

Rifle Creek Watershed Assessment

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Prepared By



Sponsored By



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Executive Summary

This study, initiated in 2015, evaluates the health of the Rifle Creek watershed using water quality as the primary indicator.

Study Objectives. Key objectives of the study were to characterize water quality impairments, identify the source(s) of water quality impairments, recommend best management practices (BMPs) targeted to improve water quality, and identify suitable project sites for BMP implementation.

Water Quality Assessment. Selenium was a parameter of major concern at the onset of this investigation in 2015. Sampling results indicate it to be of minimal extent in surface waters throughout the Rifle Creek watershed. Selenium was delisted from the state's 303(d) list in 2016. All arsenic concentrations were well above the water quality standard. This is a function of the stringent standard and local geology; agricultural and other land use practices and disturbances may play a role. Sixteen out of 79 samples (20.3%) were above the state standard for total recoverable iron. Generally, mass loading of iron increased further downstream with the mainstem of Rifle Creek containing the largest amounts. Large iron loads lower in the watershed are tied to larger sediment loads. Larger sediment loads are likely tied to land use and increased soil-water contact. A significant amount of iron is settled or reduced out in Rifle Gap Reservoir. Twenty-five of 78 samples (32.1%) were above the state standard for sulfate. Concentrations of sulfate were highest at the upper West Rifle Creek site and the Grand Tunnel Ditch site within the city limits. Mass loading was greatest in the mainstem of Rifle Creek. These results indicate that sulfate is being consistently and repeatedly introduced and removed from the water column along the elevational gradient. The source of this constituent is most likely natural.

Comparison of Recent and Historical Data. Though comparison of recent and historic data is somewhat anecdotal due to differing methods and detection limits, it is still useful. All data available through the national database Water Quality Portal and collected through this study were compared before and after 2015. This comparison indicated that concentrations of arsenic, selenium, iron, and sulfate were all higher before 2015. This may be an indication that water quality is improving.

Best Management Practices. An additional goal of this assessment is to recommend BMPs to improve watershed health. A variety of BMPs are suggested related to stream/riparian restoration, nutrient controls, grazing management, off-highway vehicle (OHV) management, detention ponds and wetlands, diversion structure improvements, irrigation water management, and other erosion control techniques.

Project Recommendations. A number of suitable project options exist for improving water quality. Some of these projects are already being considered by various watershed stakeholders. The results of this study indicate that the stream and riparian areas of mainstem Rifle Creek are most in need of restoration or enhancement. It is hoped that through this study collaboration can be initiated that will advance these projects and thus improve water quality in the Rifle Creek watershed.

1.0 Introduction

1.1 Purpose

This is a nonpoint source pollution assessment of the Rifle Creek basin. This work was initiated by the Middle Colorado Watershed Council in 2015 to document existing conditions, conduct additional monitoring to better understand water quality pollutant sources that may exist, and provide a prioritized set of recommendations for implementation of Best Management Practices (BMPs) that would improve water quality.

Results of the analysis have been used to develop science-based outreach and education materials that were shared with watershed partners who have the ability to influence, implement and manage for nonpoint source pollution reduction. In this basin, those entities include the Bureau of Land Management (BLM), U.S. Forest Service (USFS), Natural Resource Conservation Service (NRCS), Bureau of Reclamation (BOR), Bookcliff Conservation District, Silt Water Conservancy District (SWCD), Colorado River District (CRD), Garfield County, City of Rifle, Colorado State University Extension, Farmers Irrigation Company, Rifle Creek Canon Ditch Company, and the Grand Tunnel Ditch Company.

Funding for this project comes from a Colorado Department of Public Health and Environment (CDPHE) Nonpoint Source Pollution Control Program grant, BLM – Colorado River Valley Field Office grant monies, and a BOR WaterSmart grant.

1.2 Study Area Description

Rifle Creek is a major tributary to the Colorado River within the larger Middle Colorado River watershed. Notable features in the Rifle Creek Watershed include Rifle Gap Reservoir and the City of Rifle. Its waters are used for agriculture, recreation, drinking water, and aquatic and terrestrial wildlife support.

The Rifle Creek Watershed is 200 square miles in size and contains 61 linear miles of perennial streams. The major named drainages include East, Middle, and West forks of Rifle Creek, Government Creek, and the mainstem of Rifle Creek. Table 2-1 shows a breakdown of land area in these specific drainages. Rifle Gap Reservoir is located near the confluence of the Middle, East and West forks of Rifle Creek. The headwaters originate in the White River National Forest at an elevation of up to 9,200 feet and flow south to where Rifle Creek empties into the Colorado River at the City of Rifle at about 5,300 feet.

Land Ownership is mainly BLM, USFS and private land as shown below in Table 1-1 and Figure A-1 in Appendix A.

Table 1-1. Land Ownership in the Rifle Creek Watershed.

Jurisdiction	Land Area (mi ²)	Land Area (% of Total)
Bureau of Land Management	94.8	47.3%
Private	56.6	28.2%
United States Forest Service	44.1	22.0%
Local Government	2.5	1.2%

Bureau of Reclamation	2.1	1.0%
Department of Defense	0.3	0.1%
Total Rifle Creek Watershed	200.4	100.0%

2.0 Characterization of Key Watershed Elements

2.1 Hydrology

The Rifle Creek Watershed is comprised of streams of order 1 in the headwaters to order 4 where the mainstem Rifle Creek enters the Colorado River. East and Middle Rifle Creeks originate at high elevations in the national forest, while West Rifle Creek originates much lower on private and BLM lands. Government Creek originates even lower in elevation on BLM and private land and is classified as intermittent.

There is one major impoundment, Rifle Gap Reservoir, located in the center of the watershed. The reservoir is situated at the confluence of East and West Rifle Creeks. Middle Rifle Creek joins West Rifle Creek before it enters Rifle Gap Reservoir. The mainstem of Rifle Creek begins at the outlet of the reservoir. Government Creek is the other major drainage within this basin, joining Rifle Creek within the City of Rifle (See Figure A-1). The land area within these individual tributary drainages as well as the mainstem Rifle Creek drainage is shown in Table 2-1. The source of water in the Rifle Creek Watershed is snowmelt, precipitation and perennial springs.

There are a total of twelve active discharges according to Colorado Department of Public Health and environment in August of 2018. Most of these permits are in the construction sector. These active permits are described in Table A-2 and depicted in Figure A-3 in Appendix A.

Table 2-1. Land Area in the Rifle Creek Watershed.

Watershed	Land Area (mi ²)	Land Area (% of Total)
Mainstem Rifle Creek	21.0	10.5%
East Rifle Creek	57.8	28.8%
Middle Rifle Creek	43.2	21.6%
West Rifle Creek	33.5	16.7%
Government Creek	44.9	22.4%
Total Rifle Creek Watershed	200.4	100.0%

A number of instream flows exist in the Rifle Creek watershed. These are water rights owned by the Colorado Water Conservation Board and designated to stay in the stream for ecological protection. In Rifle Creek all instream flow appropriations occurred in 1980, as shown in Table 2-2.

Table 2-2. Instream flow rights in the Rifle Creek Watershed. Accessed from the Colorado Water Conservation Board website on 11-21-18.

