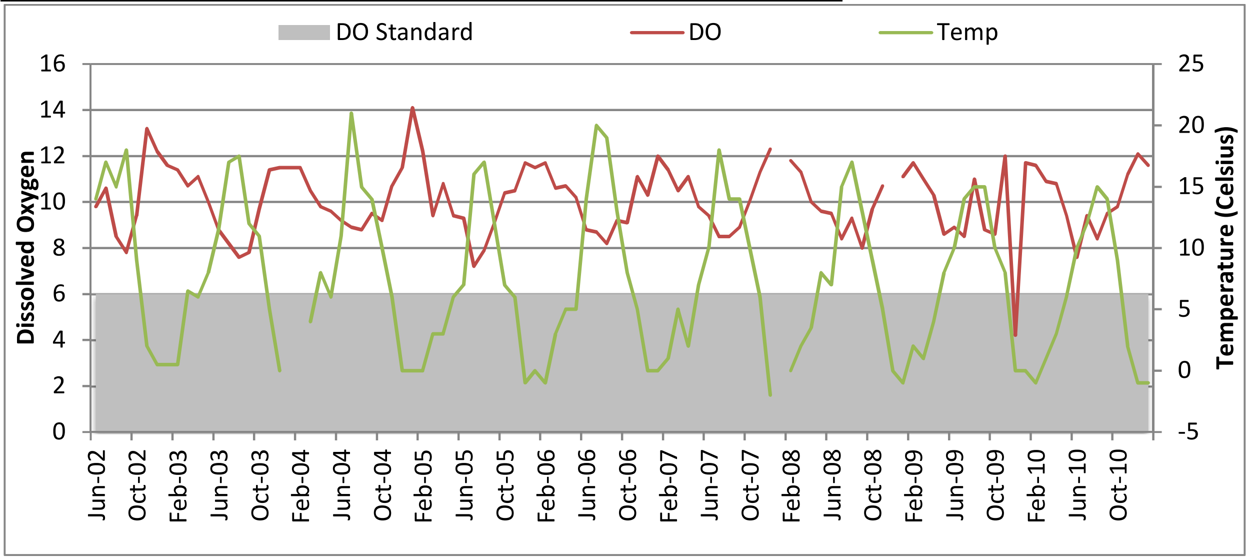


Figure 5-12 Dissolved Oxygen and Temperature at Station NF-3a

Note: A result of less than the state standard is an exceedance of the standard

Temperature

Temperature is an important factor for aquatic life health. In addition to influencing how much oxygen water can hold, temperature affects the rate of metabolic and reproductive activities. Most aquatic organisms are "cold-blooded," which means they are unable to control their body temperature. Cold-blooded organisms are adapted to specific temperature ranges. The stream segments monitored by the Network's volunteer monitoring program are classified for temperature standards as shown in Table 8.

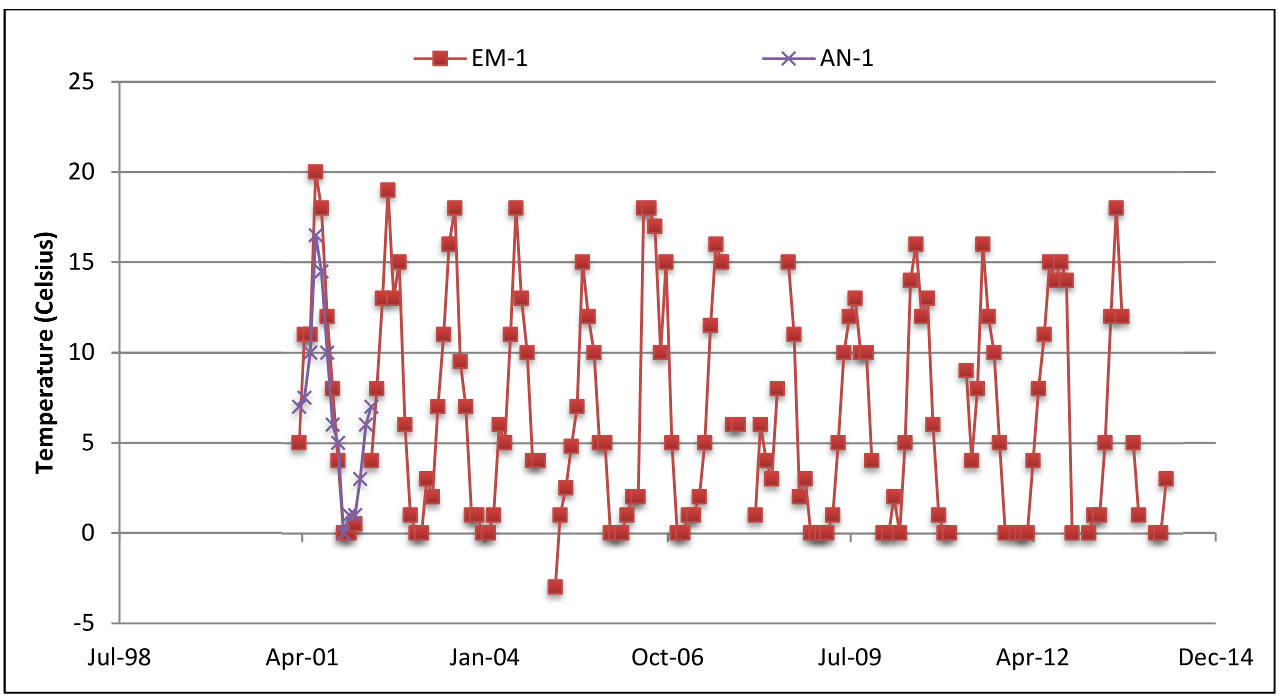


Figure 5-13 through Figure 5-16 show reported monthly temperatures in the North Fork watershed from 2001 to 2014. The upper stations (EM-1, AN-1, NF-1 and NF-2) had the coolest temperatures.

The volunteer program typically collects samples in the morning, thus the reported values do not represent the maximum weekly average temperature (MWAT) or daily maximum temperature (DM) to which the temperature standards areapplied.

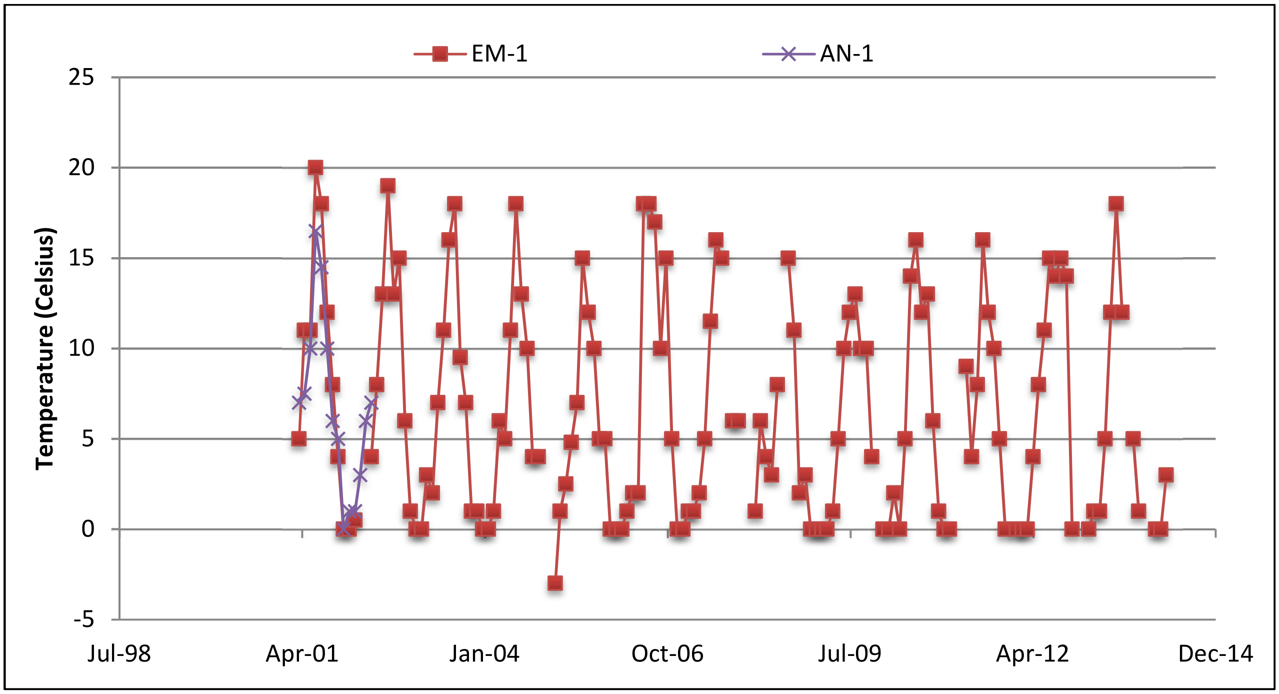


Figure 5-13 River Temperature in Upper Tributaries, Cold Stream I Classified Sites

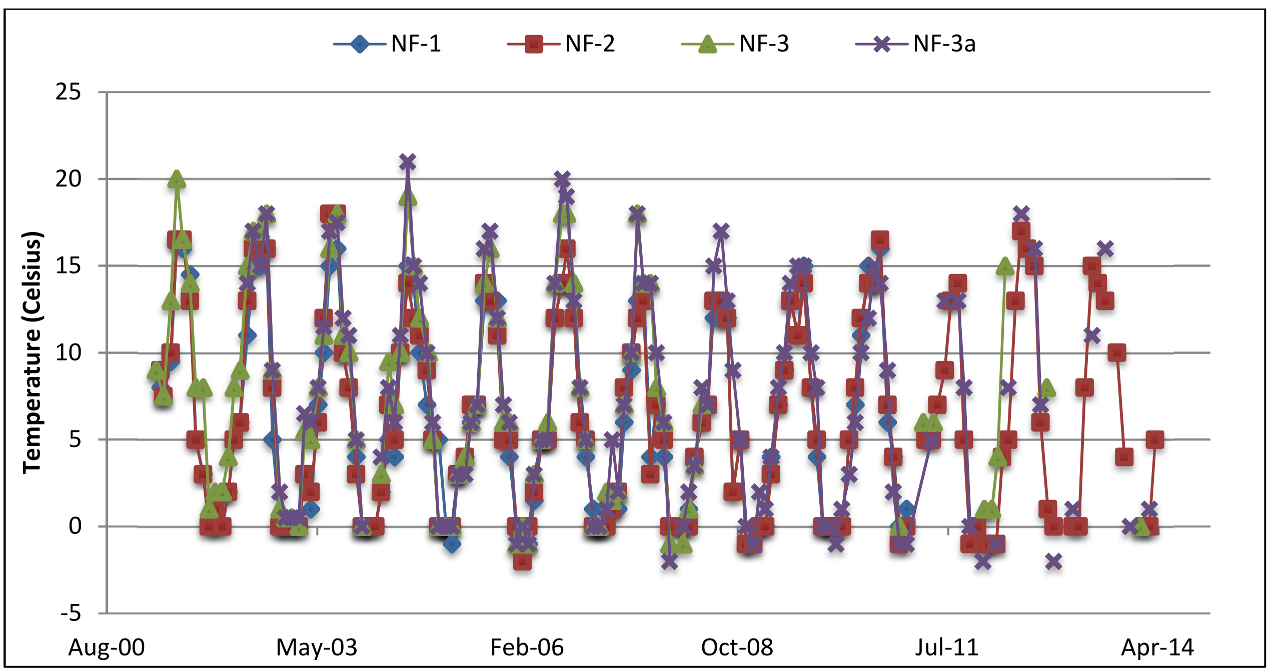


Figure 5-14 River Temperature in the Upper North Fork, Cold Stream II Classified Sites

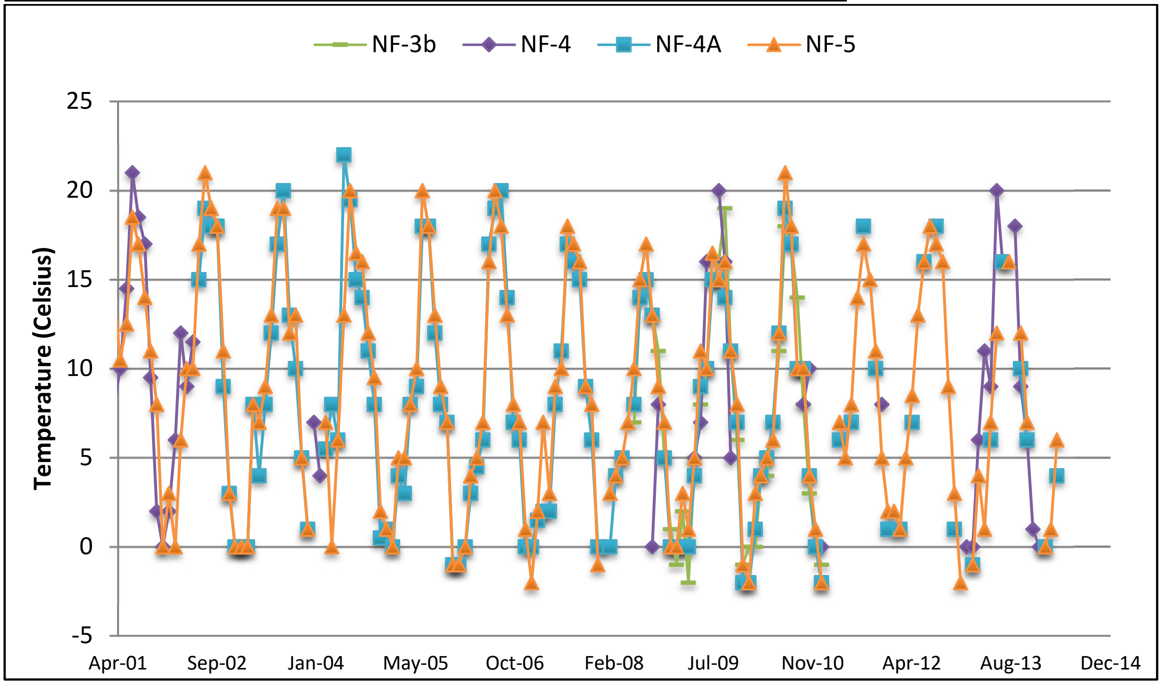


Figure 5-15 River Temperature in the Lower North Fork, Cold Stream II Classified Sites

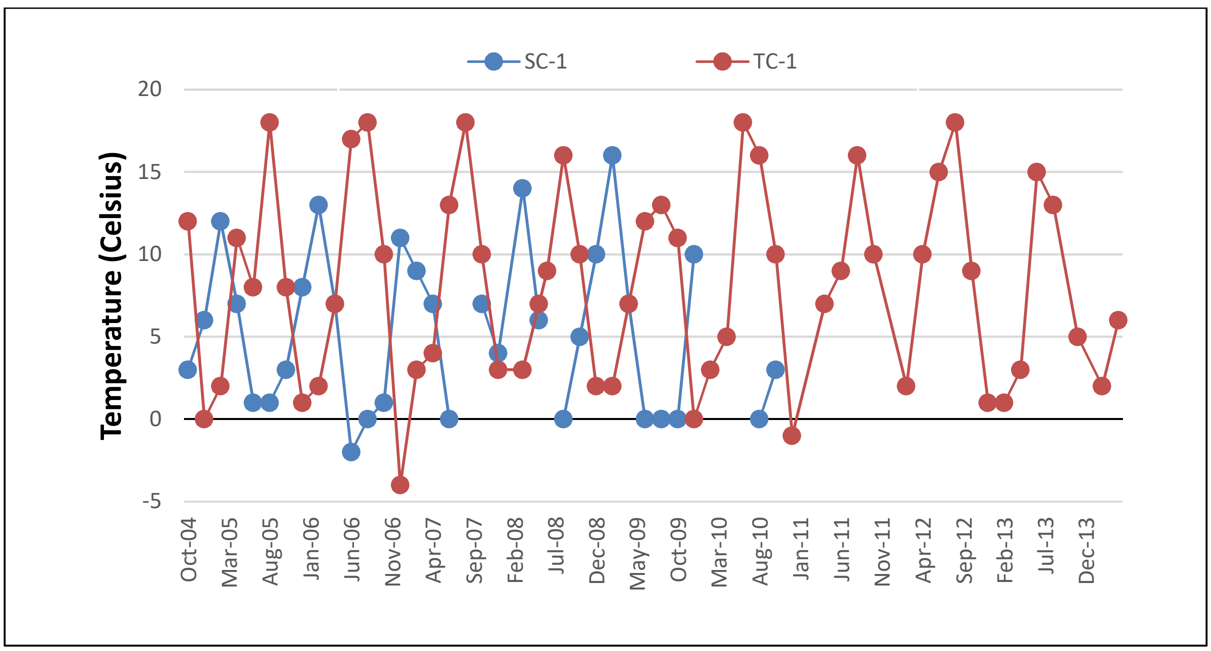


Figure 5-16 River Temperature in Lower Tributaries, Cold Stream II Classified Sites

6. NUTRIENT AND OTHER INORGANICS DATA

Network nutrient and other inorganic parameters are collected by Network volunteers and analyzed by River Watch staff at the Division of Wildlife laboratory in Ft. Collins. Nutrient and other inorganic parameters include nitrate+nitrite, ammonia, sulfate, total phosphorus, chloride and total suspended solids. The following section summarizes the results from 2001 to 2014. All stations are represented, but Anthracite Creek (AN-1) was not sampled for nutrients and is not included. Surface and Tongue Creeks have very few data points (sample size is four or less for each), but are still included where available. Many of the graphs represent data from select stations. The complete dataset can be found online on the Conservation Center's website: westernslopeconservation.org. Refer to the map in Figure 2-2 for station locations.

Sulfate

In aquatic systems, sulfate concentrations are dependent on the geochemistry of the soils and rocks that surface water contacts. Common sources of sulfur include gypsum ($CaSO_4$), and other sulfate minerals. Atmospheric deposition from the combustion of sulfur-containing fuels by cars and industrial operations can also contribute sulfate to aquatic systems. In small amounts, sulfur is important to aquatic life. Cells require sulfur to metabolize protein compounds responsible for energy transformations. When combined with metals, sulfur reacts with dissolved oxygen to create sulfate ions and sulfuric acid, which causes the water to become more acidic. Excessive amounts of sulfate in the water, however, can be toxic.

The graph of sulfate concentrations versus time (Figure 6-20) for the North Fork River sites shows a seasonal pattern similar to that of conductivity. In addition, the graph indicates that sulfate concentrations in the river increase downstream, as does conductivity. Because conductivity is an analog for TDS and sulfate is a major contributor to the total dissolved solids concentration, the similarity between the two constituents is expected. The sulfate concentration at each site is lowest during the period of spring runoff when snowmelt is the dominant source of water to the river, and highest when there is very little runoff and the dominant source of water to the river is ground water and irrigation return flows. There are no long-term trends in sulfate concentration for the period for which data were collected.