Stream Name	Appropriation Date	Upper Terminus	Lower Terminus	Lower Terminus UTM East	Lower Terminus UTM North	Segment Length (mi)	Flow Amounts (cfs, with dates)
West Rifle Creek	5/7/1980	Headwaters, in vicinity of	confl at Rifle Gap Res	261943.2	4391247	10.8	1 (1/1 - 12/31)
Rifle Creek	5/7/1980	outlet Rifle Gap Res	confl with Colorado River	260096.1	4379023	9.9	5 (10/1 - 4/30), 9 (5/1 - 9/30)
East Rifle Creek	5/7/1980	confl Three Forks Creek	confl at Rifle Gap Res	265281.2	4390570	10.8	6 (1/1 - 12/31)
Three Forks Creek	5/7/1980	Headwaters, in vicinity of	confl East Rifle Creek at	269412.9	4404614	5.2	3 (1/1 - 12/31)
Middle Rifle Creek	5/7/1980	Headwaters, in vicinity of	confl West Rifle Creek at	261600.8	4392027	10.6	3 (1/1 - 12/31)
East Rifle Creek	5/7/1980	Headwaters, in vicinity of	confl Three Forks Creek at	269412.9	4404614	2	3 (1/1 - 12/31)

2.2 Land Use

Mining. The Rifle Creek Watershed contains a number of mainly inactive mining claims, though two still have active status according to the Mineral Resource Database System. These are shown in Figure A-7 in Appendix A. Extensive historical mining extracted uranium, vanadium, lead, coal and zinc. The Rifle and Garfield mines, located south of Rifle Falls State Park along East Rifle Creek, were included in the Rifle Mining District, which has been noted in literature to have selenium bearing ore deposits (Luttrell, 1959).

The majority of mines occur in the East Rifle Creek subwatershed. Of these, many are located on BLM lands downstream of Rifle Mountain Park. Lead, zinc, and silver were commonly sought ores as well as chromium, vanadium, uranium and selenium. The Middle Rifle Creek subwatershed also has a few lead and zinc mines. None of the mines in the Rifle Creek Watershed have been identified as being a source of mine drainage by the Colorado Department of Public Health and Environment (CDPHE 2017).

Adjacent to, but not within, the Rifle Creek Watershed are two mine tailings reclamation sites that historically contained mills for vanadium and uranium. These sites are located along the Colorado River

just east of the I-70 / Highway 13 interchange and at the wastewater treatment plant approximately one mile west of that interchange. Both of these sites have been identified as containing groundwater contaminated with arsenic, molybdenum, nitrate, selenium, uranium, and vanadium; concentration that were expected to decrease over time with natural flushing have not (US DOE, 2017).

The contaminated ore that was located at the tailings sites described above was relocated to a site within the Rifle Creek Watershed in 1991. This disposal site is located in the Government Creek basin about 6 miles north of the City of Rifle. The location was chosen due to the Wasatch Formation, an aquatard, which underlies the site. The 3.5 million cubic yards of contaminated sediments are covered by a multicomponent encapsulation system; a leachate collection system is also in place at the toe of the encapsulated “cell” of tailings (US DOE, 2017).

Agriculture. As can be seen on Figure A-5 in Appendix A, agricultural uses are spread throughout the watershed with some occurrence in all the major drainages. Mainstem Rifle Creek supports the vast majority of agricultural lands as well as accompanying ditches and canals. All of the agricultural use in the basin is classified as irrigated.

Grazing. Cattle grazing has historically been a dominant land use in the area and is still prevalent throughout the watershed on USFS, BLM and private lands. At least one area in the watershed, Butler Creek, has exhibited signs of excessive grazing and the USFS has adjusted management accordingly (Clay Ramey, personal comm. Nov. 2016).

Recreation. Rifle Gap Reservoir is a highly used recreational area within the Rifle Creek Watershed. This area is managed by Colorado Parks and Wildlife with major uses consisting of fishing, boating and camping.

Rifle Falls State Fish Hatchery is located just downstream of Rifle Gap and is the largest state-owned and operated trout production hatchery in Colorado.

Rifle Falls State Park is located just downstream of this fish hatchery and is a popular attraction for walking, camping and enjoying the stunning waterfalls.

Rifle Mountain Park, managed by the City of Rifle, is a well-visited, world-renowned area for limestone sport-climbing. The watershed is also home to the Rifle Creek Golf Course south of Rifle Gap Reservoir.

2.3 Geology and Soils

Geology. The geology of the area is complex. The U.S. Geological Survey has classified the Rifle Creek Watershed as having 23 different geological units as shown on Figure A-8 in Appendix A.

There is a significant difference in geology when comparing individual sub-watersheds. A main geologic feature of the Watershed and surrounding area is the Grand Hogback Monocline. The Grand Hogback Monocline dissects the Rifle Creek Watershed between Government Creek and West Rifle Creek. The formation is a ridge of tilted bedrock that “...separates the vertically uplifted southern Rocky Mountains to the east from the flat-lying to gently folded Colorado Plateau to the west” (Kirkham et.al., 2000).

East and Middle Rifle Creeks are probably the most similar in geology among the major drainages of Rifle Creek. The most common units are Minturn and Belden Formations, with several other formations playing minor roles.

West Rifle Creek has a large variety of USGS geological units. Mancos Shale and Morrison, Curtis, Entrada, and Glen Canyon Formations are the two most common units, with about another half dozen units present in smaller amounts.

Government Creek and mainstem Rifle Creek are the most uniform in geology. They are dominated by the Wasatch Formation and Ohio Creek Formations, with Williams Fork and Green River Formations present to a lesser degree.

Major cretaceous geology in this watershed includes Mancos Shale and Williams Fork Formations of West Rifle Creek and Government Creek, respectively. This type of geology is known to contain soils with high selenium concentrations (Skinner-Martin et.al, 2002).

Soils. Soil types were generally aridisols in lower elevations and mollisols at higher elevations (see Figure A-9 in Appendix A). Mollisols are typically associated with grasslands and generally have a thick organic layer; though this may not typify the soils in this area. The mollisols in the Rifle Creek Watershed are mainly higher up in the drainage and are Cryolls, meaning they are a cold climate mollisol. Aridisols, by comparison, are very dry and generally have very little organic matter.

The soils of the Rifle Creek watershed are relatively fine in texture, containing a lot of silt and/or clay. This leads to a high erodability for many areas.

2.4 Stream Channel and Riparian Condition

The BLM assesses overall health of the lands they manage, including riparian areas, during “Land Health Assessments”. These Land Health Assessments are an effective way to evaluate whether management is meeting current functional standards called “Proper Functioning Condition”. According to the 2002 Rifle Creek BLM Land Health Assessment, the condition of BLM stream segments in the Rifle Creek Watershed are meeting Proper Functioning Condition standards for most streams. However, Government Creek is classified as “Functioning at Risk” for all segments (BLM, 2002).

3.0 Water Quality - Known Issues and Concerns

3.1 303(d) Listings

Section 303(d) of the federal Clean Water Act (CWA) requires individual states to identify waters where water quality standards for designated uses are not met. Additionally, a Monitoring and Evaluation (M&E) List identifies waterbodies where there is reason to suspect water quality issues. These listings are generated from water quality data collected by the Water Quality Control Division (WQCD) as well as data that exists in public databases. Waterbodies in the Rifle Creek Watershed included on the 303(d) and M&E lists are reported in Tables 3-1 and 3-2 as well as graphically on Figure A-2 in Appendix A.