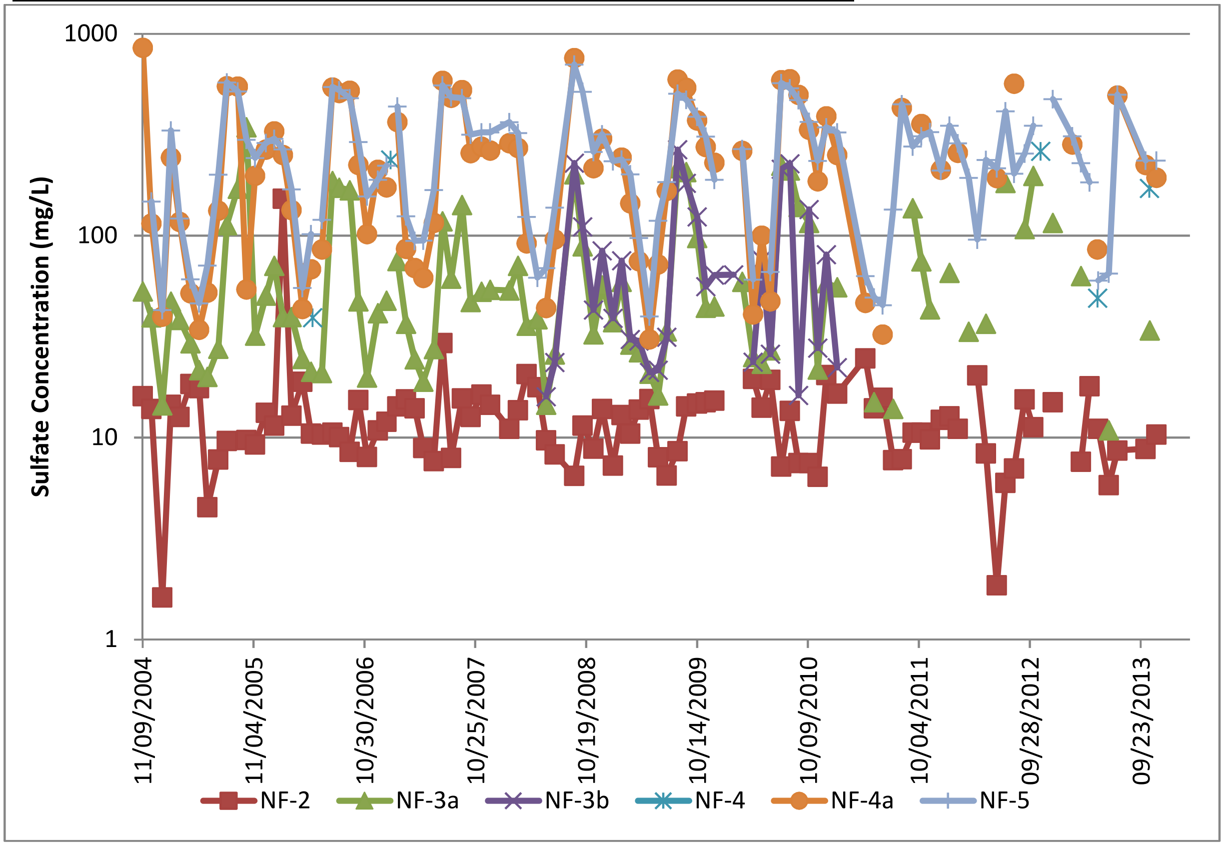


Figure 6-1: Sulfate Concentrations in the North Fork Gunnison River

After reaching peak concentrations in July and August, sulfate concentrations at sites NF-3a, 4a, and 5 decreased in late September/early October and through the winter season. This is consistent with the continuous USGS conductivity measurements near NF-5 and may be related to the end of most irrigation in the fall, and therefore a reduction in diversions from the North Fork. Reduced diversions from the North Fork, particularly from upstream areas, would leave more water in the river from low sulfate areas upstream of the Mancos Shale to dilute water from areas draining the Mancos Shale. This observation suggests that diversions for irrigation from the upper reaches of the North Fork result in less water to dilute contributions to the North Fork from tributaries that drain areas of Mancos Shale, resulting in higher dissolved sulfate and TDS concentrations during the summer months.

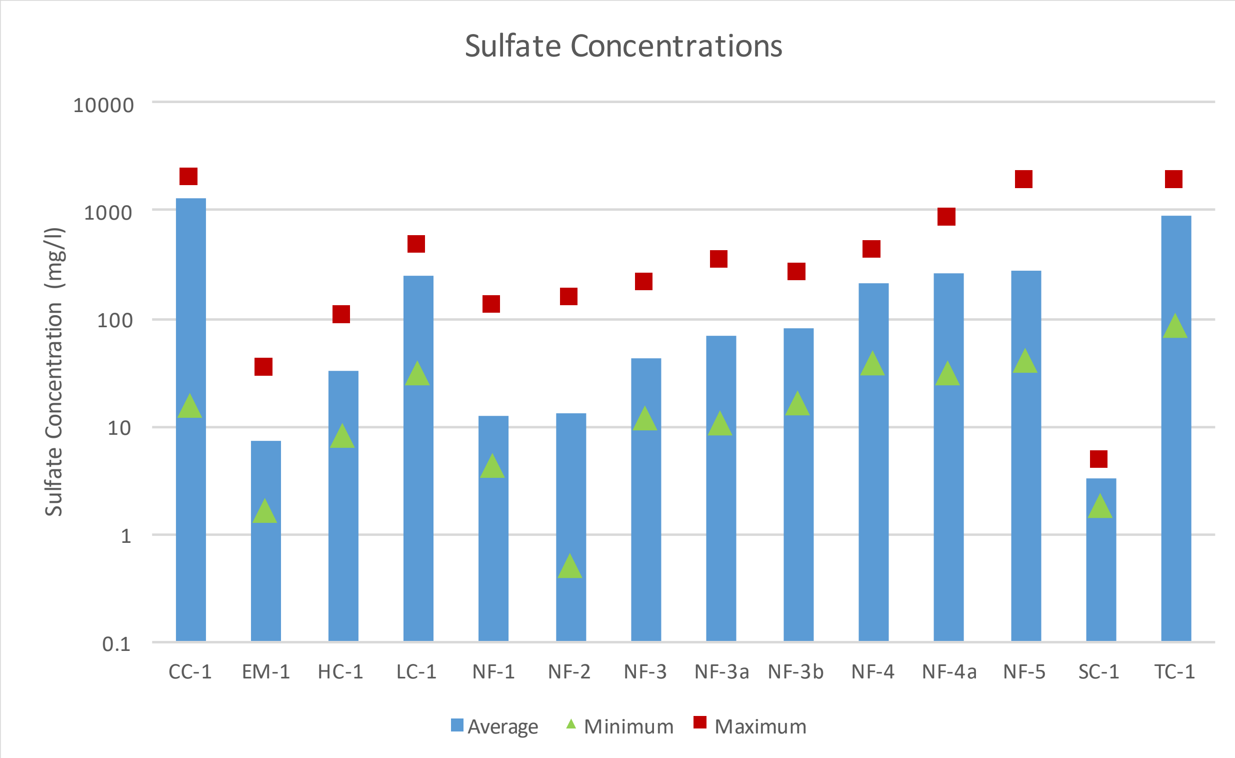


Figure 6-2: Sulfate maximum, average and minimum concentrations at all stations

Sulfate has a secondary drinking water standard of 250 mg/L due to its undesirable taste above this concentration. Secondary drinking water standards are not enforceable but are intended as guidelines to maintain aesthetic qualities relating to public acceptance of drinking water. Downstream sulfate concentrations regularly exceed the 250 mg/L standard.

Total Suspended Solids (TSS)

Total Suspended Solids (TSS) are the solids in water that are kept in suspension by turbulence in the water column. TSS can include minerals, sediment, decaying plant and animal matter, bacteria and waste material that a river transports. High concentrations of suspended solids can cause many problems for stream health and aquatic life. Suspended materials can clog fish and insect gills, smother spawning beds, impair sight dependent predation, trap sunlight, increase water temperature and possibly lower dissolved oxygen concentrations. There are currently no water quality standards for TSS, although most people consider water with a TSS concentration less than 20 mg/L to be clear. Water with TSS concentrations between 40 and 80 mg/L tends to appear cloudy, while water with concentrations over 150 mg/L usually appears “dirty” (Michigan DEQ 2018). The nature of the particles that comprise the suspended solids may cause these numbers to vary.

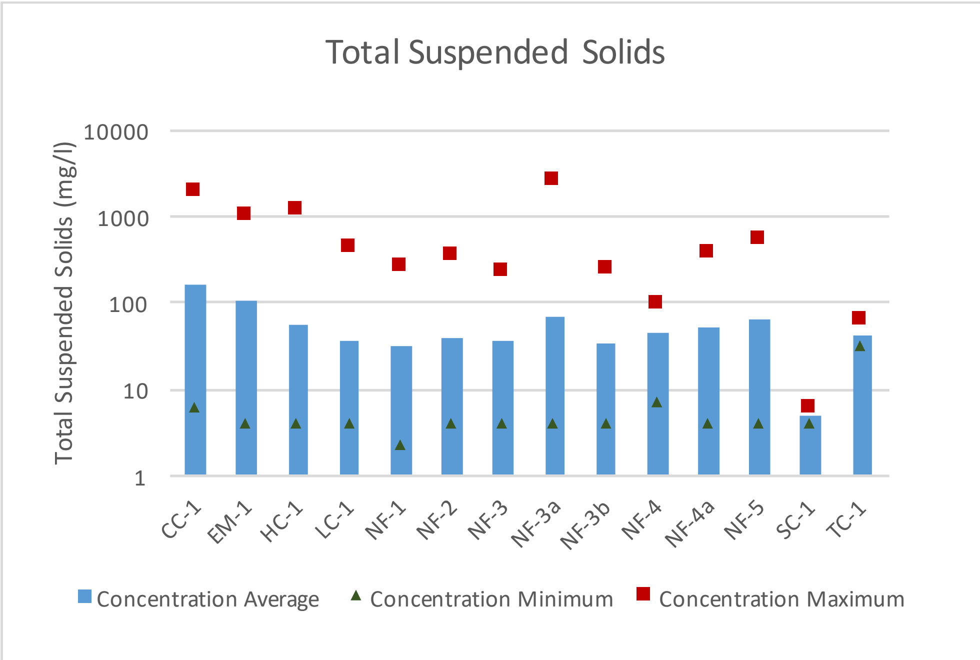


Figure 6-3 Total Suspended solids maximum, average and minimum concentrations at all stations

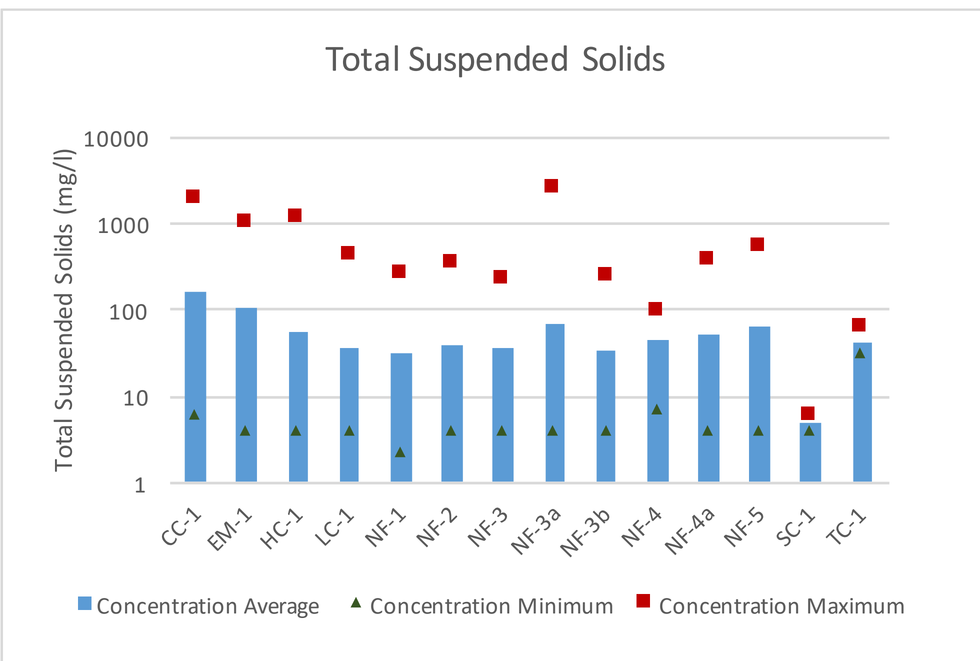


Figure 6-3 shows available data for maximum, minimum and average TSS concentrations in the North Fork for all stations. The TSS concentrations at all stations experience periods of relatively clear conditions and periods of cloudy to extremely turbid conditions. The highest recorded TSS concentration is 2,571 mg/L at station NF-3a in September 2012. Stations EM-1 and CC-1 exhibit the highest TSS concentrations, which likely reflects geological conditions within their watersheds.

Stream discharge is a primary factor affecting TSS concentrations. Fast moving water can transport more particles and larger-sized sediment. As water slows, it loses its holding capacity and deposits the suspended sediments at the bottom of a stream or lake bottom. The relationship between TSS and flow is not statistically significant, but in general increases in TSS correlate to increases in flow. This relationship is opposite of that with flow and hardness, alkalinity and sulfur; high flow events increase TSS concentrations rather than dilute them. High TSS concentrations correlate to peak flow conditions for nearly all sampling events.

Phosphorus

Phosphorus is a nutrient required by all organisms for the basic processes of life. It is a naturally occurring element found in rocks, soils and organic material. In comparison to the rich supply of the other major nutrients required for metabolism of aquatic life (carbon, nitrogen, oxygen and sulfur), phosphorus is the least abundant and most commonly limits biological productivity. Phosphorus is often referred to as a limiting nutrient in most freshwater systems.

Phosphorus binds tightly to soil particles, metal oxides and hydroxides under aerobic conditions. In clean waters, phosphorous concentrations are typically very low. However, phosphorus is used extensively in fertilizers and concentrated in sewage, so it can be found in high concentrations near human activity. The most significant form of phosphorus is dissolved inorganic phosphorus, or orthophosphate ($PO4^{3-}$). However, over 90% of the phosphorus in freshwater systems occurs as organic phosphates that adhere to inorganic particles (Wetzel 2001). Total Phosphorus (TP) is a measure of all phosphorus constituents in aquatic systems.

Colorado utilizes interim standards described in Table 6 for total phosphorus that are similar to the EPA's recommendations to control eutrophication (excessive biological activity due to inputs of nutrients). Cold water rivers and streams that do not discharge directly into lakes or reservoirs (Mueller and Helsel 1999) should not exceed a TP concentration of 0.11 mg/L. As shown in Figure 6-4, TP concentrations are below Colorado's interim standards on average, but maximums exceeded the recommended standard.

TP concentrations increased in the spring during snowmelt/spring runoff and decreased during low flow conditions in the late summer/fall. TC-1 had the highest average TP concentration of 0.097 mg/L.

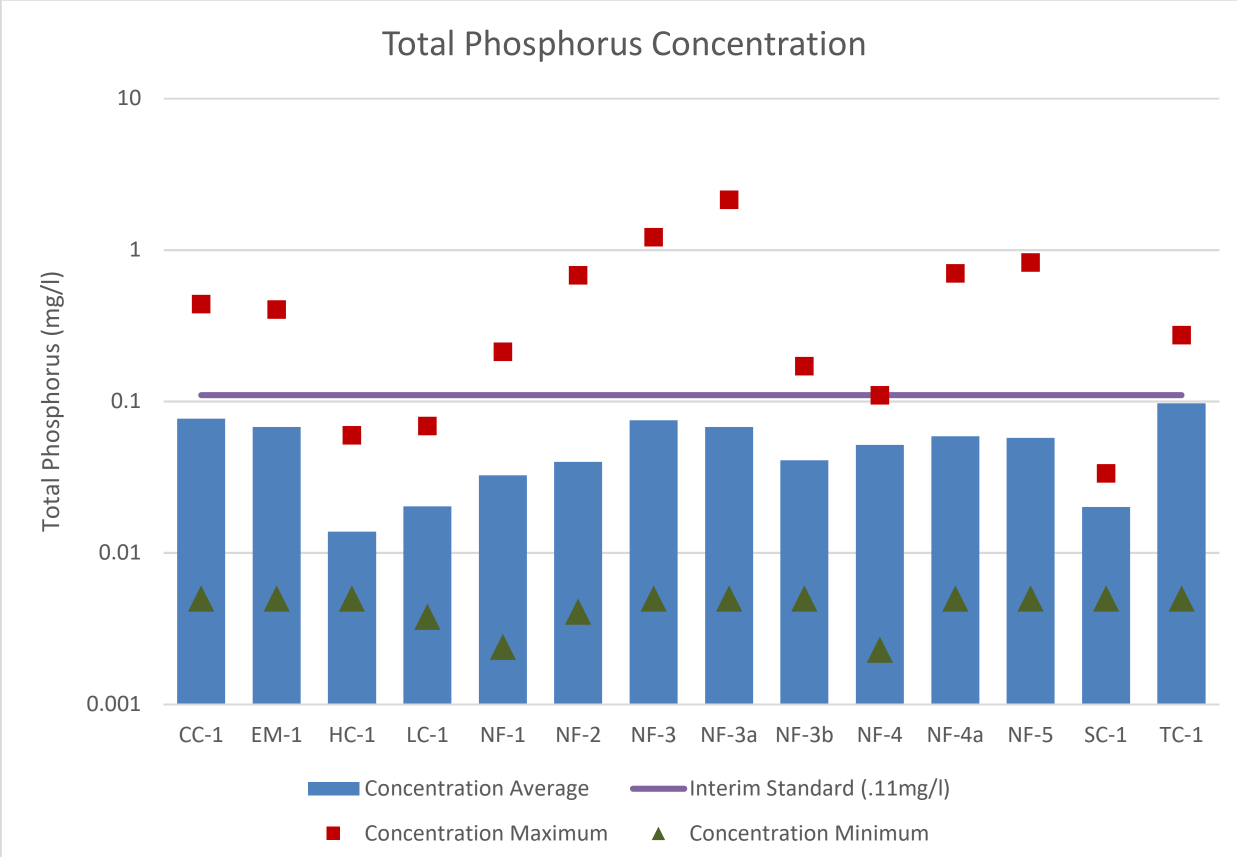


Figure 6-4 Total Phosphorus maximum, average and minimum concentrations at all stations

Nitrate and Nitrite

Nitrogen is one of the most abundant elements on earth. Gaseous nitrogen comprises about 80% of the air we breathe. Nitrogen is found in cells of all living things and is a major component of proteins. Inorganic nitrogen may exist as a gas N_2, or as nitrate NO_3^-, nitrite NO_2, or ammonia NH_3^+. Nitrate and nitrite are oxidized forms of nitrogen that together normally constitute most of the dissolved nitrogen in well aerated streams. Nitrite readily oxidizes to nitrate in natural waters; therefore, nitrate is generally by far the more abundant of the two forms.

Nitrogen-containing compounds act as nutrients in streams and rivers. At high concentrations, nitrate can overstimulate the growth of aquatic plants and algae (known as eutrophication), resulting in high dissolved oxygen consumption, causing fish and other aquatic organism mortality. At high enough concentrations, nitrate can limit the ability of red blood cells to transport oxygen. In fish, this condition is known as “brown blood disease,” and in humans it is called methemoglobinemia, or "blue baby" disease.

Nitrate concentrations at all of the monitored sites did not come close to approaching the $N0_3$ standard (10mg/L) or the interim total nitrogen standard.

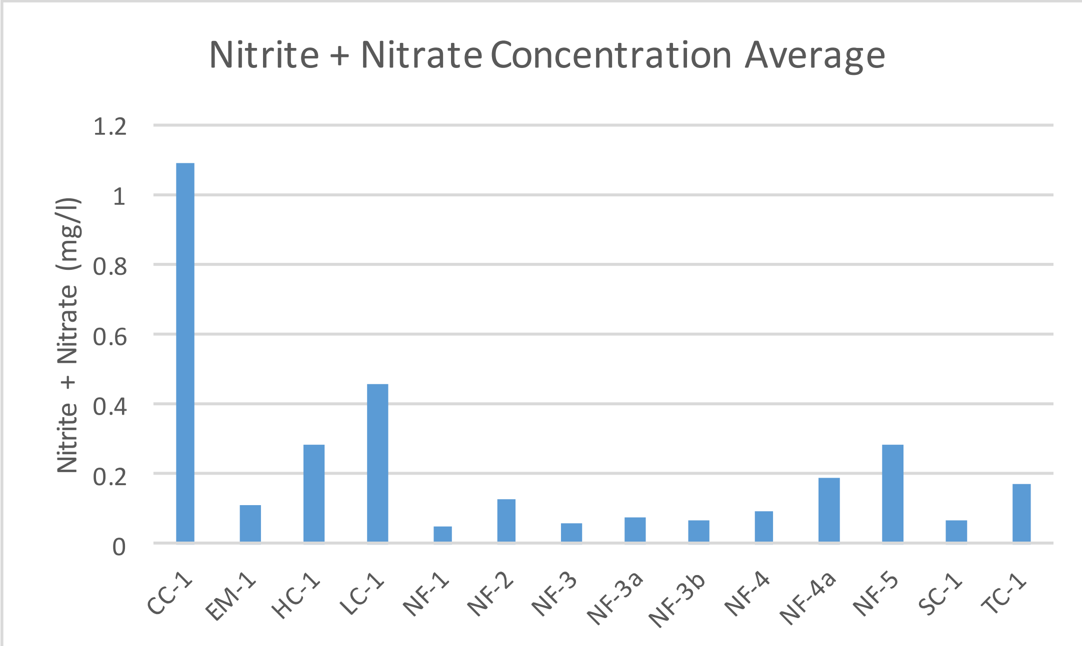


Figure 6-5 Nitrate+Nitrite average concentrations at all stations

Nitrate + nitrite concentrations in the North Fork were highest during the winter, but still remained well below the standards. The data show that winter nitrate + nitrite concentrations increase downstream. Nitrate and nitrite are both very soluble and do not bind to soils, so they have a high potential to migrate through ground water. Ground water may be a source of nitrate and nitrite to the river, resulting in higher concentrations when stream flow is lower. Other sources that would be less diluted during the winter during low flow conditions may be septic systems, livestock, and wastewater treatment effluent.

Ammonia

Ammonia is a form of inorganic nitrogen. The least stable form of nitrogen in water, ammonia is easily transformed to nitrate or nitrogen gas. Ammonia is found in water in two forms: the ammonium ion (NH_4^+) and the dissolved, unionized (no electrical charge) ammonia gas (NH_3). Total ammonia is the sum of ammonium and unionized ammonia. The dominant form depends on the pH and temperature of the water.

NH_3 is the principal form of toxic ammonia. Exposure to high concentrations of ammonia in humans can cause loss of equilibrium, convulsions, coma, and death. Ammonia concentrations can affect hatching and growth rates of fish; changes in tissues of gills, liver, and kidneys may occur during structural development.

The State of Colorado has developed chronic and acute table value standards (TVS) for ammonia based on temperature and pH. Ammonia concentrations at all stations were very low.

7. METAL DATA

Network metal parameters are collected by Network volunteers and analyzed by River Watch staff at the Division of Wildlife laboratory in Fort Collins. Metals sampled include aluminum, arsenic, cadmium, calcium, copper, iron, manganese, lead, magnesium, selenium and zinc. The following metal results include samples collected from 2001 through 2014. The results are based on all available data and provide general information regarding comparison against state metal standards. Table 15 provides date ranges for each station.

Station	Beginning	End
EM-1	4/25/01	11/13/13
AN-1	4/25/01	4/10/02
NF-1	4/25/01	11/10/10
NF-2	4/25/01	11/13/13
NF-3	4/4/01	1/29/14
NF-3a	6/12/02	8/14/13
NF-3b	6/11/08	11/10/2010
***NF-4**	04/23/2001	01/29/2014
NF-4a	06/12/2002	11/13/2013
NF-5	04/25/2001	11/13/2013
***CC-1**	01/11/2005	05/24/2005
HC-1	04/13/2011	11/13/2013
LC-1	04/13/2011	11/13/2013
***SC-1**	10/19/04	10/08/14
***TC-1**	10/19/04	10/08/14

Table 15: Metals Sampling Date Ranges for Each Station

*Note: Stations with an * have River Watch data available for prior dates, but they were not collected by the Network and thereforeis not discussed in this report.*

In general, metal concentrations appear to be lower during spring runoff due to dilution and higher during late summer low flow conditions. The graphs below illustrate patterns and concentrations in relation to state metal standards.

Information regarding complete metals dataset can be found in Appendix A. Refer to the map in Figure 2-2 for station locations.

Standards in this section were calculated using State of Colorado classifications and numeric standards for the North Fork of the Gunnison River[1]. Copper, cadmium, lead, and zinc standard calculations are based on hardness values at the time the metals were collected. Aquatic life standards are generally applied to the dissolved metals because this measurement provides a better representation of the biologically available fraction of a metal than total metals, which are present in the particulates in the water. The formulas used to determine numeric standards are from the Colorado Department of Public Health and Environment Water Quality Control Commission, 5 CCR 1002-35, Regulation No. 35: Classifications and Numeric Standards for Gunnison and Lower Dolores River Basins. Average hardness for each site (Table 16) was used to calculate standards, as opposed to the hardness reading for each sample taken.

Station	Average Hardness (mg/L)
EM-1	122
AN-1	64

[1] This report identifies instances when discrete water samples exceeded state water quality standards, as determined by the WQCC. For regulatory purposes, the state applies the 85th percentile methodology when determining if segments violate water quality standards. The 85th percentile methodology allows for 15 percent of the data for a given segment to exceed standards without being in violation of water quality standards. See the WQCC Basic Standards Methodologies for Surface Water (Regulation No. 31) for more information.

NF-1	75
NF-2	81
NF-3	155
NF-3a	193
NF-3b	199
NF-4	310
NF-4a	398
NF-5	518
CC-1	979
HC-1	118
LC-1	491
SC-1	105
TC-1	624

Table 16: Average Hardness Used to Calculate Metal Standards at Each Station

Aluminum

Aluminum is the most abundant naturally occurring metal in the earth's surface and comprises, on average, about eight percent of the earth's crust. Geologic formations are, therefore, common sources of aluminum in aquatic systems.

In humans, aluminum has been shown to be neurotoxic if it enters the bloodstream. Aluminum toxicity can cause encephalopathy (defect of the brain) and/or bone mineralization disorders. Aluminum toxicity is driven by pH. At low pH concentrations, aluminum toxicity has been documented in invertebrates, fish and amphibian larvae. Aluminum can interfere with cation exchange, electrolyte balance, calcium absorption and respiration in aquatic life. Aluminum is also reported to cause fragile eggs in birds.

Colorado has developed aluminum standards for aquatic life based on pH and hardness based on total recoverable aluminum; however, unless a stream segment is at risk of high dissolved aluminum concentrations, the standard is not included in stream segment standards. The stream segments evaluated do not have aluminum standards.

High total aluminum concentrations are characteristic of spring snowmelts/runoff periods. Spring snowmelt, naturally acidic, can liberate naturally occurring aluminum from geologic sources into stream systems. The highest aluminum concentrations were detected during spring runoff, when TSS concentrations were high, and the lowest concentrations were measured during summer and fall low flow.

Arsenic

Arsenic is a naturally occurring element in rocks, soils and the water in contact with them. It is known to cause cancer in high doses, and Colorado has developed numeric standards for dissolved arsenic concentrations. All stations have a water supply standard of .02 µg/L, except Cottonwood Creek (CC-1), which is not classified for water supply and has a 100 µg/L agricultural standard. The River Watch Laboratory arsenic reporting limit is 15 µg/L.

From late 2006 to early 2008, arsenic concentrations consistently exceeded River Watch laboratory reporting limits, unlike samples collected prior to and after this period. This indicates a problem with the laboratory results during late 2006 to early 2008. After evaluating the data, the Conservation Center has not included the late 2006 to early 2008 results in its analysis.

The average and mode concentration for all stations from 2001 through 2014 was less than the reporting limit of 15 µg/L. Due to the high reporing limit, it is not known of the water supply standard was exceeded, but it is known that in Cottonwood Creek, where all results were less than the reporting limit, the agricultural standard was not exceeded. On one occasion, the total arsenic concentration exceeded the reporting limit (at CC-1 in July 2015 the total arsenic concentration was 44 µg/L) and on one occasion the dissolved arsenic concentration exceeded the reporting limit (at NF-5 in March 2013 the dissolved arsenic concentration was 40 µg/L).

Cadmium

Cadmium is an element that is non-essential for life and is a potential carcinogen. It is widely distributed in the environment at low concentrations. Colorado has hardness based aquatic life standards for cadmium, and at every sample site, there were some exceedances of both the chronic and acute aquatic life standards. Figure 7-1 does not show this for all sites because the standards shown are for the average hardness values provided in Table 16.

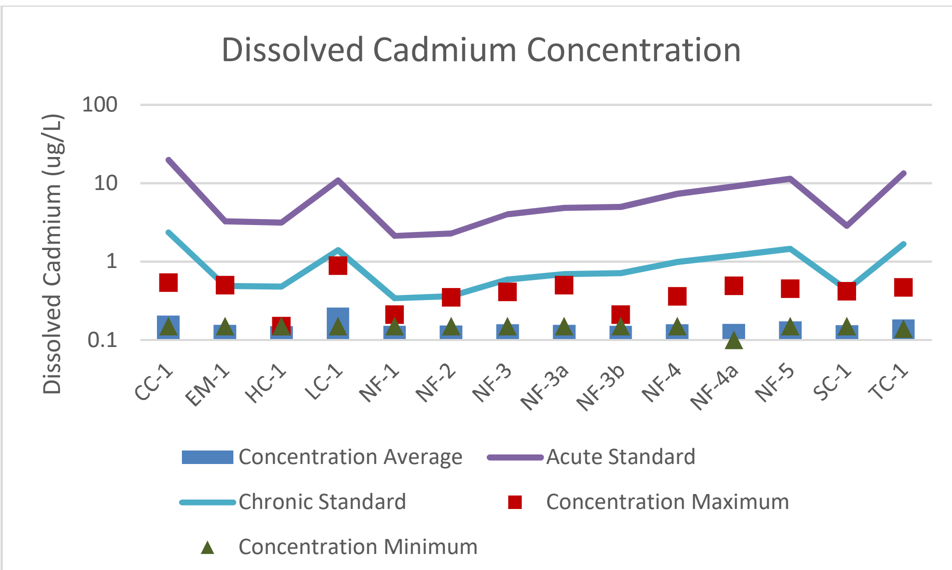


Figure 7-1: Dissolved Cadmium concentrations at all stations

Calcium

Calcium is the most abundant cation in the world's rivers. One of the most important contributors to hardness, calcium is found in water due to the leaching of soils or from anthropogenic sources such as sewage and industrial wastes. Calcium influences the growth and population dynamics of aquatic life. It is required for plant, animal and bacteria to maintain structural and functional integrity of cell membranes. There are no water quality standards forcalcium.

High calcium concentrations are a characteristic of highly calcareous soils in the watershed. In general, dissolved calcium concentrations increase as water travels downstream through the watershed. Calcium concentrations at station NF-4, NF-4a, LC-1 and TC-1 are higher than other stations at all times of the year, except during spring runoff when it is diluted to nearly the same concentration as stations higher in the watershed. The highest recorded calcium concentration was 483 mg/L at station CC-1 on May 9, 2014.

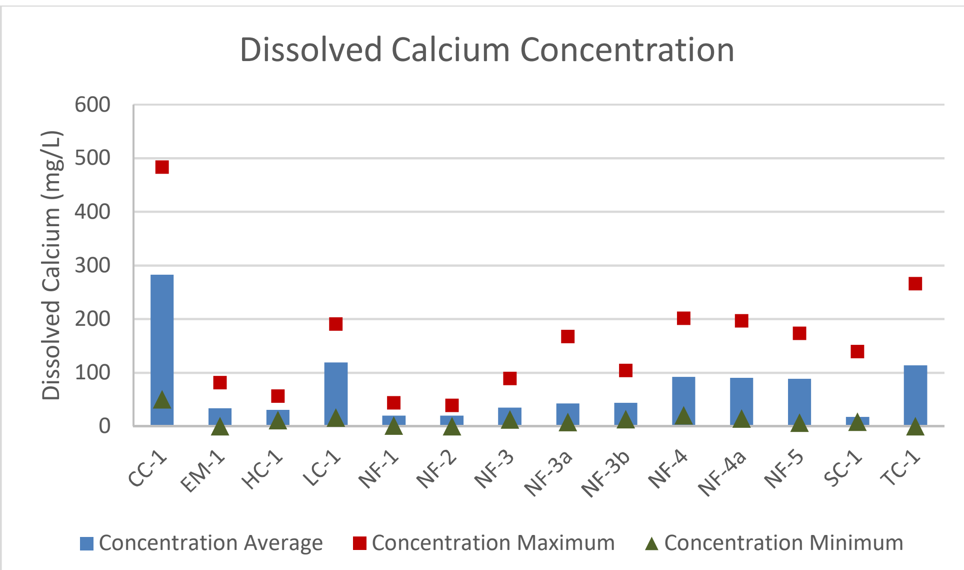


Figure 7-2 Dissolved Calcium concentrations at all stations

Copper

Copper is a naturally occurring trace element. At low concentrations, copper is an essential micronutrient that is used in cellular metabolism and oxygen transport. At high concentrations, copper can be toxic to aquatic life. The state of Colorado has developed hardness-based aquatic life standards for copper.

Figure 7-3 shows dissolved copper concentrations for all stations. Overall, dissolved copper concentrations did not exhibit much variation or seasonal trends. In general, concentrations were higher at the upper stations. All but one dissolved copper value was less than 4 µg/l. The highest recorded dissolved copper concentration was 7.7 µg/L at station NF-2 in January 2009. There were no exceedances of copper standards.

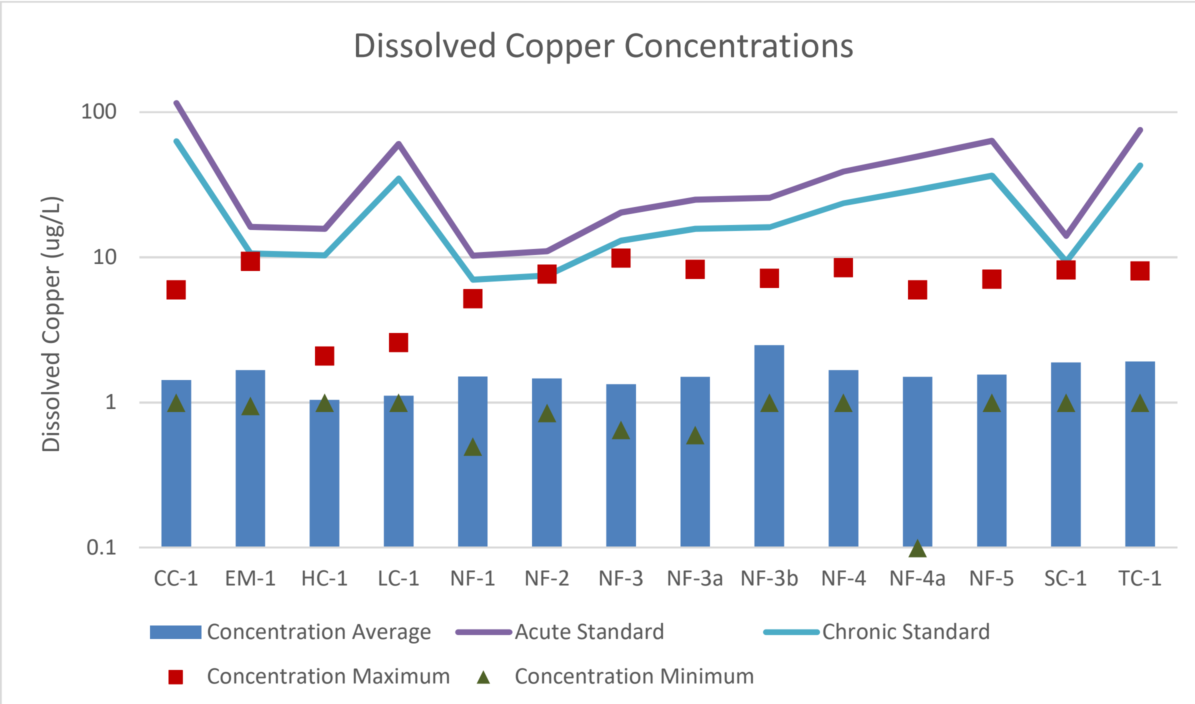


Figure 7-3: Dissolved Copper concentrations at all stations

Iron

Iron is the fourth most abundant element, by weight, in the earth's crust. It is naturally present in aquatic systems but in variable amounts depending on the local geology. It is an important micronutrient that is required for life in small quantities, but can be toxic in excessive amounts. Iron is normally present in waterways in its soluble ferrous form (Fe^{2+}). However, iron is easily oxidized into its insoluble form, ferric iron (Fe^{2+}). In alkaline streams, such as the North Fork, iron primarily exists in colloidal and particulate (solid) forms. This is because iron solubility is very low above a pH of 5 (Wetzel 2001).

Sections of segment COGUNF06A, Cottonwood Creek (CC-1), are on the State Monitoring and Evaluation list for total recoverable iron.

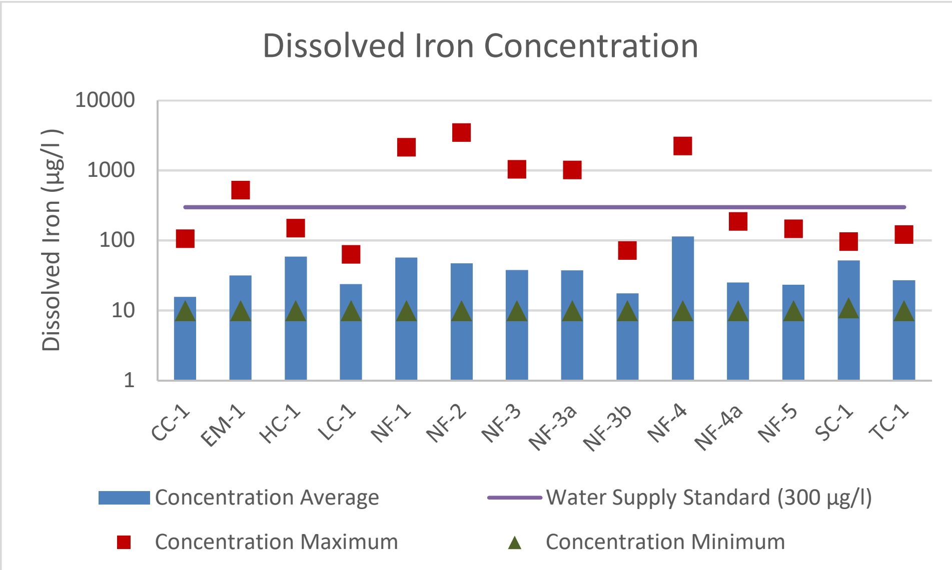


Figure 7-4 shows dissolved iron concentrations in the North Fork at all stations. The dissolved iron water supply standard (300 µg/l) was exceeded twice at NF-1 (August 2001 and May 2009), once at NF-2 (May 2005) and multiple times at NF-3a, NF-4, NF-4a and NF-5. In many Colorado streams, high iron concentrations are due to natural occurrences.