Table 3-1. 303(d) listings in 2012 and 2016 for waterbodies in the Rifle Creek watershed. 2016 listings were reaffirmed during the 2018 listing cycle.

Year	Water Body Identification Number (WBID)	Stream or Lake Segment Description	Portion	303(d) Parameter(s) of Impairment	TMDL Priority
2018 2016	COLCLC 10_A	East Rifle Creek from White River NF Boundary to Rifle Gap Reservoir and Rifle Creek from Rifle Gap Reservoir to Colorado River	All	Total Arsenic (aquatic life)	Low
	COLCLC10_B	West Rifle Creek and Tributaries	All	Total Arsenic (aquatic life)	Low
2018 2016 2012	COLCLC20_B	Rifle Gap Reservoir, Harvey Gap Reservoir, and Vega Reservoir	Rifle Gap Reservoir	Aquatic Life Use – Mercury in Fish Tissue	High
2012	COLCLC10	East Rifle Creek below USFS Boundary, West Rifle Creek and Rifle Creek, including tributaries from Rifle Gap to the Colorado River	All	Selenium	Low

Table 3-2. M&E listings in 2012 and 2016 for waterbodies in the Rifle Creek watershed. 2016 listings were reaffirmed during the 2018 listing cycle.

Year	Water Body Identification Number (WBID)	Stream or Lake Segment Description	Portion	Monitoring & Evaluation Parameter(s)
2018 2016	COLCLC 10_A	East Rifle Creek from White River NF Boundary to Rifle Gap Reservoir and Rifle Creek from Rifle Gap Reservoir to Colorado River	All	<i>E. coli</i>
	COLCLC10_B	West Rifle Creek and Tributaries	All	<i>E. coli</i> , Iron (total recoverable and dissolved, aquatic life), Sulfate (water supply)
2012	COLCLC10	East Rifle Creek, West Rifle Creek and Rifle Creek, including tributaries from Rifle Gap to the Colorado River	All	<i>E. coli</i>
	COLCLC10	East Rifle Creek, West Rifle Creek and Rifle Creek, including tributaries from Rifle Gap to the Colorado River	West Rifle Creek	Iron (total recoverable), Sulfate

Impairment Thresholds. The Colorado Department of Public Health and Environment (CDPHE) Water Quality Control Commission (WQCC) establishes the numeric standards by which it evaluates water quality data and determines which waterbodies warrant 303(d) or M&E listings. These numeric standards are shown in Table 3-3.

Table 3-3. Statewide table value standards for arsenic, iron, selenium, and sulfate. Source: CDPHE Regulation 31 (note that conditions apply). The most applicable standards for Rifle Creek are shown in **bold**.

Parameter	Aquatic Life		Agriculture	Domestic Water Supply	Water + Fish	Fish Ingestion
	Acute	Chronic				
Arsenic (µg/l)	340	150	100 (30-day)	0.02 – 10 (30-day)	0.02	7.6
Iron (µg/l)		1000 (tot.rec.)		300 (dis) (30-day)		
Selenium (µg/l)	18.4	4.6	20 (30-day)	50 (30-day)	170	4,200
Sulfate (mg/L)				250		

The four parameters of arsenic, selenium, iron, and sulfate originating in the 303(d) and M&E lists form the focus of water quality investigations undertaken by this study. More information on the importance of these parameters and their regulation is provided below. Salinity, although not on the impairment lists, is of local interest and is also discussed.

Arsenic. Arsenic impairments from the 303(d) list pertain to the water supply and fish ingestion classification for lower East Rifle Creek, West Rifle Creek below USFS boundary, Government Creek and mainstem Rifle Creek. The standard for arsenic was updated during the last cycle of state standards review to reflect the fact that arsenic is currently classified by the United States Environmental Protection Agency (EPA) as a Class A Carcinogen. This resulted in the standard becoming more stringent than before. Arsenic for Water + Fish is set at 0.02 µg/L calculated from fish tissue accumulation estimates. This 0.02 µg/L standard is applied by the state only to the segment COLCLC10, which is West Rifle Creek, East Rifle Creek below the USFS boundary, and mainstem Rifle Creek, including all tributaries. (Note that a temporary modification for chronic levels of arsenic are in place through 2021.) For the rest of the watershed (Middle Rifle Creek, and East Rifle within the National Forest), a standard of 7.6 µg/L applies and is being met. For the purposes of this study, the strictest standard of 0.02 µg/L will be referenced most often.

Arsenic is a highly toxic element. It is classified as a metalloid, however, it is often referred to as a metal. Arsenic is naturally occurring in soils. Short-term exposure to arsenic concentrations of 300 to 30,000 µg/L can lead to symptoms such as stomachache, nausea, vomiting, and diarrhea (ATSDR 2007). Long-term exposure to inorganic arsenic may cause “patches of darkened skin and the appearance of small ‘corns’ or warts’ on the palms, soles, and torso” (ATSDR 2007). Cancer may also develop.

Organic arsenic may build up in fish and shellfish tissues. However, this arsenic occurs mainly in an organic form that is much less harmful to humans and animals (ATSDR 2007).

Selenium. Selenium impairments were included in the 303(d) list at the onset of this investigation; it has since been delisted due to new data being made available (See Table 3-1). Selenium is a well-documented problem in the Colorado River (Richard and Moore, 2015). At low levels selenium is a nutrient; however, at only slightly higher levels it is toxic and can detrimentally affect human health as well as fish and wildlife populations. It also has a tendency to bioaccumulate in aquatic environments (Lemly, 2002). Selenium can lead to reproductive impairment in fish and impact fish gills' ability to exchange gases at high concentrations. The most protective concentration of selenium is 4.6 µg/L, which represents the chronic concentration protective for aquatic life. EPA is in the process of reviewing and reissuing selenium standards criteria which will likely be more restrictive than current levels.

Iron. Iron is currently on the M&E list for West Rifle Creek (See Table 3-2). The most restrictive concentration for iron is 300 µg/L for water supply but this is considered a secondary standard. Secondary standards are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. The more important threshold used here is the 1,000 µg/L concentration for chronic toxicity to aquatic life.

Iron is a necessary nutrient and component of hemoglobin, which transports oxygen in the bloodstream. At higher concentrations, iron becomes toxic to living organisms. Probably more impactful than direct toxic effects, iron precipitates can physically or indirectly affect fish and macroinvertebrate populations by reducing interstitial space and reducing primary production (Vuori 1995, Linton et al. 2007). Elevated total iron can smother aquatic species habitats. Iron can decrease the bioavailability of certain toxic metals (such as arsenic), but it can subsequently increase dietary supply of such toxic elements (Vuori 1995).

Soil type and geology, human impacts such as mining, agricultural drainage, and intense forestry are known to increase iron concentrations. The main human causes are due to increased soil-water contact via disturbance.

Sulfate. Sulfate is currently on the M&E list for West Rifle Creek (see Table 3-2). Sulfate, or SO_4^{2-} in formula notation, is a combination of one sulfur atom and four oxygen atoms. It dissolves in water but also bonds to form insoluble compounds such as calcium sulfate and barium sulfate. Sulfates can increase the pH of the water at high concentrations, thereby impacting fish and wildlife. Sulfate is also treated as a secondary standard with a guideline concentration of 250 mg/L due to the salty taste it imparts to water.

Factors that may affect sulfate concentrations include: mining, oil and gas development, geothermal activity and soil type.

3.2 Salinity

Salinity is a well-documented problem in the Colorado River (Richard and Moore, 2015). It is not regulated by a specific numeric standard, except at the Hoover, Parker, and Imperial Dams (5 CCR 1002-

39 Regulation No. 39 Colorado River Salinity Standards). Colorado participates in a multi-state basin-wide effort to control salinity through the Colorado River Basin Salinity Control Forum. The United States is also required to deliver water of a certain quality to Mexico. The Environmental Protection Agency (EPA) has developed a salinity guideline of 500 mg/L, primarily for drinking water taste.

The causes of salinity in streams are mainly natural, i.e. geology and soil. Mancos Shale and Eagle Valley Evaporite, in particular, have been identified as main sources of salts in the Upper Colorado River Basin (Tuttle and Grauch, 2009). Anthropogenic influences can accelerate salinization by way of activities such as mining, irrigation, and oil and gas exploration (Tuttle and Grauch, 2009). Invasive species such as tamarisk are documented to have increased salinity levels of riparian area soils and associated waterways via root uptake and deposition from their leaves (Barrows, 1996).

High concentrations of salinity have detrimental effects on agriculture. Salinity is of special interest to federal land managers due to the Colorado River Basin Salinity Control Program implemented in 1995. This program is intended to “enhance and protect the quality of water available in the Colorado River for use in the United States and Republic of Mexico” (www.usbr.gov).

Saline soils develop on agricultural fields over time and are often associated with poor drainage. Agriculture is negatively impacted by excessively saline soils; it is in the interest of sustainable agriculture to keep salinity at a tolerable level. Salinity often increases as water travels downstream and accrues salts. It is important to consider the concentration of dissolved salts in all areas of the Colorado Basin, including the headwaters, so that excessively saline water and soils can be prevented.

3.3 Fish and Wildlife

The Colorado River immediately downstream of where Rifle Creek empties into the Colorado River is habitat for federally endangered Colorado Pikeminnow (*Ptychocheilus lucius*) and Razorback Sucker (*Xyrauchen texanus*) (Harvey et. al., 2008). Water quality issues in this system may impact these critically important fish species.

The Rifle Creek Watershed, which is part of the Upper Colorado River Basin, historically contained what is called the “Green Lineage” of Colorado River Cutthroat Trout (CR654215CT). This lineage is not documented in the Rifle Creek Watershed currently. Blue Lineage CRCT is closely related to the Green Lineage and is native to the White River and Yampa River Basins. A population of Colorado River Cutthroat Trout (CRCT) is present in Butler Creek, a tributary to Middle Rifle Creek. This population is under threat and current efforts are being made by the Middle Colorado Watershed Council (MCWC) and USFS to restore habitat in this stream.

A population of Bluehead Suckers (*Catostomus discobolus*) is present in Middle Rifle Creek. This species is listed as “Sensitive” by the BLM and USFS and as a “Species of Special Concern” by Colorado Parks and Wildlife (CPW) due to their limited range and relative vulnerability as a species. CPW is currently undertaking efforts to supplement the Middle Rifle Creek population through stocking.

Several waterfowl species are present around Rifle Gap Reservoir. This area has been categorized by CPW as habitat for these species that include dabbling ducks that feed on underwater vegetation. Such

species are at high risk of exposure to toxic sediments and plants that have accumulated toxic elements through their feeding habits. Northern Leopard frogs have also been documented in the area, which are sensitive aquatic species.

Though other factors undoubtedly play a role, adequate water quality and quantity is vital to the health of fish and wildlife populations in the Rifle Creek watershed.

4.0 Methods of Field Investigation

4.1 Timing

A spring, late summer, and fall water quality sampling schedule was chosen in order to assess different flow regimes and to capture potential effects of differing land management. Spring sampling aims to capture spring runoff, summer sampling is conducted to capture surface water return irrigation flows and any contaminants that may come with it, and fall data collection is intended to capture base flow conditions.

Sampling in 2015 was conducted during the months of August and October (no spring sample). Sampling in 2016 occurred in May and October (no summer sample). Sampling in 2017 occurred in May, August, and October.

4.2 Site Selection

Thirteen sample sites were selected to characterize the watershed from top to bottom, including its various tributaries. Sites were also located based on their relation to potential disturbances and accessibility. See Table A-1 for a list of sites and Figure A-1 in the Appendix for an illustration of their location.

4.3 Site Notes

Sampling occurred only twice at the Government Creek site (site #926, 32 Mi Gulch) in May of 2016 due to lack of water during every other sampling event. Results from this site are at certain times omitted from the section on “Data Synthesis” due to this lack of data. The site on Hubbard Creek was never sampled due to lack of flow. Therefore, Hubbard Creek has no water quality data, but is briefly considered in terms of land use.

The site labeled “Grand Tunnel Ditch” is not the official Grand Tunnel Ditch. The site was assigned this label for its proximity to the actual Grand Tunnel Ditch and the fact that it contains water that originated from the irrigation channel. The source of the water in the small channel that was sampled for this study is somewhat unclear. It appears to be mainly coming from subsurface flows and perhaps local irrigation water that percolates or runs off. There is always water flowing at this site, according to local residents. This small drainage captures water from the west side of the City of Rifle.

4.4 Sample Preparation and Collection

For all samples a “composite” sample was taken by wading across the creek and collecting the sample from all parts of the stream (left, middle, and right banks) while facing upstream. Care was taken not to disturb or contaminate the water upstream of the sample collection. Protocols were followed according to River Watch of Colorado (who use CDPHE standards). For more detailed information, see the River Watch QAPP (CDPHE 2015). The following text outlines those steps:

1. Determining which stations will be sampled during the day.
2. When metals are collected, prepare all sample bottles as follows:
 - a) Pre-fix all metals samples with 12 drops HNO₃.
 - b) Collect non-filtered water sample for total elements, collecting water from all parts of the stream for a representative sample.
 - c) Collect filtered sample using a 0.45 micron filter for dissolved elements.
 - d) Every 5th sample collected will have an associated blank and duplicate sample.
 - e) Blank samples are filled with DI water for both filtered and non-filtered samples.
 - f) Label bottles as appropriate.
3. When nutrients are collected, prepare all samples as follows:
 - a) Collect water sample from all parts of the stream. In bottles with preservative, do not overflow.
 - b) Bring materials for a nutrients duplicate if appropriate to do so (instructions for nutrients duplicates provided by River Watch).
 - c) Label bottles as appropriate.
 - d) Keep refrigerated.
 - e) Ship / deliver samples within 48 hours.

4.5 Field Measurements

Field measurements for temperature, conductivity, specific conductance, salinity and dissolved oxygen (DO) were collected in situ. These parameters were measured using YSI Model 85 and YSI Model 63 handheld meters. The YSI Model 85 was used for DO only. The YSI Model 63 was used to measure temperature, conductivity, specific conductance and salinity.

A 16 oz. bottled sample was taken from each station for laboratory analysis of alkalinity and hardness. All stream samples were collected as composite samples to ensure they are representative. Composite samples consisted of 1/3 taken from the left bank, 1/3 taken from the thalweg (the line of fastest flow in the stream channel and often the deepest), and 1/3 taken from the right bank.

A Marsh-McBirney flow meter was used to estimate flow using three measurements. These measurements are taken at ¼, ½, and ¾ across the width of the stream at 60% height in the water column, which is generally accepted at the average velocity location.