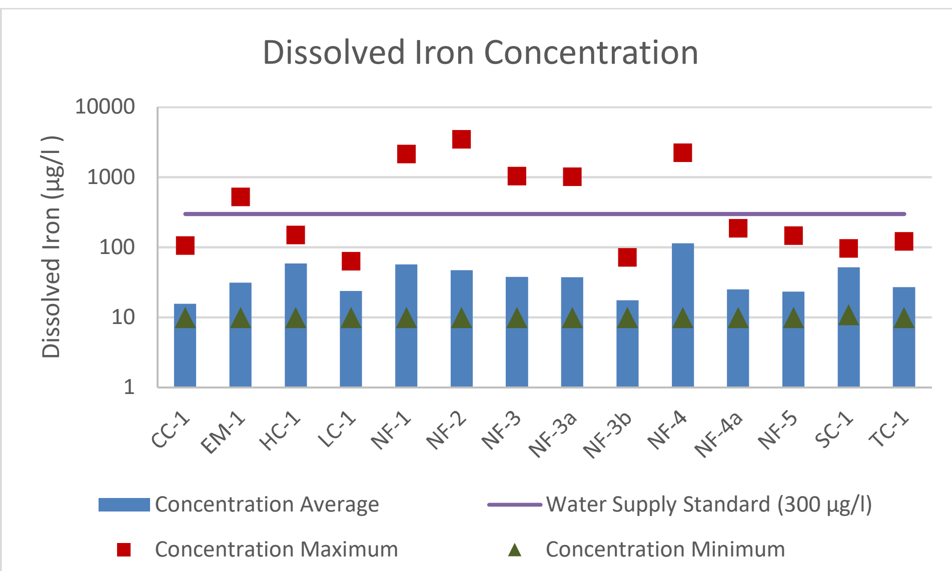


Figure 7-4 Dissolved Iron concentrations at all stations

Lead

Lead can be toxic to aquatic life. Lead commonly occurs in ores with zinc, silver and copper. Lead concentrations in the North Fork are generally very low. Only 11% of the reported total lead concentrations exceeded the River Watch laboratory reporting limit of 3 µg/L during the reporting period. Lead concentrations were well below the acute standard. Sample averages exceeded the chronic standard at NF-1, NF-2, and SC-1.

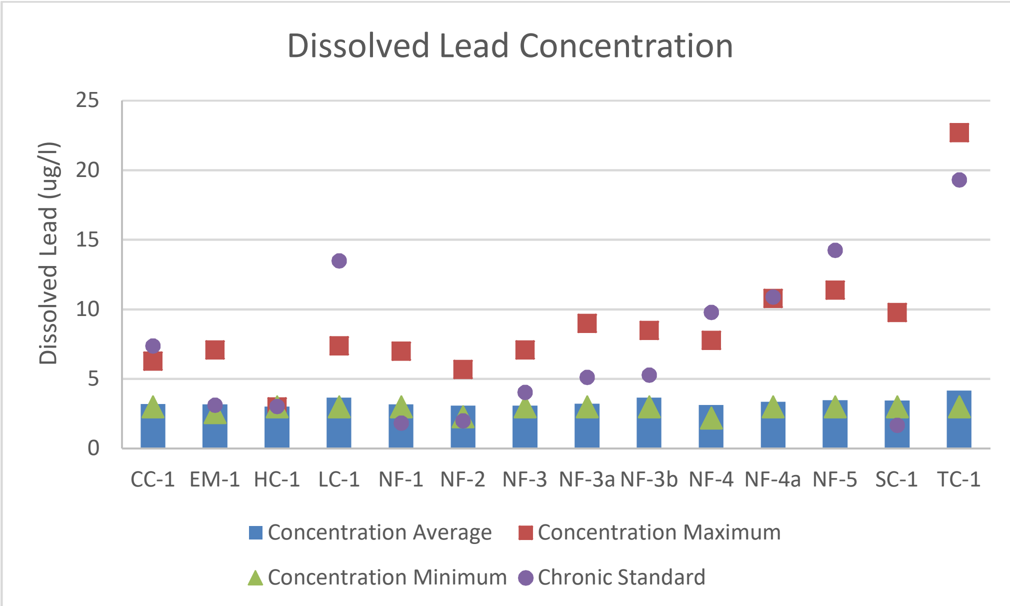


Figure 7-5: Dissolved Lead concentrations at all stations

Manganese

Manganese is a naturally occurring free (uncombined) element that usually occurs with iron. It is an essential element in plant and animal metabolism, but toxic in excessive amounts. Colorado has hardness based-standards for manganese.

Maximum dissolved manganese values exceeded the 50 µg/L water supply standard at most sites. CC-1 is the only sampling site that is not classified as a water supply stream segment. CC-1 was evaluated against the agricultural standard of 200 µg/L, which was not exceeded.

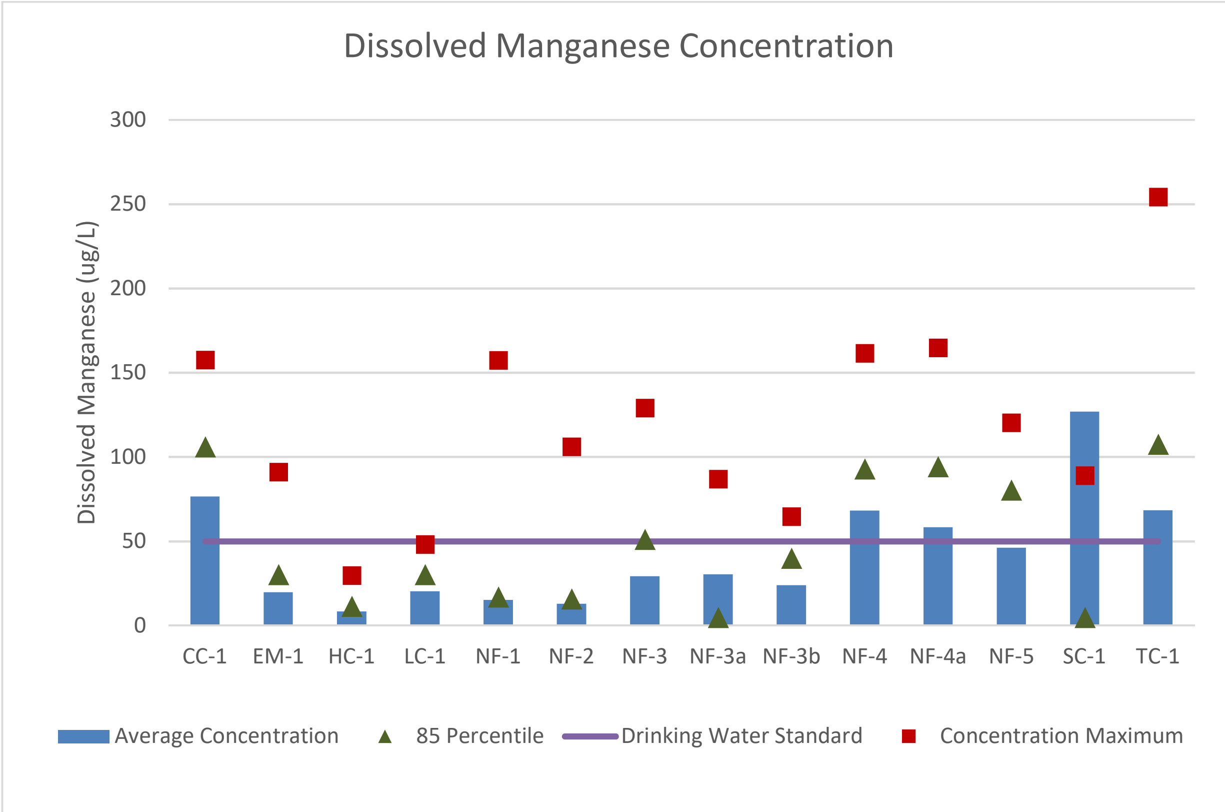


Figure 7-6 Dissolved Manganese concentrations at all stations

Magnesium

Like calcium, magnesium is a major component of hardness and is primarily derived from the weathering of rocks. Magnesium is much more soluble than calcium and rarely precipitates. There are no water quality standards for magnesium.

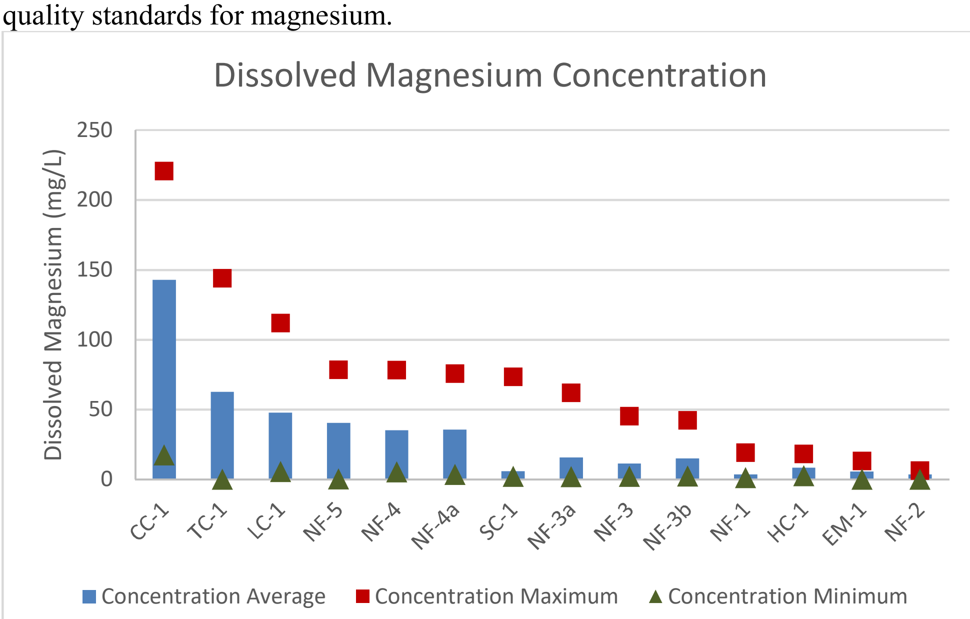


Figure 7-7 shows average, minimum and maximum dissolved magnesium concentrations. The highest reported total magnesium value in the North Fork, 220 mg/L, occurred in March 2013 at CC-1. In general, magnesium concentrations were higher in the lower watershed.

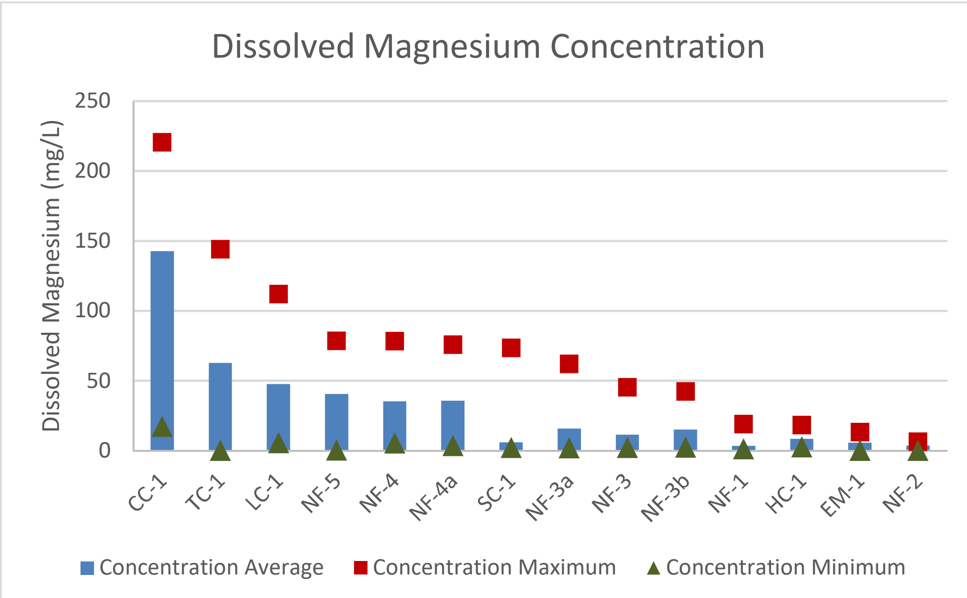


Figure 7-7 Dissolved Magnesium concentrations at all stations

Selenium

In the North Fork watershed, selenium is commonly associated with the Mancos shale, which is present throughout western Colorado.

Selenium is a naturally occurring trace element that is needed for metabolism in aquatic life and humans. Selenium is a bioaccumulative metal and subject to a range of toxicity values depending upon numerous site-specific variables. Selenium is known to cause reproductive failure and deformities in fish and aquatic birds (Gunnison Basin Selenium Task Force 2009). Significant human consumption of fish containing high concentrations of selenium may result in human health problems. Selenium is widely distributed in rocks, soils and living organisms. Selenium may be leached from the soil into local waterways when water used for irrigation and other purposes passes through soils derived from the Mancos shale.

Irrigated agriculture can increase the amount of selenium in surface water and ground water. Deep percolation from irrigation can mobilize large quantities of selenium in ground water, where it eventually may discharge to surface water. The Gunnison/Grand Valley Selenium Task Force has been studying selenium for over a decade. The Taskforce found that upstream of major irrigated areas in the Gunnison basin, selenium concentrations are generally less than 1 µg/L, but downstream from irrigated areas selenium concentrations of surface waters often exceeded 5 µg/L[7].

The State of Colorado has numeric standards for dissolved and total recoverable selenium (Table 2-7). Selenium is designated as a Colorado Monitoring and Evaluation parameter by the State for East Muddy Creek (EM-1) and Tongue Creek (TC-1) and Surface Creek are on the 303(d) list for selenium.

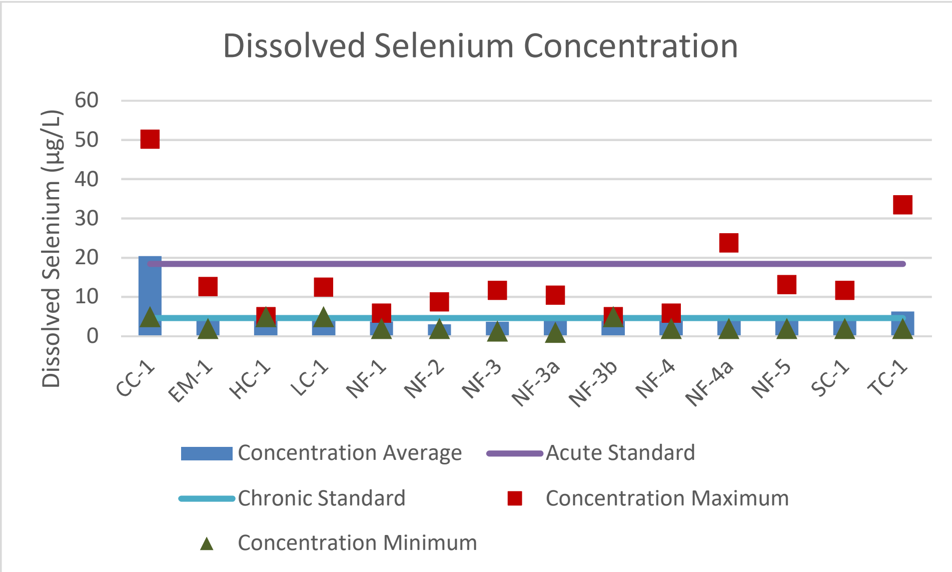


Figure 7-8 shows that dissolved selenium concentrations at all monitored stations exceeded state aquatic life standards. Due to problems with more recent laboratoryselenium results, only selenium data collected prior to 2007 were used for this report.

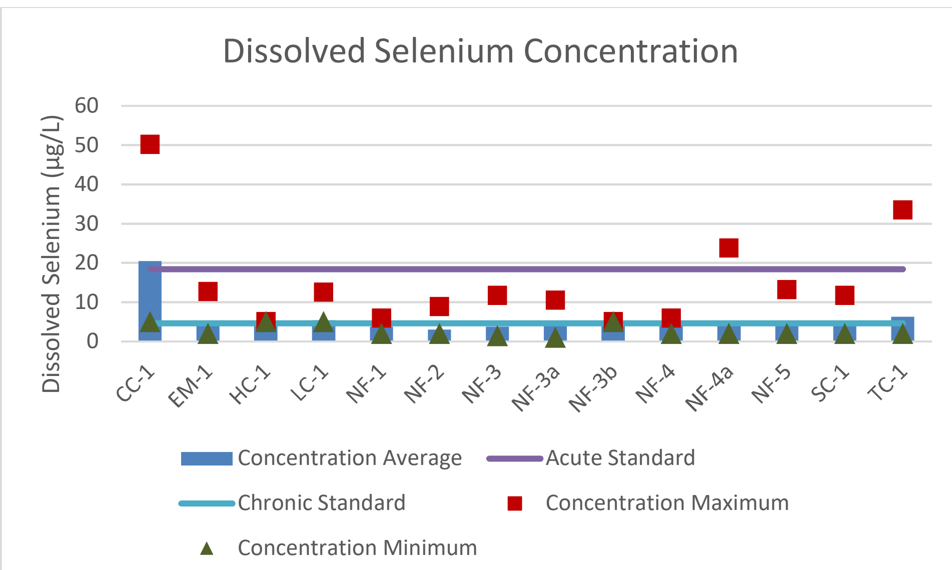


Figure 7-8 Dissolved Selenium concentrations at all stations

Average concentrations for stations CC-1, HC-1, LC-1, NF-3b, NF-4, NF-4a, NF-5, SC-1, and TC-1 all exceeded the chronic water quality standard for selenium during the time of sampling up through 2006. Cottonwood Creek (Station CC-1) had the consistently highest reported selenium concentrations, with the highest being 50 µg/L for dissolved selenium and 48.5 µg/L for total selenium.

Due to the concentrated efforts of the Selenium Task force and local ranchers and farmers, irrigation water lower in the watershed is increasingly being piped rather than being moved via unlined ditches. This may decrease selenium concentrations in future water samples.

Zinc

Zinc is a naturally occurring element that is essential for cell growth. It can bioaccumulate and can be toxic to aquatic life. Dissolved zinc concentrations in the North Fork were below both the acute and chronic standards.