Salinity / Specific Conductance. Specific conductance (conductivity at 25C°) is directly correlated to salinity. Meters are generally able to most accurately measure conductance and calculate salinity from that. For the purposes of this study, specific conductance was used as an indicator of salinity.

4.6 Laboratory Analysis

Once in the lab, nutrients bottles were immediately refrigerated. Collected water samples were tested for alkalinity and hardness. Alkalinity and hardness were hand titrated according to procedures outlined in the *River Watch of Colorado Water Quality Sampling Manual*. All data were recorded on appropriate data sheets and submitted with metals and nutrients samples to River Watch of Colorado.

The River Watch Laboratory was responsible for analysis of all bottled samples. Parameters of analysis included:

- Aluminum
- Arsenic
- Cadmium
- Calcium
- Copper
- Iron
- Lead
- Magnesium
- Potassium
- Manganese
- Nitrite (NO₂), Nitrate (NO₃), and Ammonia (NH₃)
- Sulfate
- Total Phosphorus
- Chloride
- Total Suspended Solids
- Selenium
- Sodium
- Zinc

Select parameters were analyzed by private laboratories in addition to River Watch. These included selenium, arsenic, iron, and sulfate, all parameters included on 303(d) and M&E lists for the watershed and therefore of special interest. Private laboratories were able to provide faster results and detect these constituents at lower concentrations than the River Watch lab.

The Method Detection Limit (MDL) is the lowest non-zero concentration that can be effectively detected. A method reporting limit (MRL) is the lowest concentration that can be determined accurately enough for the numeric value to be trusted. A typical MRL is around 3 times the MDL for a given parameter.

Arsenic. Arsenic was detected in only four of the samples sent to the River Watch laboratory for analysis. However, it should be noted that their MRL is 5 µg/L, which is well above the strictest standard for arsenic (0.02 µg/L). The River Watch laboratory was used for the first two sampling events, August and October of 2015 (See Table 4-1).

Grand Junction Laboratories have a MDL of 1 µg/L and no MRL. During the one sampling event this laboratory was utilized, October 2016, zero sites had detectable arsenic levels. See Table 4-2.

Among the laboratories utilized, ACZ laboratories has the most accurate detection levels (Table 4-2). Their MDL is 0.1 µg/L and MRL is 0.3 µg/L. Therefore, greater emphasis is given to results from the May 2016 and 2017 sampling events when this laboratory was utilized.

Selenium. Selenium was not detected in any of the samples analyzed by the River Watch laboratory. Their MRL is 5 µg/L, which is above the chronic aquatic life standard for selenium. The River Watch laboratory was used for the first two sampling events, August and October of 2015 (See Table 4-1).

Grand Junction Laboratories have a MDL of 1 µg/L for selenium and no MRL. During the one sampling event this laboratory was utilized, October 2016, 4 sites had detectable selenium concentrations, all matching the MDL of 1 µg/L.

ACZ laboratories has the most accurate detection levels with an MDL of 0.1 µg/L and MRL of 0.3 µg/L. Greater reliance is placed on results from the May 2016 and 2017 sampling events when this laboratory was utilized.

Iron. River Watch and Grand Junction Laboratories protocols report iron concentrations of 10 µg/L or higher which is also the accuracy of their tests. ACZ Laboratories reporting limit is 1 µg/L. Despite this difference, all iron data are treated as comparable due to the concentrations of iron being relatively high compared to this difference in accuracy.

Sulfate. River Watch and Grand Junction Laboratories' protocols report sulfate concentrations of 0.5 and 1 mg/L or higher, respectively. ACZ Laboratories reporting limit is 5 µg/L. Despite this difference all sulfate data are treated as comparable due to the concentrations of sulfate being relatively high compared to this discrepancy in accuracy.

Table 4-1. Laboratory results utilized for arsenic, selenium, total iron and sulfate analysis according to sampling date.

Lab Utilized	Sampling Event Date						
	8/25/2015	10/14/2015	5/27/2016	10/8/2016	5/24/2017	8/24/2017	10/19/2017
River Watch	✓	✓					
ACZ			✓		✓	✓	✓
Grand Junction				✓			

Table 4-2. MDL and MRL for arsenic, selenium, total iron and sulfate by laboratory.

Parameter	River Watch		Grand Junction Labs.		ACZ Laboratories	
	MDL	MRL	MDL	MRL	MDL	MRL
Arsenic	5.8 µg/L	10 µg/L	1 µg/L	1 µg/L	0.0002 µg/L	0.001 µg/L
Selenium	2.4 µg/L	5 µg/L	1 µg/L	1 µg/L	0.0001 µg/L	0.0003 µg/L
Iron (total)	5.2 mg/L	10 mg/L	10 mg/L	10 mg/L	0.004 µg/L	0.01 µg/L
Sulfate		0.5 mg/L	1 mg/L	1 mg/L	5 mg/L	25 mg/L

For those seeking additional information on specific sampling methods and laboratory protocols, please reference CDPHE's Quality Assurance Project Plan for Surface Water Monitoring and Assessment (May 2015), which are the methods utilized for the River Watch Program.

4.7 GIS and Data Uploading

Geographic information system (GIS) data were obtained from the BLM network which included data compiled by BLM GIS specialists. This mainly consisted of base layers such as land ownership and topography. Water quality data were also obtained from River Watch of Colorado as well as the federal data clearinghouse known as the Water Quality Portal. USGS stream layer and watershed layers were utilized as well. CDPHE data included water quality as well as discharge permits.

All data collected as part of this project were uploaded to the national database maintained by EPA called the Water Quality Data Exchange (WQX). This allows CDPHE and other decision-makers to access and use these data to make informed decisions about land and water management and policy.

4.8 Mass Loading

Pollutant mass load is the total amount or mass of a substance that is present in the water. It is calculated by multiplying concentration by discharge and is often reported as pounds/day or kilograms/day. The necessary conversions were executed for this study in order to report loading in pounds per day.

Loading was calculated at the three sites surrounding Rifle Gap Reservoir using flow estimates measured by BOR gauges every 15 minutes. These sites are on West and East Rifle Creeks just before they empty into Rifle Gap and Mainstem Rifle Creek just after it is released out of Rifle Gap Reservoir. West Rifle Creek was measured after its confluence with Middle Rifle Creek.

Flows were estimated at all other sites using a method of three averaged measurements of velocity and depth. Only one of these estimates was used when comparing East Rifle Creek, West Rifle Creek, and Below Rifle Gap since BOR had a data gap for East Rifle Creek on 8/24/2015. These less-accurate in-situ flow estimates were used to estimate overall loading of the four parameters of special concern at all other sites where BOR gages are not present. An average of 28% error was calculated for the in situ-measurement protocol when compared with BOR gage flows.

4.9 Data Representation

For purposes of data synthesis, in addition to interpreting individual data points, median is the statistic most often used. The median is a better representation of a dataset than an average when data are not normally distributed. When looking at this dataset as a whole, there are a few outliers that drastically affect average values. For this reason, median is considered more representative.

5.0 Data Synthesis

The following presentation of results and discussion is organized by parameter. All parameters mentioned in the methods section were assessed but not necessarily synthesized here except for constituents of particular interest. The four 303(d) parameters of concern (arsenic, selenium, iron, and

sulfate) are emphasized based upon their regulatory importance, despite the limited number of samples available. The field collected parameters of specific conductance, pH, alkalinity, hardness, and dissolved oxygen are all discussed. Because the Government Creek sampling site was sampled only twice due to flow limitations, results from this site are offered separately at the end of this section.

Overall Results

For each of the four parameters of principle interest, a total of 79 concentrations were obtained across the different sites. A wide range of concentrations were witnessed spatially and temporally. As indicated in Table 5-1, numerous selenium and arsenic samples were analyzed using methods unable to detect concentration below the standards, rendering them useless for purposes of this evaluation. Median statistics were utilized since the data is not normally distributed. 85th percentiles are shown because this is the threshold used by CDPHE when determining impairment listings.

Specific parameters will be discussed in more detail in the following sections. Note that arsenic, iron, and sulfate all saw 85th percentiles above the CDPHE standard. Spikes in maximum iron and arsenic concentrations at Government Creek were extreme.

Specific Conductance, included in Table 5-1 as well, is a general water quality indicator which is why it is included here. Specific conductance ranged from 814 uS/L to 2441 uS/L.

Median statistics for each site are shown in Table 5-2. Median results alone do not show many areas of high concentration. One exception is West Rifle Creek at State Wildlife Area. This area showed elevated iron and sulfate.

Loading was calculated for each tributary. Additionally, loading allows us to see potential areas that may be sources or sinks for particular constituents. Table 5-3 shows the median calculated loads at all of the sites. East Rifle Creek and mainstem Rifle Creek saw the highest loading, presumably due to higher flows.

Table 5-1. Overall results for total arsenic, total iron, dissolved selenium, and total sulfate in the Rifle Creek Watershed. These results take only detectable results into consideration.

Parameter	Total Count	Less than MDL Count	Percent less than MDL	Median	85th Percentile	Max.	CDPHE Standard (chronic)	Number of Exceedances	Percent Exceeding (of detected)
Arsenic (Total, ug/L)	79	33	41.8%	0.6	1.4	222	0.02	46	100.0%
Selenium (Dissolved, ug/L)	79	29	36.7%	1	1.3	2.5	4.6	0	0.0%
Iron (Total, ug/L)	79	0	0.0%	299	1296.9	981000	1000	16	20.3%
Sulfate (mg/l)	78	0	0.0%	192.5	429.55	1910	250	25	32.1%

Specific Conductance (uS/L)	80	0	0.0%	814	1423.3	2441	N/A	N/A	N/A
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Table 5-2. Median concentrations for total arsenic, total iron, dissolved selenium, and total sulfate. These results take only detectable results into consideration. Government Creek results not shown, as there were only two data points.

Site #	Site Name	Median Arsenic (µg/L) (tot. rec.)	Median Iron (µg/L) (tot. rec.)	Median Selenium Dis (µg/L)	Median Sulfate (mg/L)
923	Rifle Creek - Centennial Lower	1.35	490	1.45	257
924	Grand Tunnel Ditch	1.55	330	1.2	440
925	Rifle Creek - Centennial Upper	1.1	474	1.35	241
927	Rifle Creek - Below Gov't Creek	1.2	591	1.3	252
929	Rifle Creek - Below Rifle Gap	1.2	87	1.1	162
930	West Rifle Creek – At Rifle Gap Res	0.75	395	0.85	191
931	Middle Rifle Creek	0.55	177	0.9	142
932	West Rifle at State Wildlife Area	1.4	1287	0.8	403
935	East Rifle - At Rifle Gap	0.8	356	1.4	122
936	East Rifle - Rifle Falls State Park	0.6	21	1.2	87
937	East Rifle - Rifle Mountain Park	0.5	32	1.1	102

Table 5-3. Median loading results for parameters of interest at all sites.

Site #	Site Name	Median Total Arsenic Load (lbs/day)	Median Total Iron Load (lbs/day)	Median Dissolved Selenium Load (lbs/day)	Median Sulfate Load (lbs/day)
923	Rifle Creek - Centennial Lower	0.245	53.6	0.125	22106
924	Grand Tunnel Ditch	0.003	1.8	0.002	903
925	Rifle Creek - Centennial Upper	0.230	48.5	0.123	25224
927	Rifle Creek - Below Gov't Creek	0.080	37.4	0.105	19668
928 & 939	Government Creek*	0.034	95.6*	0.006	678
929	Rifle Creek - Below Rifle Gap	0.238	12.1	0.232	23170
930	West Rifle - At Rifle Gap Res	0.018	10.7	0.033	6744
931	Middle Rifle Creek	0.009	3.9	0.022	4080
932	West Rifle at State Wildlife Area	0.001	0.9	0.001	478
935	East Rifle - At Rifle Gap	0.093	40.5	0.140	15597
936	East Rifle - Rifle Falls State Park	0.108	4.6	0.220	20512

937	East Rifle - Rifle Mountain Park	0.027	1.9	0.060	4891
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*Government creek only had flow during two out of seven sampling events, the median loads shown here ignore those times of zero discharge.

5.1 Arsenic

Results. Reliable arsenic results are available for 4 total sampling events: one in May 2016 and 3 throughout 2017.

Arsenic concentrations generally increased from up to downstream in the drainage, as shown in Figures 5-1 and 5-2. Concentrations in mainstem Rifle Creek were approximately three times that of the Rifle Mountain Park, the site highest up in the drainage.

Of the forks of Rifle Creek, West Rifle Creek had the highest concentrations. Mainstem Rifle Creek also had high levels of arsenic compared to Middle and East forks. All concentrations were well above the most restrictive standard of 0.02 µg/L.

The highest concentration of arsenic was observed in Government Creek at Hubbard Mesa; 222 µg/L. This was one of only two sampling events for Government Creek, which goes dry for much of the year. The other Government Creek site had a concentration of 4.6 µg/L.

As seen in Figures 5-2 and 5-3, total arsenic loading was highest in mainstem Rifle Creek. Figure 5-3 indicates that arsenic is being added into the stream from Rifle Gap Reservoir. The greatest loading of arsenic was measured at the Upper Centennial Park site on mainstem Rifle Creek. The lowest loading came from the Middle Rifle Creek and Grand Tunnel Ditch sites. East Rifle Creek has a greater arsenic load compared to West Rifle Creek when comparing the two major drainages in Figure 5-3.