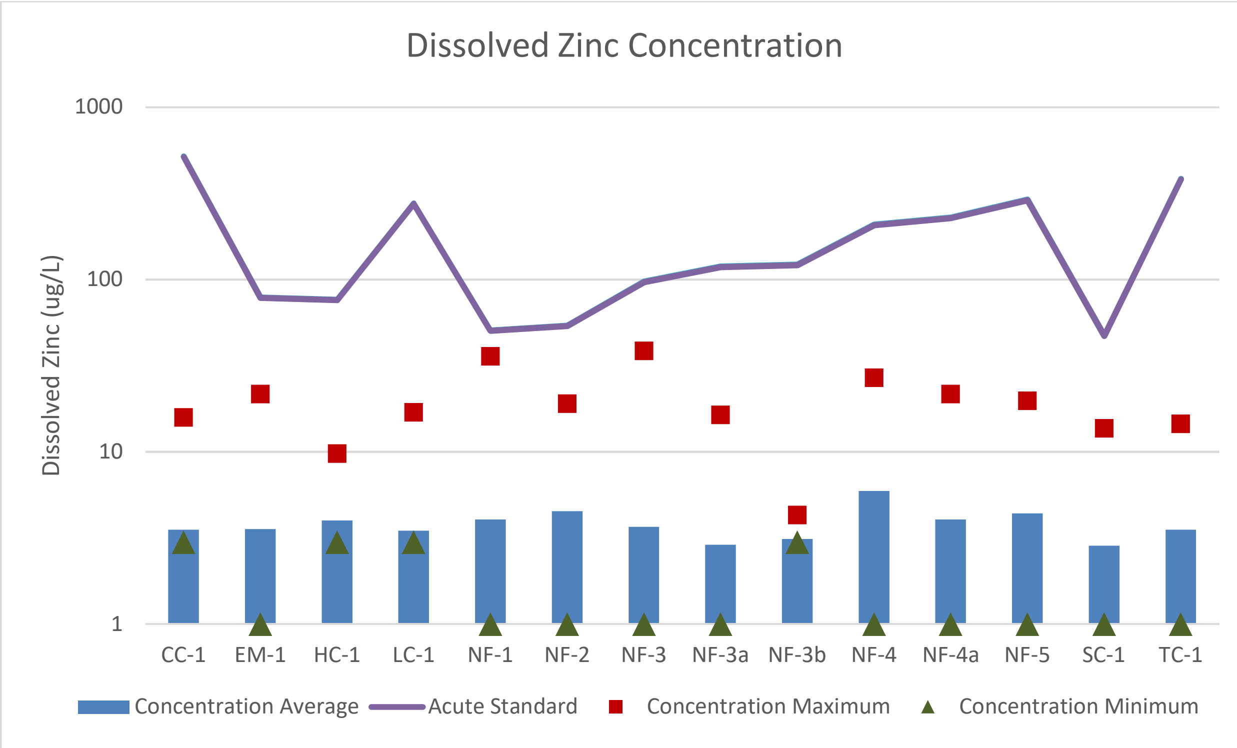


Figure 7-9 Dissolved Zinc concentrations at all stations

8. BACTERIA DATA

Total coliform bacteria are a collection of relatively harmless microorganisms that live in the intestines of warm and cold blooded animals and aid in digestion. Fecal coliforms are a subset of intestinal bacteria that are associated only with the fecal material of warm-blooded animals. The most common type of fecal coliform is *Escherichia coli (E. coli).*

The presence of *E. coli* in aquatic environments indicates that water has been contaminated with fecal materials from sewage or animal waste. This is an important water quality indicator because the presence of fecal contamination means water may be contaminated by waterborne pathogenic diseases such as typhoid fever and hepatitis. *E. coli* can be washed into water ways during rainfall, snow melt and other precipitation events. Sources of *E. coli* in the North Fork watershed may include livestock, septic systems, and wildlife. The survival of waterborne pathogens, such as *E. coli*, in streams and rivers is variable. Conditions such as turbidity, oxygen, presence of nutrients and pesticides, pH, organic matter, and solar radiation can impact pathogen survival rates (Moore et al 1988). In particular, bacteria are known to have significantly longer survival times in sediment- laden waters (Sherer et al 1992).

Measured *E. coli* concentrations were compared to the Colorado Department of Public Health and Environment Water Quality Control Commission Natural Swimming Areas standard of 235 organisms/mL. Figure 8-1 and Figure 8-2 show the monthly geometric *E. coli* means for 2009 and 2010. In several reported instances, the *E. coli* results were over the quantitation value of 2,419.6 MPN/100 mL. In these instances, 2,419.6 MPN/100 mL was used to calculate the geometric mean. In general, *E. coli* concentrations peaked during summer months.

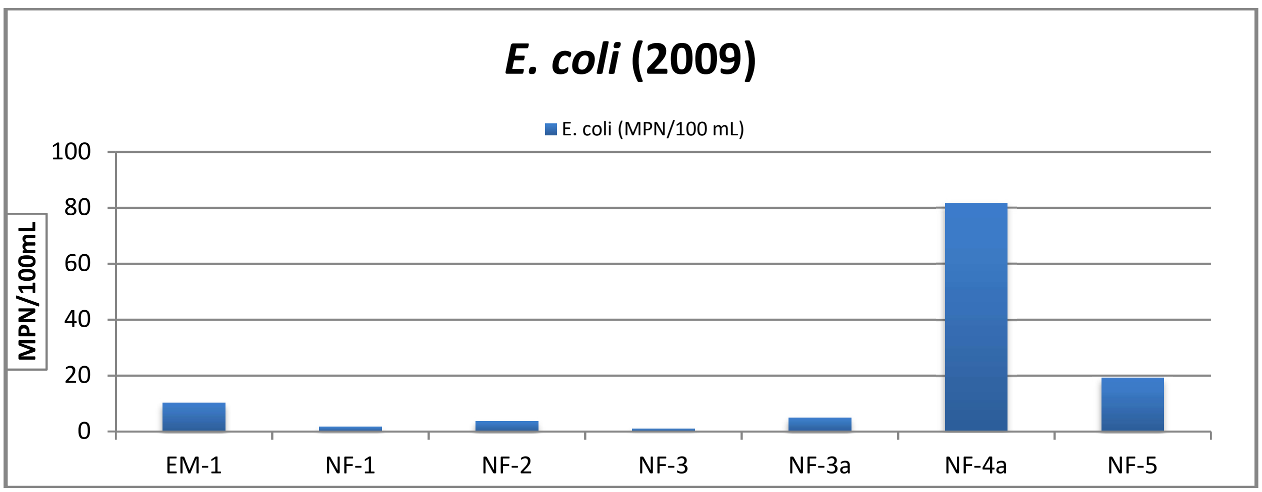


Figure 8-1 Monthly Geometric Mean of *E. coli*, (November only) 2009

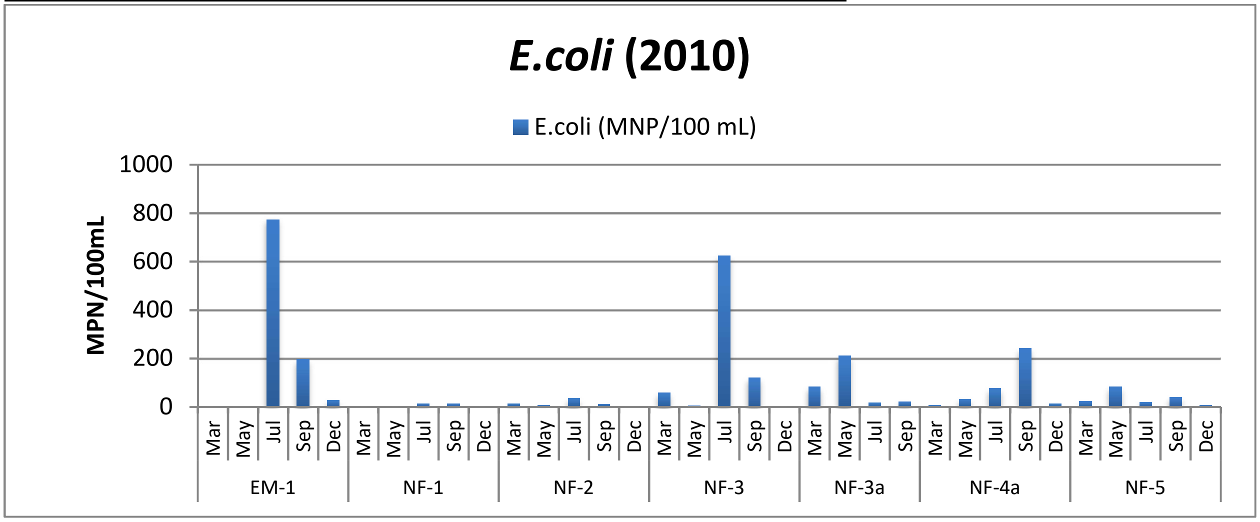


Figure 8-2 Monthly Geometric Mean of *E. coli*, 2010

In 2011, two changes to bacteria sampling took place. Instead of three replicate samples per station, one was taken and analyzed, with one duplicate taken on each sampling date that rotated between stations. Instead of three results per station per sampling date, this returned one result per station per sampling date. In addition, stations were sampled with less frequency, some years being sampled every other month, and some being sampled every third month.

In the graphs that follow, sample size (n) is provided for each geometric mean calculated and graphed.

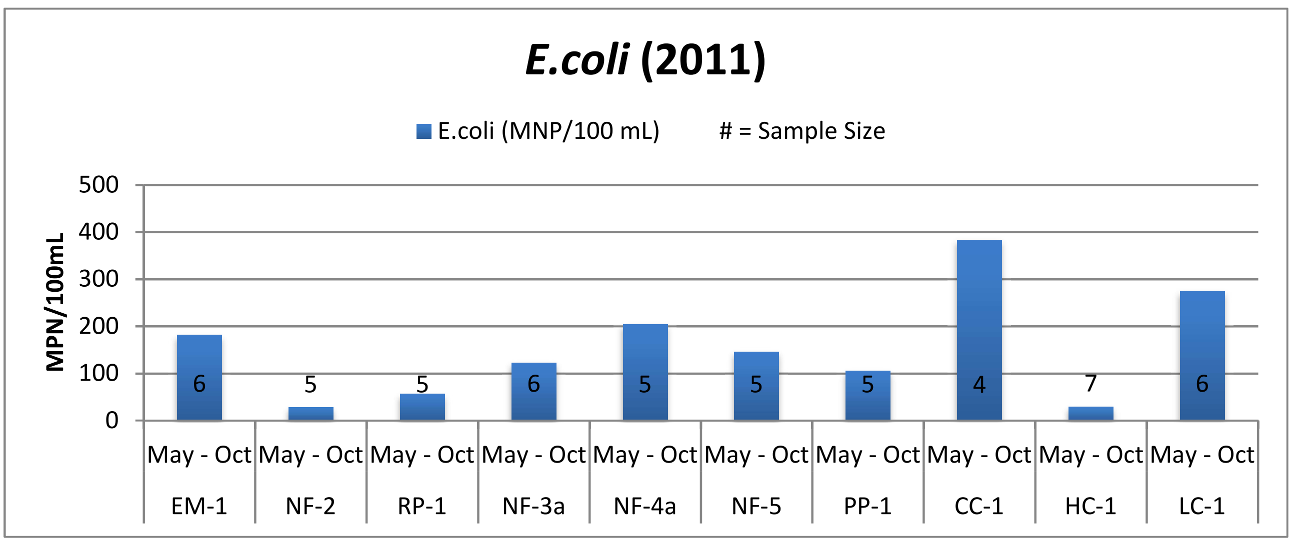


Figure 8-3 Seasonal Geometric Mean of *E. coli* in the North Fork, 2011

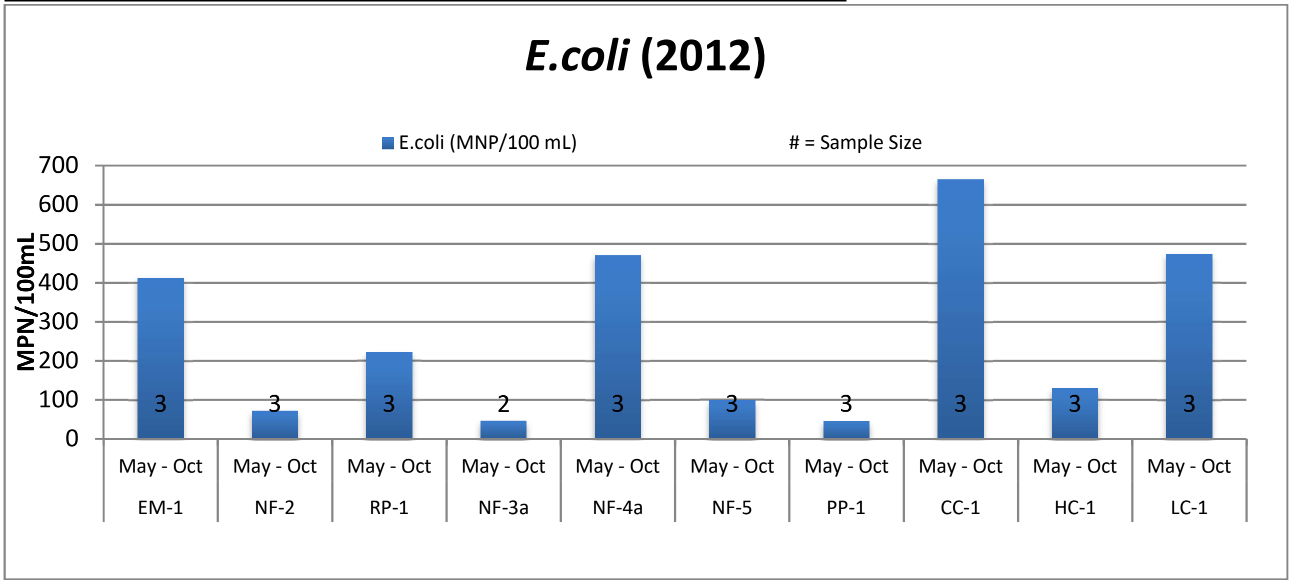


Figure 8-4 Seasonal Geometric Mean of *E. coli* in the North Fork, 2012

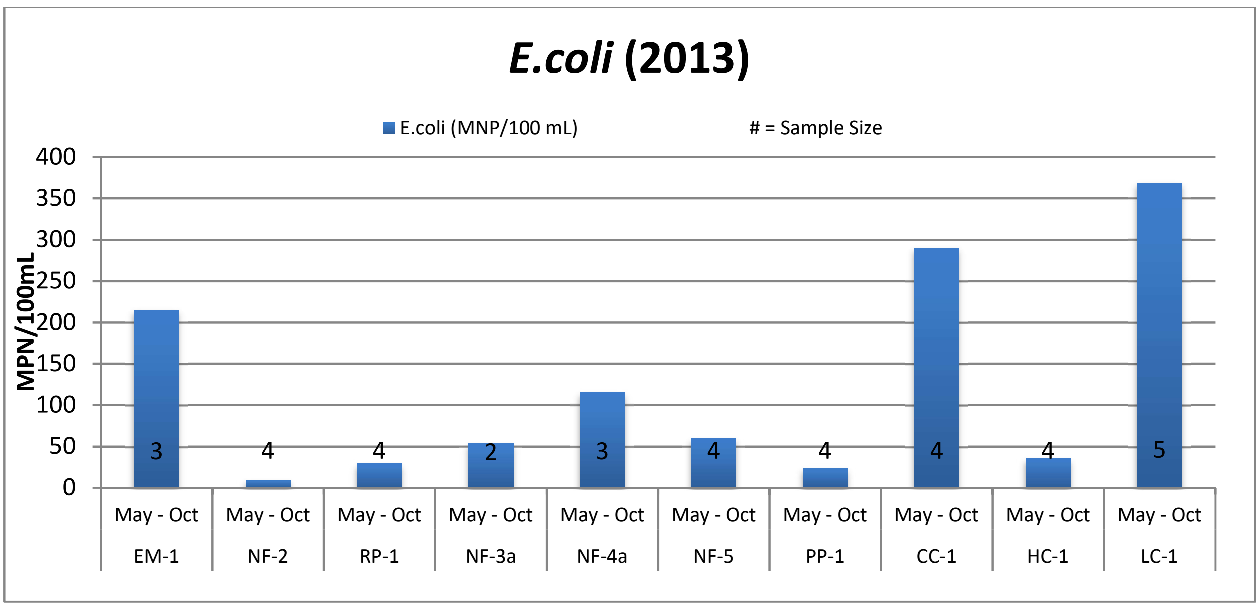


Figure 8-5 Seasonal Geometric Mean of *E. coli* in the North Fork, 2013

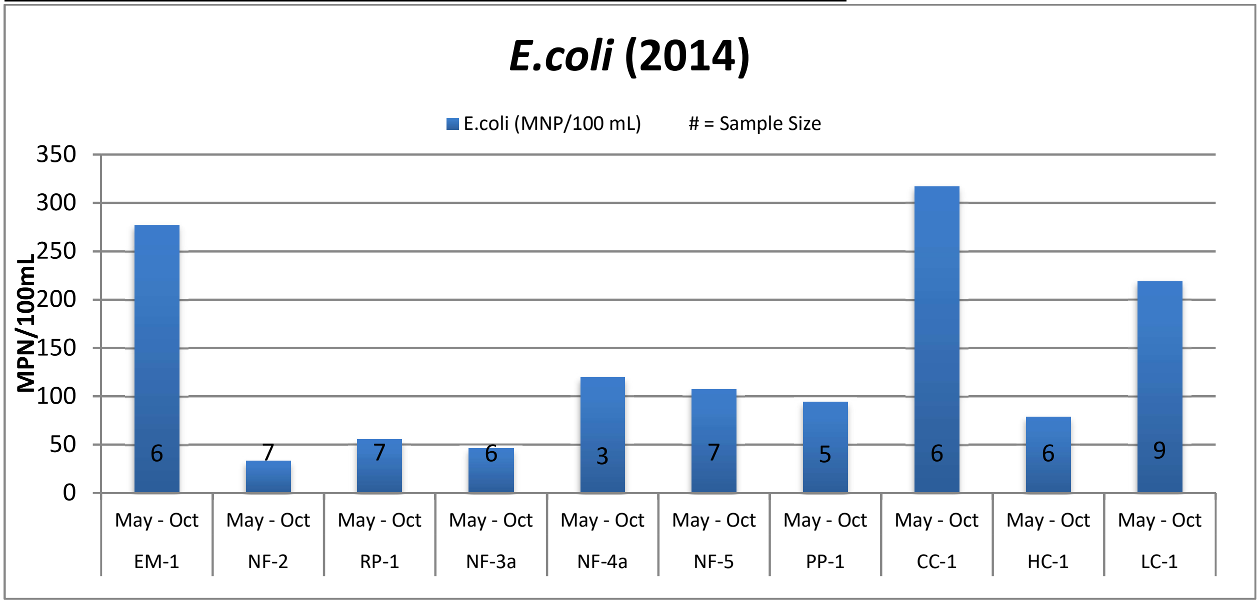


Figure 8-6 Seasonal Geometric Mean of *E. coli* in the North Fork, 2014

E. coli was consistently above the natural swimming area standard (235 organisms/mL) at East Muddy Creek (EM-1), Cottonwood Creek (CC-1) and Leroux Creek (LC-1) for the last five years of sampling, but there is little or no primary contact recreation in these streams. NF-4a on the North Fork, a location where primary contact recreation (boating) occurs, also exceeded the recreation standard in 2011 and 2012. Because sample size is less than desired, more sampling is needed at these stations in order to better assess the frequency of exceedances.

9. MACROINVERTEBRATE DATA

Biological monitoring focuses on the aquatic organisms that live in streams and rivers. Changes that occur in the number and types of organisms present in a stream system may indicate the effects of human activity in a stream. Biological monitoring is based on the fact that different species react to pollution in different ways. Pollution-sensitive organisms are more susceptible to the effects of physical or chemical changes in a stream than other organisms. These organisms act as indicators of the absence of pollution. Pollution-tolerant organisms are less susceptible to changes in the environment and act as an indirect measure of pollution. Pollution-sensitive organisms will decrease in number or disappear in polluted streams, while pollution-tolerant organisms will increase in number and variety.

Benthic macroinvertebrates are animals without backbones that are large enough to see with the naked eye and live on the river bottom. Macroinvertebrates are commonly used as water quality indicators because they are easy to sample, continuous indicators and sit near the bottom of the aquatic food web.

Macroinvertebrates were sampled ten times between October 2004 and October 2013. Network volunteers collected macroinvertebrates using the River Watch rocky substrate collection method. Samples were collected from the kick net and sent to the River Watch laboratory in Fort Collins for professional analysis.

Table 17 summarizes seven common metrics uses to evaluate macroinvertebrate communities. The table briefly defines each metric and indicates how the predicted community response to disturbance. Note that samples were collected at different stations in different years.

Overall, the metrics indicate that the North Fork has a healthy and thriving macroinvertebrate community. There are no major differences in community structure and abundance between stations, as indicated by the total number of organisms and taxa richness. This suggests that the biological community has not experienced any significant disturbance. The metrics that evaluate pollution tolerance include the percent of ephemeroptera, plecoptera and trichoptera species (% EPT) and the Hilsenhoff Biotic Index (HBI), developed by Hilsenhoff (1988), indicate that the macroinvertebrate community is relatively intolerant of pollution. Nearly half of the macroinvertebrates collected are pollution-sensitive EPT taxa and the HBI values indicate good to excellent water quality.