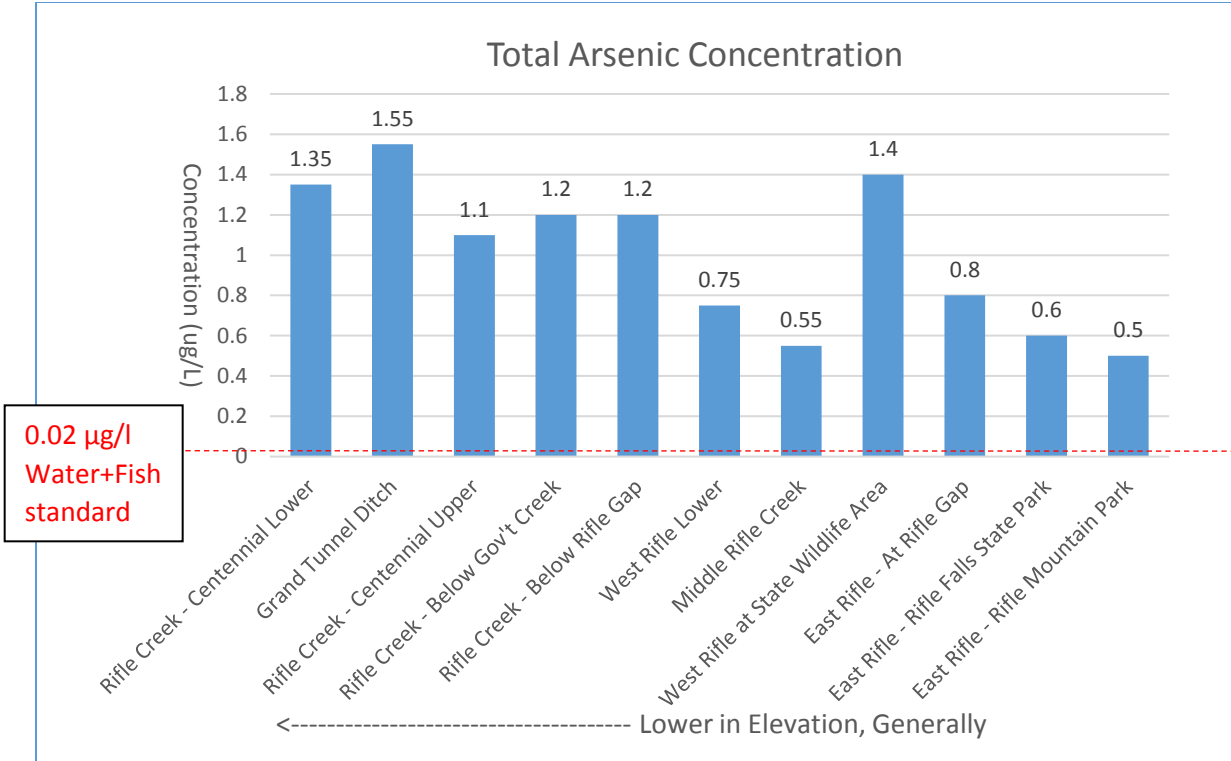


Figure 5-1. Median total arsenic concentrations at sites throughout the Rifle Creek Watershed. Excludes Government Creek sites, which were 4.6 and 222 µg/L for the two sampling events. Only detectable arsenic results were utilized. Includes four data points per median. Samples all processed by ACZ Laboratories.

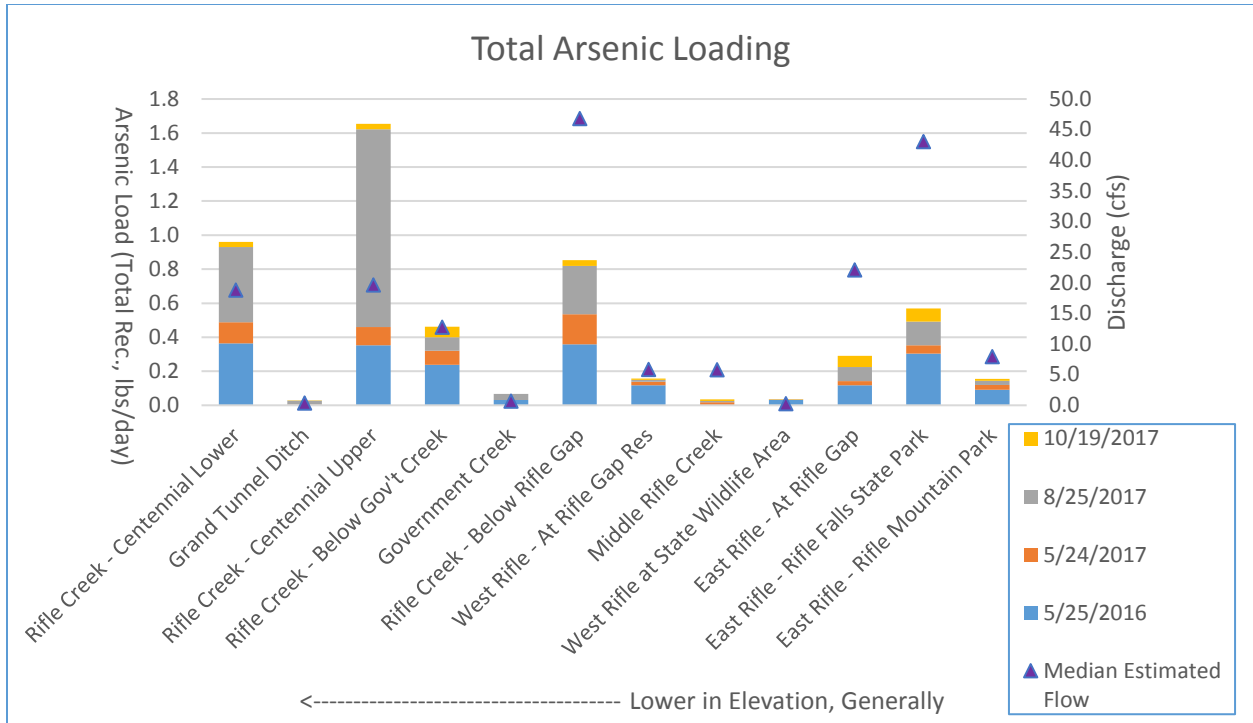


Figure 5-2. Total recoverable arsenic loading and estimated discharge at all sampling sites in the Rifle Creek Watershed. Four discharge measurements were averaged from both BOR gage data and in situ-measurement estimate method.