The trophic structure in streams is often defined in comparison to the River Continuum Concept (RCC). The RCC describes the longitudinal changes that occur in a river as related to differences in size and terrestrial setting. The RCC is particularly useful for describing how ecological function varies along riverine ecosystems. Figure 9-1 illustrates the distribution of functional feeding groups at stations in the North Fork. The North Fork, a 4th order stream, functions like a RCC mid-order stream. This is expected because the North Fork does not have a wooded riparian zone to contribute shade and allochthonous material to the system. The distribution of functional feeding groups (e.g. high percentage of collectors and scrapers) suggests that the North Fork has a variety of energy inputs and is partially autotrophic.

Table 17 Evaluation Matrix of North Fork Macroinvertebrates

Metric	NF-1 10/04	NF-3 10/04	NF-4a 11/05	NF-3a 10/07	NF-3a 12/08	NF-3a 10/09	NF-3a 10/10	NF-3a 10/11	NF-3a 10/12	NF-3a 10/13	Interpretation	Predicted response to increasing disturbance
Community Structure and Abundance												
Total # of organisms	344	321	324	321	620	636	373	356	314	317	Organism density is variable and affected by loss of habitat, low pH and toxic substances	Decrease
Taxa Richness	7	7	8	6							Measures diversity.	Decrease
Pollution Tolerance												
% EPT	59%	45%	39%	53%	71%	65%	71%	78%	75%	56%	Summarizes taxa richness within the orders Ephemeroptera, Plecoptera and Trichoptera (groups considered to be pollution sensitive)	Decrease
HBI	3.04	4.64	3.6	1.81							Summarizes overall pollution tolerance to organic and sediment pollution (above 5.5= poor water quality)	Increase
Trophic Structure												
% Scrapers	18%	15%	13%	26%	13%	2%	1%	2%	2%	1%	Reflects riffle community food base, indicates availability of periphyton. Will decrease following sediment and organic pollution.	Decrease
% Collectors/ Filterers	53%	14%	16%	12%	62%	59%	65%	59%	68%	63%	Filter feeders increase in response to fine particulate organic matter (FPOM). Filter feeders can be sensitive to toxicants bound to FPOM.	Variable

Functional Feeding Groups for Macroinvertebrates in the North Fork

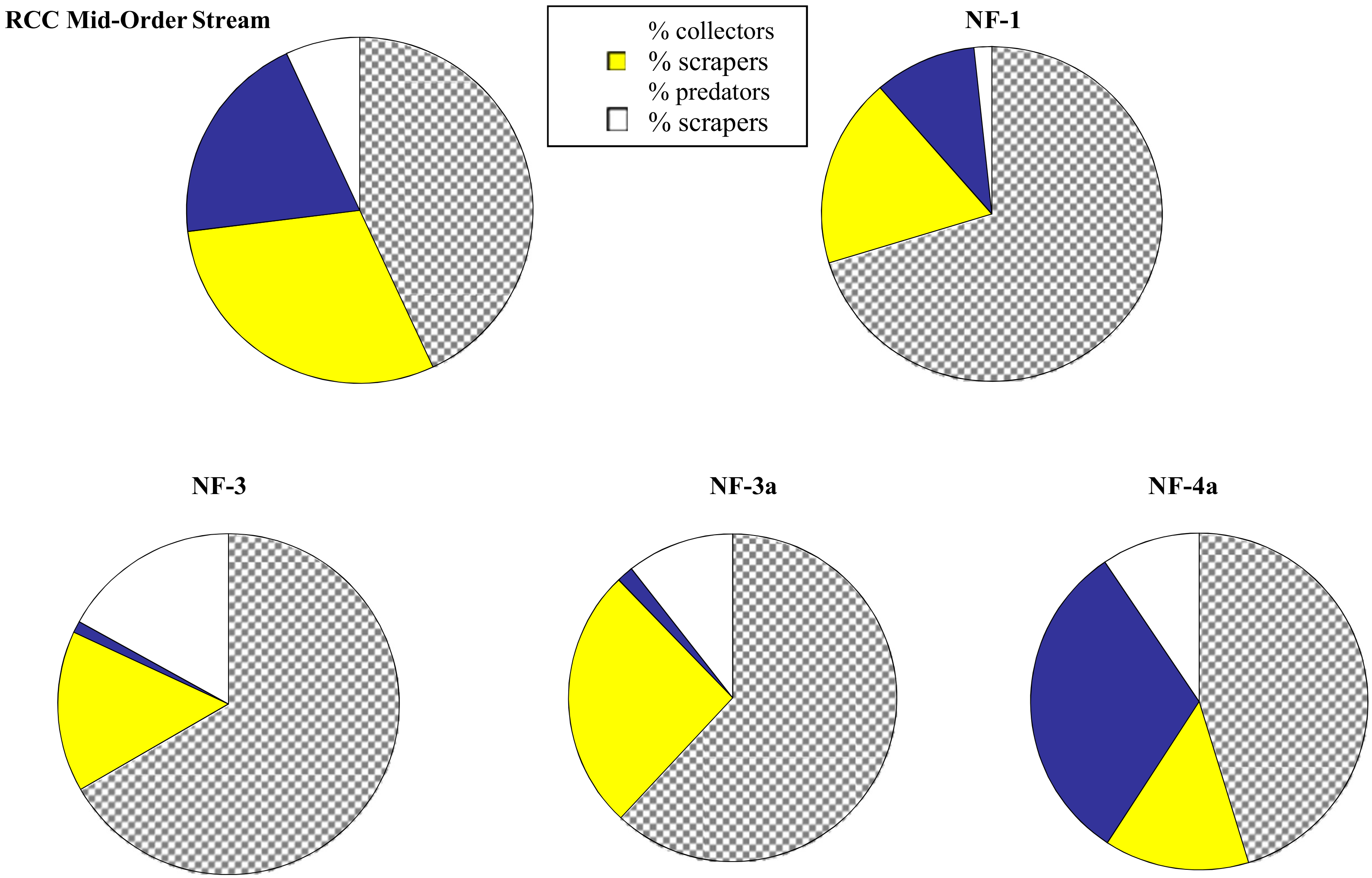


Figure 9-1: Functional Feeding Groups in the North Fork

10. LONG TERM TRENDS AND SEASONAL VARIABILITY

In general, the North Fork Watershed exhibits seasonal variability and lacks any particular long-term trends during the time of sampling.

Conductivity measurements indicate that concentrations of TDS were at their lowest during spring runoff/snowmelt season and then increased through the summer as runoff decreased and ground water and irrigation return flows become the dominant source of water to the river. For many parameters, the increased flows associated with spring runoff correlate with lower concentration values due to dilution. For example, sulfate had the lowest concentrations during times when snowmelt was the dominant source of water and highest concentrations during times when the dominant source of water to the river is ground water and irrigation return flows. Sulfate, like the other parameters, did not exhibit any particular long-term trend during the time of sampling beyond the seasonal variability described above.

While TDS decreases during spring runoff/snowmelt season indicates lower concentrations of salts, metals, minerals, etc., concentrations for parameters such as total phosphorus and iron increased during times of higher flows and decreased during lower flows. This is because both phosphorus and iron bind tightly with sediment particles in the water that increase with runoff events typical of spring. Accordingly, total suspended solids concentrations typically increase during high flow events. As TSS increases and decreases, parameters like iron and phosphorus that bind to sediment exhibit corresponding concentration increases and decreases.

Total phosphorus (TP) concentrations increased in the spring during snowmelt/spring runoff and decreased during low flow conditions in the late summer/fall. These concentrations correlate with the concentration of total suspended solids as TP binds tightly with sediments, metal oxides and hydroxides under aerobic conditions. This correlation is illustrated by Figure 10-1.

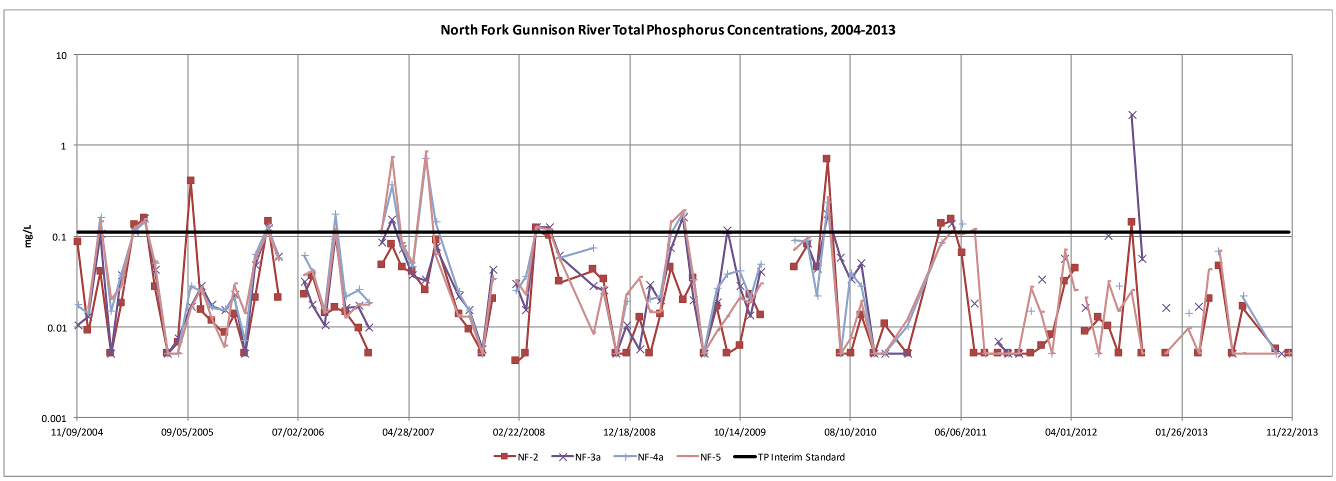


Figure 10-1: Total Phosphorus Concentrations

There is some seasonality reflected in sampled iron concentrations, which increase during times of higher flow. However, there is not a clear relationship. This is likely because there are many contributing sources including storm and snowmelt runoff, ground water inflow, and potentially irrigation return flows at different locations that inhibit not only a clear seasonal trend but also any clear trend in concentration upstream to downstream. Iron concentrations are illustrated in Figure 10-2.

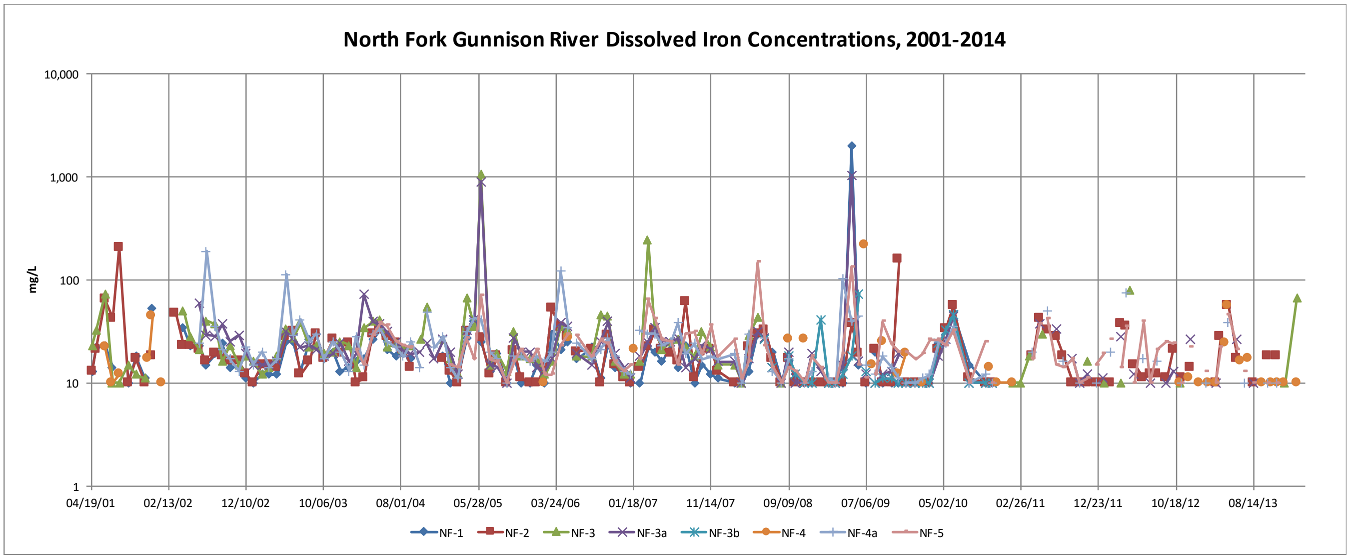


Figure 10-2: Dissolved Iron Concentrations

11. CONCLUSIONS

The water quality data presented in this report were not collected for compliance or regulatory purposes; rather these data are designed to give background information on water quality conditions in the watershed, help water users understand seasonal and natural variation within the watershed, and provide a basic understanding of how the water quality of the North Fork Gunnison River compares to state stream standards.

The North Fork Watershed exhibits seasonal variability and lacks any particular long term trends. Parameters concentrations typically decrease during times of high flows and increase during times of low flows. Parameters such as TP and iron exhibit an opposite seasonal trend, increasing during times of high flows and decreasing during times of low flows. Besides these seasonal trends, the North Fork's lack of long term trends indicates that human-caused effects have not obviously degraded nor improved water quality during this time. One potential exception to this may regard selenium; however, there were not useable data after 2006 to make any conclusions that might relate to the work of the Selenium Taskforce and other salinity control efforts.

Water quality samples collected by the Network between 2001 and 2014 indicated that overall, the North Fork Gunnison River has excellent to good water quality in the upper watershed and excellent to moderate water quality in the lower watershed largely due to natural sources that increase metal and dissolved solids concentrations in the lower portions of the watershed. Increases in concentrations as water travels downstream are a reflection of the natural soils and geology of the North Fork Valley. Hubbard Creek has excellent water quality, and Leroux Creek and Surface Creek have excellent to good water quality. Tongue Creek and Lower Cottonwood Creek have moderate to poor water quality, depending on flow.

Field Parameters

The geology and natural soils of the watershed provide the North Fork with the capacity to buffer against changes in pH and the toxic effects of metals to aquatic life. The North Fork watershed has water that is slightly basic and pH values are within an acceptable range for aquatic life. The alkaline character of the water decreases the solubility of many of the toxic metals that are present in the North Fork. Buffering capacity, as measured by hardness and alkalinity, was highest at downstream locations. Local geology and irrigation return flows are likely the sources of the parameters that contribute to hardness and alkalinity. Conductivity reflects seasonal variability that is dependent on the dominant source of water to the river, and conductivity increases from upstream to downstream stations.

Nutrients and Other Inorganic Parameters

In general, nutrient concentrations are well below state and/or federal standards indicating there are no significant nutrient problems in the North Fork Watershed. The exception is sulfate, with concentrations near Hotchkiss routinely exceeding the secondary drinking water standard.

Metals

The water quality data indicate that metals are not a significant concern in the North Fork watershed, with the exception of selenium. Concentrations of other metals have seldom exceeded applicable water quality standards. Maximum dissolved iron concentrations exceeded water supply standards at some stations, although average concentrations were below the water supply standard. Average concentrations for dissolved selenium exceeded the chronic standard at most stations from 2001 to 2006; after 2006, the selenium laboratory results were not useable.

Bacteria

The presence of *E. coli* in aquatic environments indicates that water has been contaminated with fecal materials from sewage and/or animal waste. When sampled year-round, *E. coli* values were highest during summer months.

Macroinvertebrates

Overall, the North Fork has a healthy and thriving macroinvertebrate community. The metrics that evaluate pollution tolerance, % EPT and HBI, indicate that the macroinvertebrate community is relatively intolerant of pollution. Nearly half of the macroinvertebrates collected are pollution-sensitive EPT taxa and the HBI values indicate moderate to good water quality.

12. WORKS CITED

Cohen, Andrew. 2004. Calcium Requirements and the Spread of Zebra Mussels. San Francisco Estuary Institute. Available at: http://repositories.cdlib.org/csgc/rp/PPInvSp04 01.
Colorado Department of Public Health and Environment, Water Quality Control Commission. 2016. Regulation 31: The Basic Standards and Methodologies for Surface Water. 5 CCR 1002-31.
Colorado Department of Public Health and Environment, Water Quality Control Commission. 2016. Regulation 35: Classifications and Numeric Standards for Gunnison and Lower Dolores River Basins. 5 CCR 1002-35.
Colorado Department of Public Health and Environment, Water Quality Control Commission. 2016. Regulation No. 93: Section 303(d) List Water-Quality-Limited Segments Requiring TMDLs. 5 CCR 1002-93.
Colorado Department of Public Health and Environment, Water Quality Control Commission. 2016. Regulation No. 93: Colorado's Section 303(d) List of Impaired Waters and Monitoring and Evaluation List 5 CCR 1002-93.
Corvallis, and USDA, Portland, OR. Pell, A. N. 1997. Manure and microbes: Public and animal health problem? J. Dairy Sci. 80:2673-2681.
Food and Agriculture Organization of the United Nations (FAO). 2003. Agricultural Drainage Water Management in Arid and Semi-Arid Areas. FAO Irrigation and Drainage Paper 61. Available at: http://www.fao.org/docrep/005/y4263e/y4263e00.htm#Contents.
Gunnison Basin Selenium Task Force. 2009. What is the Problem with Selenium? Available at: http://www.seleniumtaskforce.org/aboutselenium/whatistheproblem.html.
Hem, J.D. 1992. Study and interpretation of chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254.
Hilsenhoff, W.L. 1988. Rapid Field Assessment of Organic Pollution with a Family Level Biotic Index. Journal of the North American Benthological Society 7:65-68.
Liebermann, Timothy D. 1989. Characteristics and Trends of Streamflow and Dissolved Solids in the Upper Colorado River Basin, Arizona, Colorado, New Mexico, Utah, and Wyoming. Washington, D.C.: U.S. Dept. of the Interior, U.S. Geological Survey. Web. 28 Oct. 2016.
Michigan Department of Environmental Quality. 2018. Total Suspended Solids. Available at: http://www.michigan.gov/documents/deq/wrd-npdes-water-quality_570237_7.pdf.
Moore, J. A., J. Smyth, S. Baker, and J. R. Miner. 1988. Evaluating coliform concentrations in runoff from various animal waste management systems. Special Report 817. Agricultural Experiment Stations Oregon State University.
Mueller, David K. and Helsel, Dennis R. 1999. "Nutrients in the Nation's Waters--Too Much of a Good Thing?" U.S. Geological Survey Circular 1136. National Water-Quality Assessment Program. Available at: http://water.usgs.gov/nawqa/circ-1136.html.
Rivers of Colorado Water Watch Network. Raw data from 2001 through 2014. Available at: http://wildlife.state.co.us/riverwatch/
Rivers of Colorado Water Watch Network. Water Quality Sampling Manual. Available at: http://wildlife.state.co.us/riverwatch/
Sherer, B. M., J. R. Miner, J. A. Moore, and J. C. Buckhouse. 1992. Indicator bacterial survival in stream sediments. J. Environ. Qual. 21:591-595.
U.S. Environmental Protection Agency (EPA). Region 8. Raw bacteria data from 2004 through 2014.
US Geological Survey (USGS). Real Time flow data from 2001 through 2014. Available at: http://waterdata.usgs.gov/nwis/rt
US Geological Survey (USGS). Southwest Regional Gap Analysis Project. Gap Analysis Program. Land Cover Data.
Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems. Third Edition. Academic Press.

13. APPENDICES

A. **2001 to 2014 Water Quality Results**
B. **CDPHE WQCC Regulation No. 31**
C. **CDPHE WQCC Regulation No. 35**
D. **Hydrographs**

A. 2001 to 2014 Water Quality Results

The data gathered by the North Fork Volunteer Water Quality Monitoring Network is available online at the Western Slope Conservation Center's website or by request. Please call (970) 527-5307 and the Conservation Center will send you the data.

B. CDPHE WQCC Regulation No. 31

Below include Colorado standards for specific physical, biological, inorganic, and metal parameters. Additional information regarding these standards can be found in the Colorado Department of Public Health and Environment's Water Quality Control Commission Regulation No. 31.

TABLE I PHYSICAL AND BIOLOGICAL PARAMETERS									
Parameter	Recreational			Aquatic Life			Agriculture	Domestic Water Supply	
	CLASS E (Existing Primary Contact) and CLASS U (Undetermined Use)	CLASS P (Potential Primary Contact Use)	CLASS N (Not Primary Contact Use)	CLASS 1 COLD WATER BIOTA	CLASS 1 WARM WATER BIOTA	CLASS 2			
PHYSICAL									
D.O. (mg/l)[1][9]	3.0(A)	3.0(A)	3.0(A)	6.0[2](G) 7.0(spawning)	5.0[2](G)	5.0(A)	3.0(A)	3.0(A)	
pH (Std. Units)[3]	6.5–9.0 (Bm)	6.5–9.0 (Bm)	6.5–9.0 (Bm)	6.5–9.0(A)	6.5–9.0(A)	6.5–9.0(A)		5.0–9.0(A)	
Suspended Solids[4]									
Temperature (°C) [5]				**Rivers & Streams:** **Tier I[a]:** June-Sept = 17.0 (ch), 21.7(ac) Oct –May = 9.0 (ch), 13.0 (ac) **Tier II[b]:** Apr-Oct =18.3 (ch), 23.9 (ac) Nov-Mar =9.0 (ch), 13.0 (ac) **Lakes & Res:** Apr-Dec = 17.0 (ch), 21.2 (ac) Jan-Mar = 9.0 (ch), 13.0 (ac) **Large Lakes & Res[c]:** Apr-Dec = 18.3(ch), 23.8 (ac) Jan-Mar = 9.0(ch), 13.0 (ac)	**Rivers & Streams:** **Tier I[d]:** Mar-Nov = 24.2(ch), 29.0 (ac) Dec-Feb= 12.1(ch), 14.5(ac) **Tier II[e]:** Mar-Nov= 27.5(ch), 28.6(ac) Dec-Feb=13.8 (ch), 14.3 (ac) **Tier III[f]:** Mar-Nov = 28.7 (ch), 31.8 (ac) Dec-Feb = 14.3 (ch), 15.9 (ac) **Lakes & Res:** Apr-Dec = 26.3 (ch), 29.5 (ac) Jan-Mar = 13.2 (ch), 14.8 (ac)	Same as Class 1			

WSCC Volunteer Water Quality Monitoring Data Report

TABLE II INORGANIC PARAMETERS

PARAMETER	AQUATIC LIFE					AGRICULTURE	DOMESTIC WATER SUPPLY
	CLASS 1 Cold Water Biota		CLASS 1 Warm Water Biota		CLASS 2		
INORGANICS:							
Ammonia (mg/l as N) Total	chronic = elsp or elsa [1] acute = sp [1] (N)		chronic = Apr 1-Aug 31=elsp[1] Sept 1-Mar 29=elsa[1] acute = sa[1] (N)		Class 2 Cold/Warm have the same standards as Class 1 Cold/Warm (N)		
Total residual Chlorine (mg/l)	0.019 (L) (1-day)	0.011 (L) (30-day)	0.019 (L) (1-day)	0.011 (L) (30-day)	0.011 (L) (30-day)		
Cyanide - Free (mg/l)	0.005(H) (1-day)		0.005(H) (1-day)		0.005(H) (1-day)	0.2(G) (1-day)	0.2(B,D[m]) (1-day)
Fluoride (mg/l)							2.0[3](E) (1-day)
Nitrate (mg/l as N)						100(4)(B)	10[4](K) (1-day)
Nitrite (mg/l as N)	TO BE ESTABLISHED ON A CASE BY CASE BASIS (3)				A CASE BY CASE BASIS [3]	10(2)(B) (1-day)	1.0(2)[4](K) (1-day)
Sulfide as H_2S (mg/l)	0.002 undissociated(A) (30-day)		0.002 undissociated(A) (30-day)		0.002 undissociated(A) (30-day)		0.05(F) (30-day)
Boron (mg/l)						0.75(A,B) (30-day)	
Chloride (mg/l)							250(F) (30-day)
Sulfate (mg/l)							250(F) (30-day)
Asbestos							7,000,000 fibers/L[5]

NOTE: Capital letters in parentheses refer to references listed 31.16(3); numbers in parentheses refer to table II footnotes.

TABLE III METAL PARAMETERS (Concentration in ug/l)

METAL[1]	AQUATIC LIFE[1][3][4][J]		AGRICULTURE[2]	DOMESTIC WATER-SUPPLY[2]	WATER + FISH[7]	FISH INGESTION[10]
	ACUTE	CHRONIC				
Aluminum	$e^{(1.3695[\ln(\text{hardness})]+1.8308)}$ (tot.rec.)	87 or $e^{(1.3695[\ln(\text{hardness})]-0.1158}$ (tot.rec.)[11]			---	---
Antimony				6.0 (30-day)	5.6	640
Arsenic	340	150	100[A] (30-day)	0.02 – 10[13] (30-day)[14]	0.02	7.6
Barium				1,000[E](1-day) 490 (30-day)	---	---
Beryllium			100[A,B] (30-day)	4.0 (30-day)	---	---
Cadmium	$(1.136672-[\ln(\text{hardness})\times(0.041838)])\times e^{0.9151[\ln(\text{hardness})]-3.1485}$ (Trout)= $(1.136672-[\ln(\text{hardness})\times(0.041838)])\times e^{0.9151[\ln(\text{hardness})]-3.6236}$	$(1.101672-[\ln(\text{hardness})\times(0.041838)])\times e^{0.7998[\ln(\text{hardness})]-4.4451}$	10[B] (30-day)	5.0[E] (1-day)	---	---
Chromium III[5]	$e^{(0.819[\ln(\text{hardness})]+2.5736)}$	$e^{(0.819[\ln(\text{hardness})]+0.5340)}$	100[B] (30-day)	50[E] (1-day)	---	---
Chromium VI[5]	16	11	100[B] (30-day)	50[E] (1-day)	100(30-day)	---
Copper	$e^{(0.9422[\ln(\text{hardness})]-1.7408)}$	$e^{(0.8545[\ln(\text{hardness})]-1.7428)}$	200[B]	1,000[F] (30-day)	1,300	---
Iron		1,000(tot.rec.)[A,C]		300(dis)[F] (30-day)	---	---
Lead	$(1.46203-[(\ln(\text{hardness})*(0.145712)])*e^{(1.273[\ln(\text{hardness})]-1.46)}$	$(1.46203-[(\ln(\text{hardness})*(0.145712)])*e^{(1.273[\ln(\text{hardness})]-4.705)}$	100[B] (30-day)	50[E] (1-day)	—	---
Manganese	$e^{(0.3331[\ln(\text{hardness})]+6.4676)}$	$e^{(0.3331[\ln(\text{hardness})]+5.8743)}$	200[B] (30-day)[12]	50(dis)[F] (30-day)	—	---
Mercury		FRV(fish)[6] = 0.01 (Total)		2.0[E] (1-day)	—	---
Molybdenum			300[O] (30-day)[16]	210 (30-day)		

TABLE III METAL PARAMETERS (Concentration in ug/l)						
METAL[(1)]	AQUATIC LIFE[(1)(3)(4)(J)]		AGRICULTURE[(2)]	DOMESTIC WATER-SUPPLY[(2)]	WATER + FISH[(7)]	FISH INGESTION[(10)]
	ACUTE	CHRONIC				
Nickel	$e^{(0.846[\ln(hardness)]+2.253)}$	$e^{(0.846[\ln(hardness)]+0.0554)}$	200[(B)] (30-day)	100[(E)] (30-day)	610	4,600
Selenium[(9)]	18.4	4.6	20[(B,D)] (30-day)	50[(E)] (30-day)	170	4,200
Silver	$\frac{1}{2}e^{(1.72[\ln(hardness)]-6.52)}$	$e^{(1.72[\ln(hardness)]-9.06)}$ (Trout) = $e^{(1.72[\ln(hardness)]-10.51)}$		100[(F)] (1-day)	—	---
Thallium		15[(C)]		0.5 (30-day)	0.24	0.47
Uranium[(17)]	$e^{(1.1021[\ln(hardness)]+2.7088)}$	$e^{(1.1021[\ln(hardness)]+2.2382)}$		16.8 – 30[(13)] (30-day)	---	---
Zinc	$0.978*e^{(0.9094[\ln(hardness)]+0.9095)}$	$0.986*e^{(0.9094[\ln(hardness)]+0.6235)}$ (sculpin)[(15)] = $e^{(2.140[\ln(hardness)]-5.084)}$	2000[(B)] (30-day)	5,000[(F)] (30-day)	7,400	26,000
NOTE: Capital letters in parentheses refer to references listed in section 31.16(3); Numbers in parentheses refer to Table III footnote						

C. CDPHE WQCC Regulation No. 35 Classifications and Numeric Standards for Gunnison And Lower Dolores River Basins

The selected formulas below present standards for stream segments in the Gunison and Lower Dolores River Basins for various parameters examined in this report. Additional information regarding these standards can be found in the Colorado Department of Public Health and Environment's Water Quality Control Commission Regulation 35.

(3) Table Value Standards

In certain instances in the tables in Appendix 35-1, the designation "TVS" is used to indicate that for a particular parameter a "table value standard" has been adopted. This designation refers to numerical criteria set forth in the Basic Standards and Methodologies for Surface Water. The criteria for which the TVS are applicable are on the following table.

TABLE VALUE STANDARDS

(Concentrations in µg/l unless noted)

PARAMETER[(1)]	TABLE VALUE STANDARDS [(2)(3)]
Aluminum (Trec)	Acute = $e^{(1.3695[\ln(hardness)]+1.8308)}$ pH equal to or greater than 7.0 Chronic=$e^{(1.3695[\ln(hardness)]-0.1158)}$ pH less than 7.0 Chronic= $e^{(1.3695[\ln(hardness)]-0.1158)}$ or 87, whichever is less
Copper	Acute = $e^{(0.9422[\ln(hardness)]-1.7408)}$ Chronic = $e^{(0.8545[\ln(hardness)]-1.7428)}$
Lead	Acute = $(1.46203-[(\ln(hardness)*(0.145712)])*e^{(1.273[\ln(hardness)]-1.46)}$ Chronic = $(1.46203-[(\ln(hardness)*(0.145712)])*e^{(1.273[\ln(hardness)]-4.705)}$
Manganese	Acute = $e^{(0.3331[\ln(hardness)]+6.4676)}$ Chronic = $e^{(0.3331[\ln(hardness)]+5.8743)}$
Nickel	Acute = $e^{(0.846[\ln(hardness)]+2.253)}$ Chronic = $e^{(0.846[\ln(hardness)]+0.0554)}$
Selenium[(6)]	Acute = 18.4 Chronic = 4.6

Temperature

TEMPERATURE TIER	TIER CODE	SPECIES EXPECTED TO BE PRESENT	APPLICABLE MONTHS	TEMPERATURE STANDARD (^oC)	
				MWAT	DM
Cold Stream Tier 1	CS-I	brook trout, cutthroat trout	June – Sept.	17.0	21.7
			Oct. – May	9.0	13.0
Cold Stream Tier 2	CS-II	all other cold-water species	April – Oct.	18.3	23.9
			Nov. – March	9.0	13.0
Cold Lakes	CL	brook trout, brown trout, cutthroat trout, lake trout, rainbow trout, Arctic grayling, sockeye salmon	April – Dec.	17.0	21.2
			Jan. – March	9.0	13.0
Cold Large Lakes (>100 acres surface area)	CLL	rainbow trout, brown trout, lake trout	April – Dec.	18.3	23.8
			Jan. – March	9.0	13.0
Warm Stream Tier 2	WS-II	brook stickleback, central stoneroller, creek chub, longnose dace, Northern redbelly dace, finescale dace, razorback sucker, white sucker	March – Nov.	27.5	28.6
			Dec. – Feb.	13.8	14.3
Warm Stream Tier 3	WS-III	all other warm-water species	March – Nov.	28.7	31.8
			Dec. – Feb.	14.3	15.9
Warm Lakes	WL	black crappie, bluegill, common carp, gizzard shad, golden shiner, largemouth bass, Northern pike, pumpkinseed, sauger, smallmouth bass, spottail shiner, striped bass, tiger muskellunge, walleye, wiper, white bass, white	April – Dec.	26.3	29.5
			Jan. – March	13.2	14.8

Zinc

Acute = $0.978 * e^{(0.9094[\ln(hardness)]+0.9095)}$

Chronic = $0.986 * e^{(0.9094[\ln(hardness)]+0.6235)}$

Where hardness is less than 102 mg/L $CaCO^3$ and mottled scuplin are expected to be present:

Chronic (sculpin) = $e^{(2.140[\ln(hardness)]-5.084)}$

Ammonia [4]

Cold Water = (mg/l as N)Total

$$acute = \frac{0.275}{1 + 10^{7.204 - pH}} + \frac{39.0}{1 + 10^{pH - 7.204}}$$

$$chronic = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * MIN\left(2.85,\ 1.45 * 10^{0.028(25 - T)}\right)$$

Warm Water = (mg/l as N)Total

$$acute = \frac{0.411}{1 + 10^{7.204 - pH}} + \frac{58.4}{1 + 10^{pH - 7.204}}$$

$$chronic\ (Apr1 - Aug31) = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * MIN\left(2.85,\ 1.45 * 10^{0.028(25 - T)}\right)$$

$$chronic\ (Sep1 - Mar31) = \left(\frac{0.0577}{1 + 10^{7.688 - pH}} + \frac{2.487}{1 + 10^{pH - 7.688}} \right) * 1.45 * 10^{0.028 * (25 - MAX(T,\ 7))}$$

Cadmium

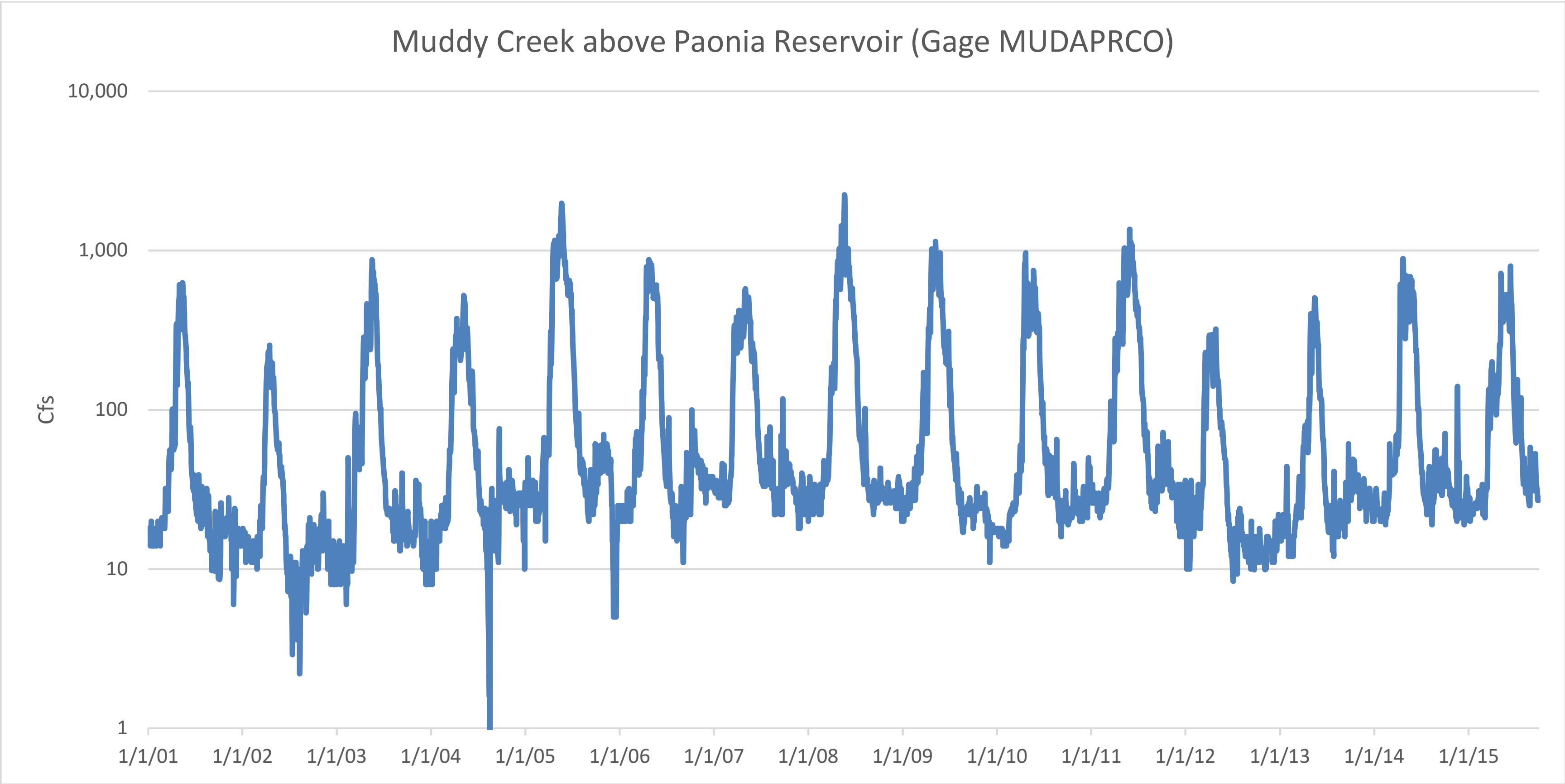
Acute = (1.136672-[ln(hardness) x (0.041838)])x $e^{0.9151[\ln(hardness)]-3.1485}$

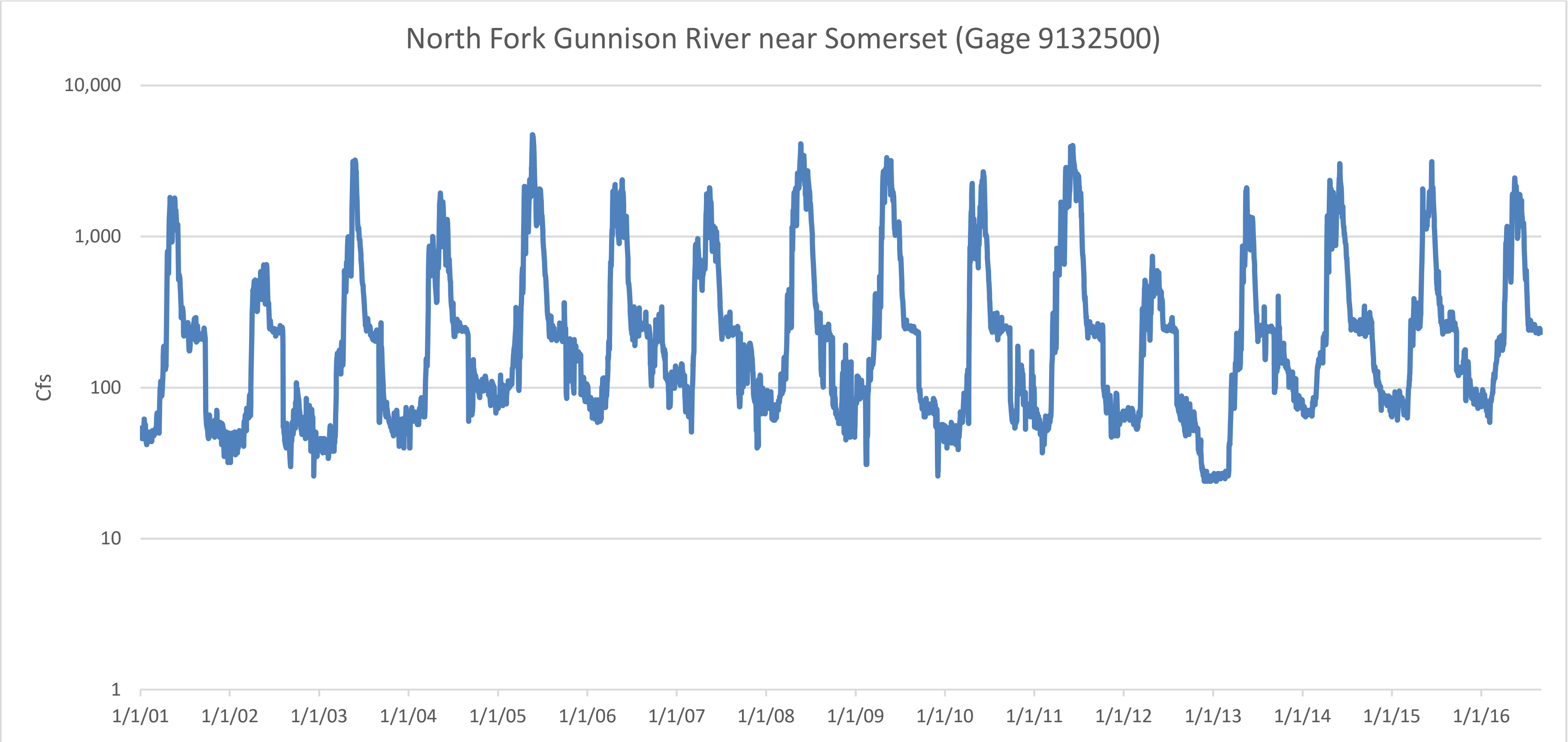
Acute(Trout) = (1.136672-[ln(hardness)x (0.041838)])x $e^{0.9151[\ln(hardness)]-3.6236}$

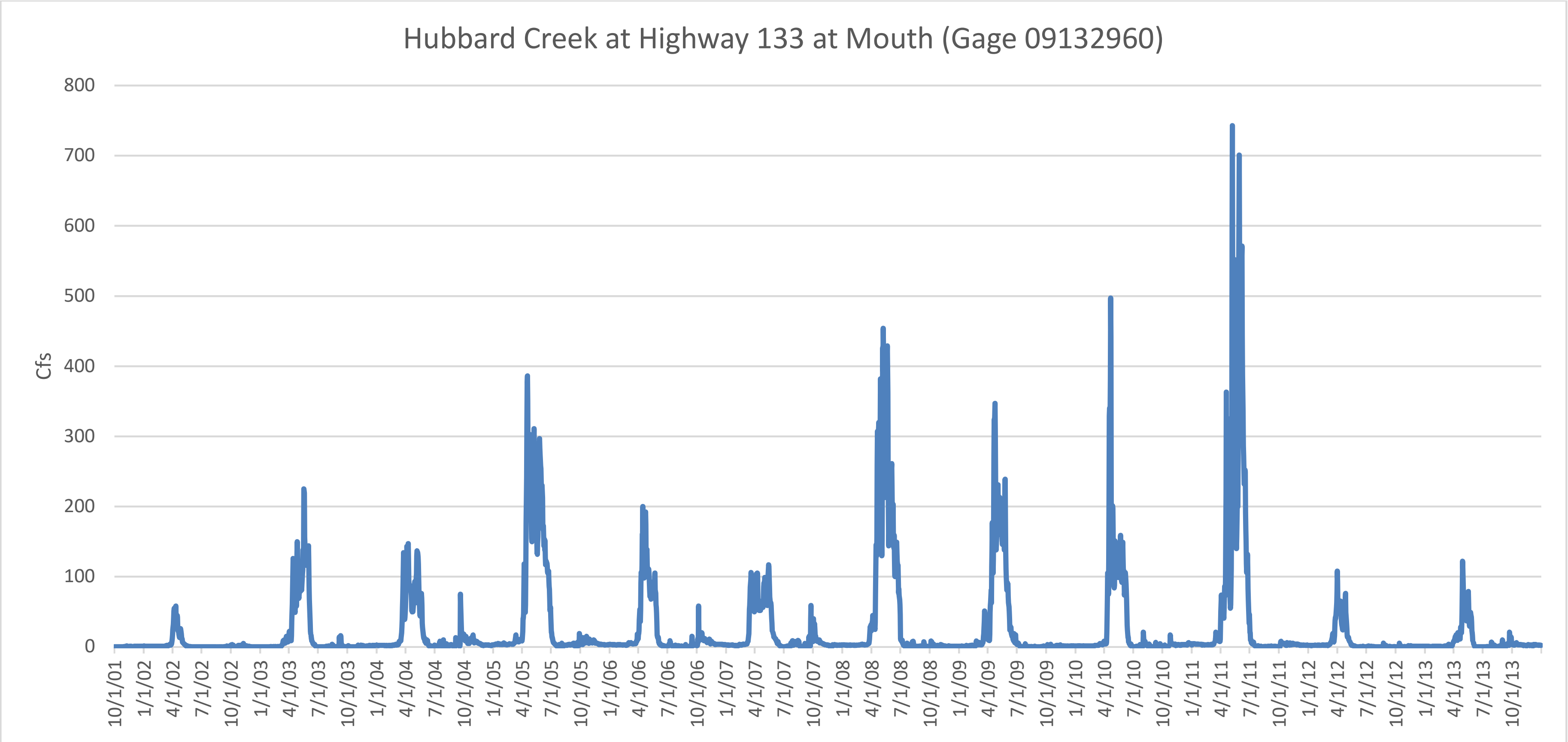
Chronic = (1.101672-[ln(hardness) x(0.041838)] x $e^{0.7998[\ln(hardness)]-4.4451}$

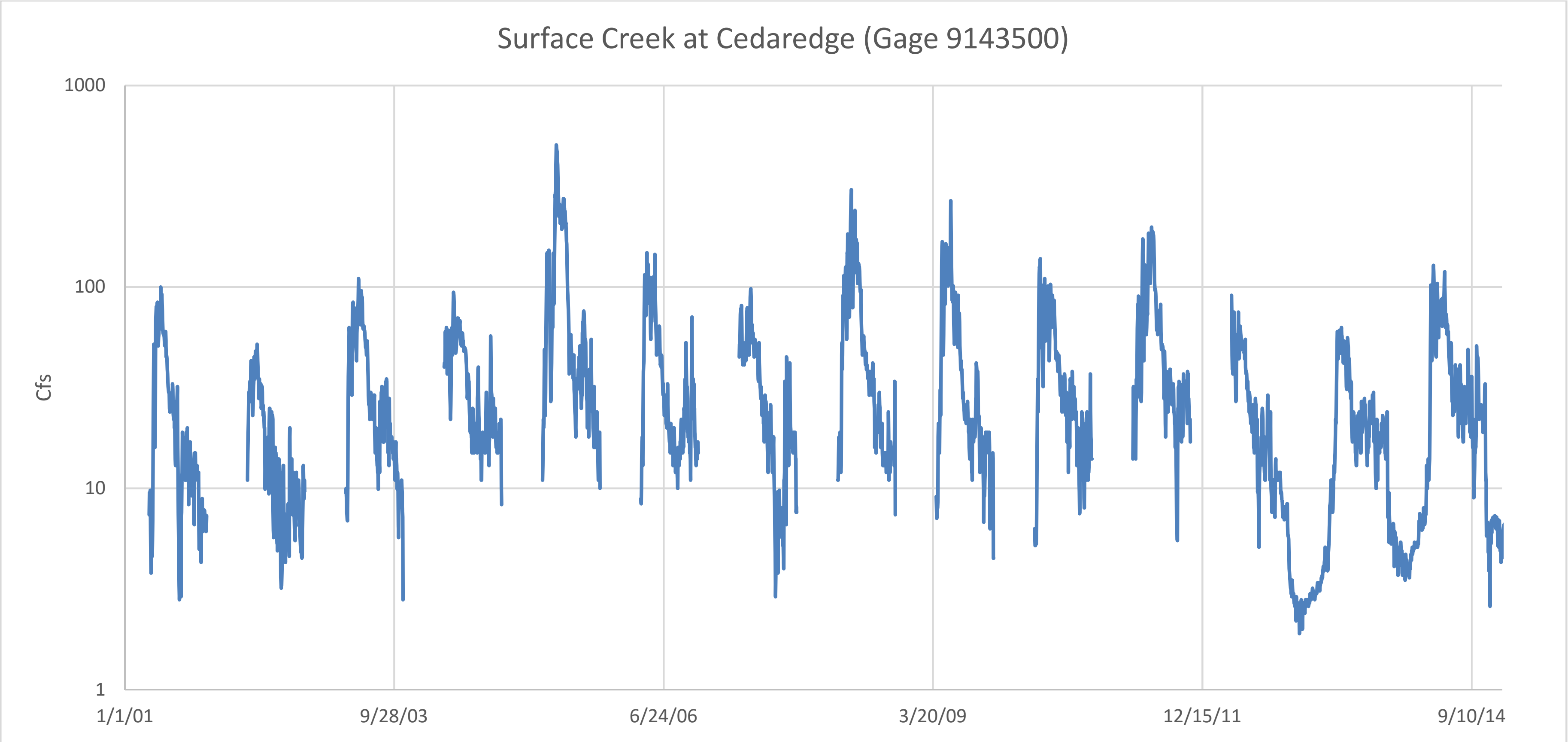
D. Hydrographs

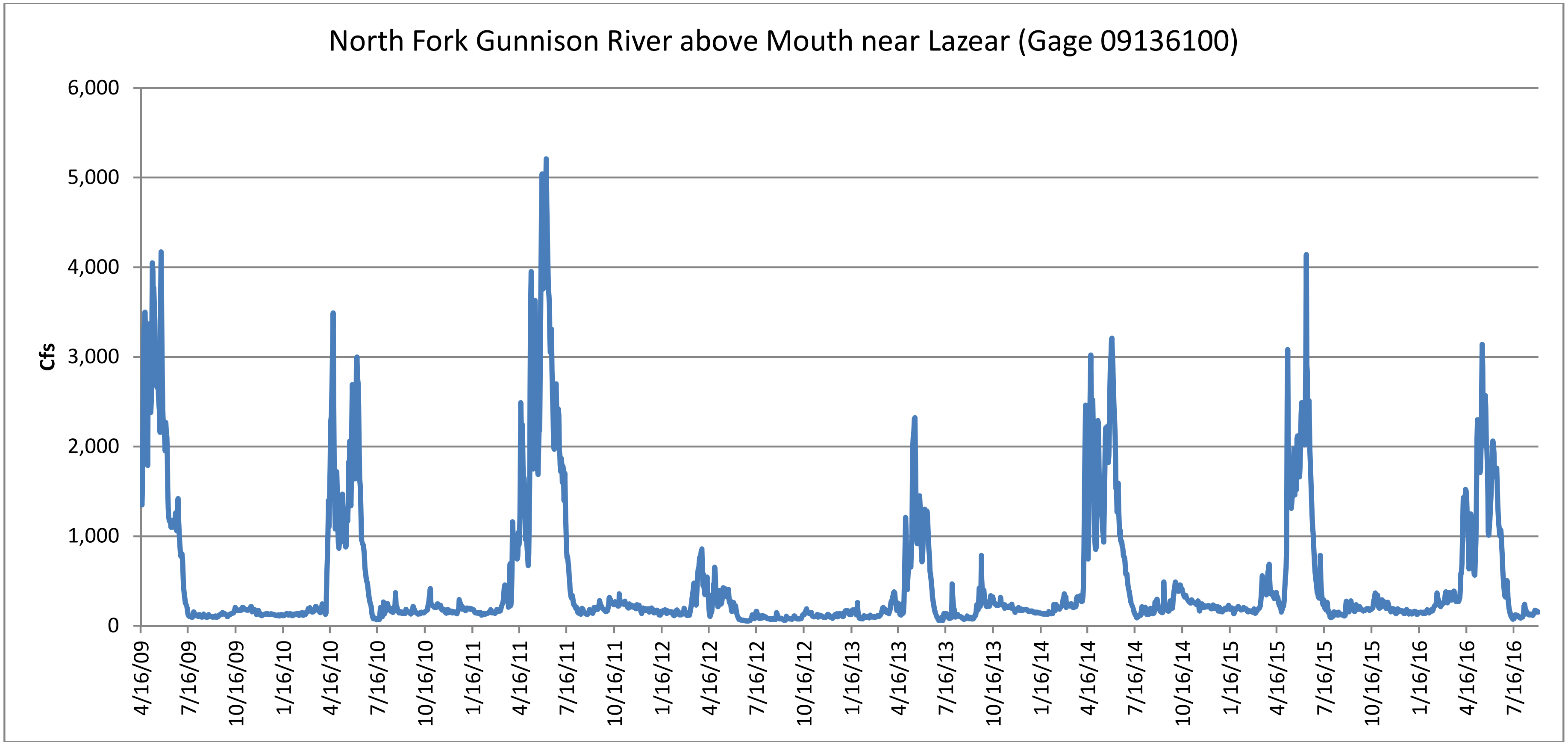
Included below are hydrographs with data gathered from USGS gaging stations within the North Fork of the Gunnison watershed. The hydrographs illustrate the mean daily discharge rates of flow.

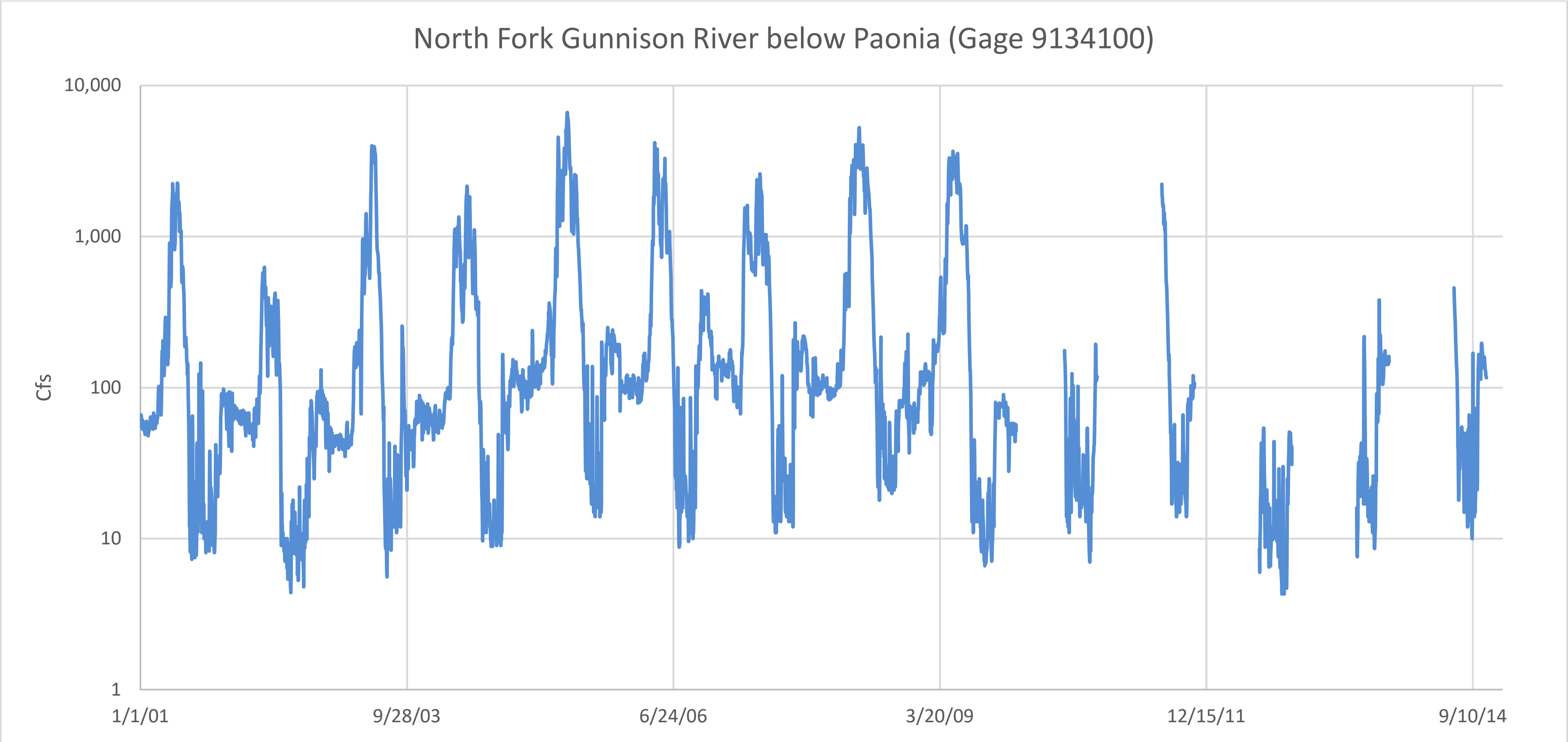



North Fork Gunnison River near Somerset (Gage 9132500)
Cfs
10,000
1,000
100
10
1
1/1/01
1/1/02
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13
1/1/14
1/1/15
1/1/16


Hubbard Creek at Highway 133 at Mouth (Gage 09132960)
Cfs
800
700
600
500
400
300
200
100
0
10/1/01
1/1/02
4/1/02
7/1/02
10/1/02
1/1/03
4/1/03
7/1/03
10/1/03
1/1/04
4/1/04
7/1/04
10/1/04
1/1/05
4/1/05
7/1/05
10/1/05
1/1/06
4/1/06
7/1/06
10/1/06
1/1/07
4/1/07
7/1/07
10/1/07
1/1/08
4/1/08
7/1/08
10/1/08
1/1/09
4/1/09
7/1/09
10/1/09
1/1/10
4/1/10
7/1/10
10/1/10
1/1/11
4/1/11
7/1/11
10/1/11
1/1/12
4/1/12
7/1/12
10/1/12
1/1/13
4/1/13
7/1/13
10/1/13


Surface Creek at Cedaredge (Gage 9143500)
1000
100
10
1
Cfs
1/1/01
9/28/03
6/24/06
3/20/09
12/15/11
9/10/14


North Fork Gunnison River above Mouth near Lazear (Gage 09136100)
Cfs
6,000
5,000
4,000
3,000
2,000
1,000
0
4/16/09
7/16/09
10/16/09
1/16/10
4/16/10
7/16/10
10/16/10
1/16/11
4/16/11
7/16/11
10/16/11
1/16/12
4/16/12
7/16/12
10/16/12
1/16/13
4/16/13
7/16/13
10/16/13
1/16/14
4/16/14
7/16/14
10/16/14
1/16/15
4/16/15
7/16/15
10/16/15
1/16/16
4/16/16
7/16/16


North Fork Gunnison River below Paonia (Gage 9134100)
10,000
1,000
100
10
1
Cfs
1/1/01
9/28/03
6/24/06
3/20/09
12/15/11
9/10/14