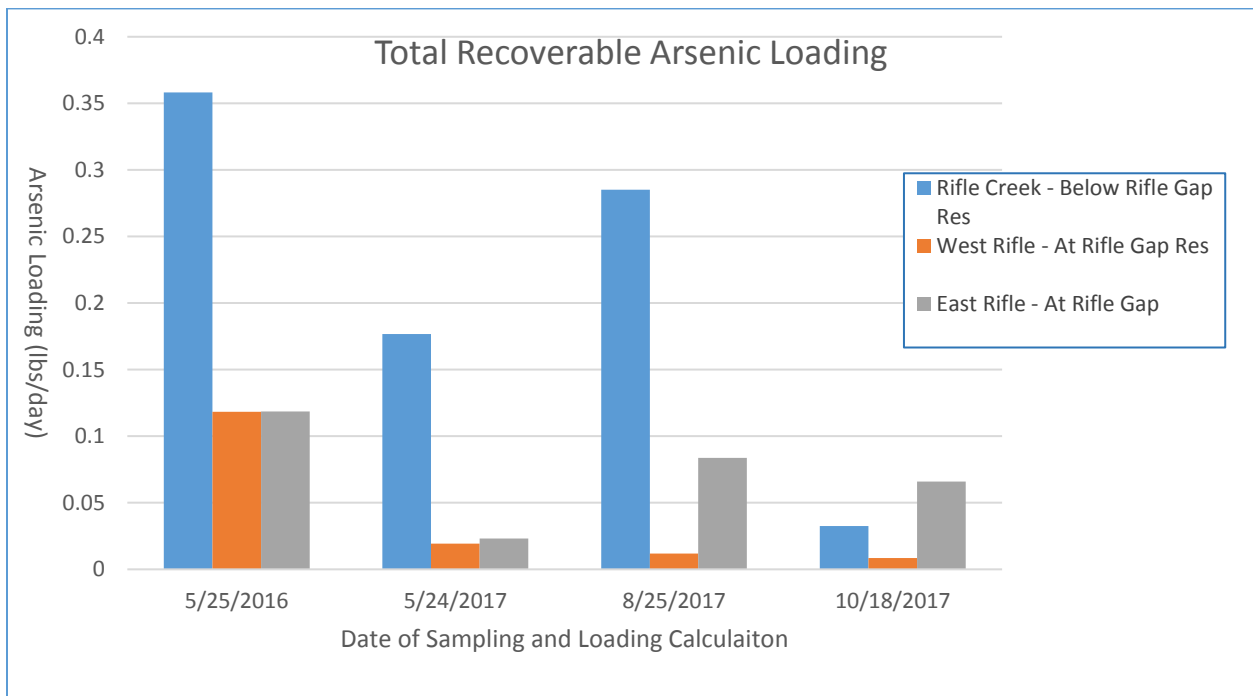


Figure 5-3. Total arsenic loading in East, West and Mainstem Rifle Creek (below Rifle Gap Reservoir) for four sampling events. Loading was calculated in pounds/day based on the concentration and discharge at the time of sampling on the day shown.

Discussion. All detectable arsenic concentrations were well above the state standard of 0.02 µg/L. This leads to the question of why there is such a strict numeric standard placed on arsenic. The standard is based upon calculations of water concentration and their relation to concentration of arsenic in fish tissue. Still the standard seems unattainable.

High arsenic concentration occurred in the Government Creek drainage, as there were only two data points for this creek (see Results above). It is difficult to know the frequency and impact of increased concentrations from intermittent stream without more frequent sampling. Loading may be a better indicator of overall watershed health impact.

Loading. Arsenic loading showed some unexpected results. Rather than arsenic settling out or reducing in Rifle Gap Reservoir, the reservoir appears to add arsenic, as seen in Figure 5-3, at least during three out of four sampling events for which there is accurate loading data. The larger arsenic load from East Rifle Creek is attributed to the higher flow in that drainage.

Arsenic loading fluctuated within each sub-basin, most notably on mainstem Rifle Creek where it decreased between Rifle Gap and below Government Creek before drastically increasing at the Upper Centennial Park site. Arsenic loading on East Rifle Creek increased between Rifle Mountain Park and Rifle Falls, then decreased at Rifle Gap. West Rifle Creek saw a decrease in arsenic concentration moving downstream. Loading, however, increased certain days and decreased others. This type of fluctuation, a flipping of decreasing to increasing or vice versa between sites, was witnessed throughout the dataset.

Loading contrasted with overall concentration, the latter of which tended to gradually increase downstream. The reasons for these tendencies are difficult to surmise. One factor that undoubtedly plays a role is difference in stream discharges at different sites, as discharge is the differentiating factor between concentration and loading. Figure 5-3 shows the correlation of discharge and arsenic loading, as well as which sites are contributing disproportionately to their flow.

Arsenic is often introduced into the aquatic environment as a result of local geology. It enters the water through infiltration and leaching (ATSDR 2007). Common anthropogenic sources of arsenic include nonferrous metal mining and pesticide application. According to the Integrated Water Quality Monitoring and Assessment Report (2018), in Colorado, geologic sources of arsenic are common, yet the major source of this constituent for a specific stream is generally unknown. It is likely that site-specific geology is playing a role, as well as other factors that are difficult to surmise, especially with this sample size.

Lastly, arsenic variation between sites and events could be due to natural fluctuations, testing error, and intrinsic variation when collecting samples from a dynamic system.

Potential Impacts. Arsenic is a highly toxic element. It was recently classified as a Class A carcinogen by the EPA, which resulted in a tightening of the state standard in 2016. The most stringent standard for Rifle Creek, including West and East Forks, applies to Water + Fish. This Water + Fish classification is implemented in waterbodies with a water supply classification and where fish consumption is common.

Although arsenic tends to build up in fish tissue, it generally accumulates in the organic form of arsenobetaine, which is commonly called “fish arsenic” and is much less harmful compared to inorganic

forms (ATSDR 2007). The EPA drinking water standard for arsenic is 10 µg/L, much higher than the Water + Fish standard of 0.02 µg/L. Human health risks associated with arsenic and drinking water are likely low in this system, but it is difficult to know what concentrations exist at a given private well.

5.2 Selenium

Results. Reliable selenium results are available for 4 total sampling events: one in May 2016 and 3 throughout 2017. Results are shown in Figures 5-4, 5-5, and 5-6.

Selenium concentrations were fairly consistent, ranging from a median of 0.8 to 1.45 µg/L, when detectable. The highest concentration occurred in in mainstem Rifle Creek at Centennial Park (2.5 µg/L in October of 2017).

Overall selenium loading was highest in mainstem Rifle Creek (Below Rifle Gap) and in East Rifle Creek at Rifle Falls State Park. See Figure 5-5 for a graphical representation of selenium loading.

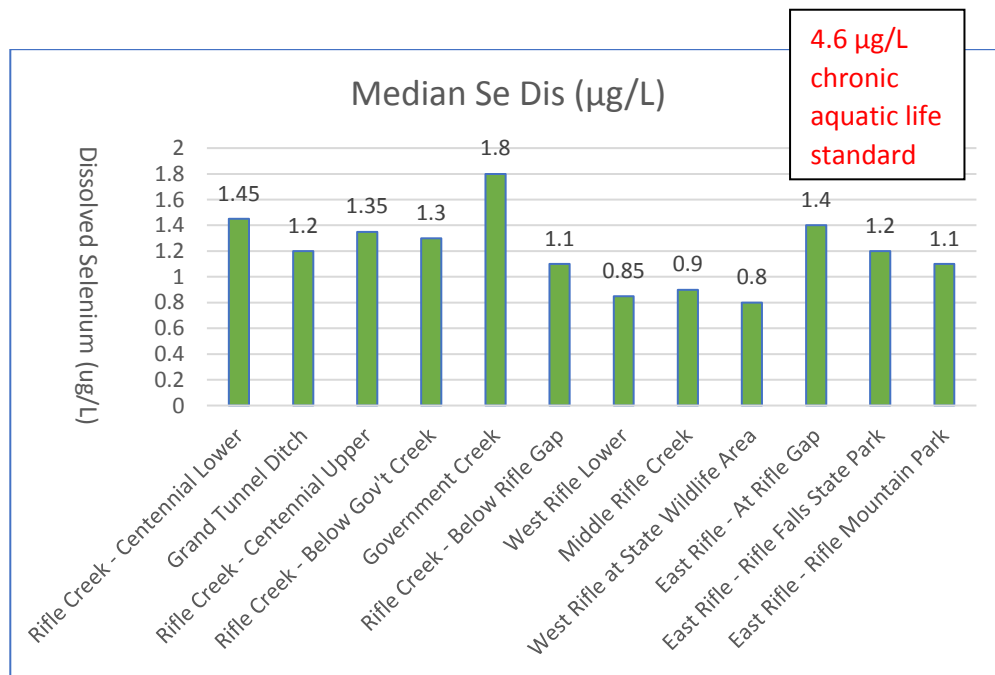


Figure 5-4. Median dissolved selenium concentrations at sites throughout the Rifle Creek Watershed. Only detectable results were taken into account. Four data points per median, except Gov. Creek, which had two. All samples processed by ACZ Laboratories.

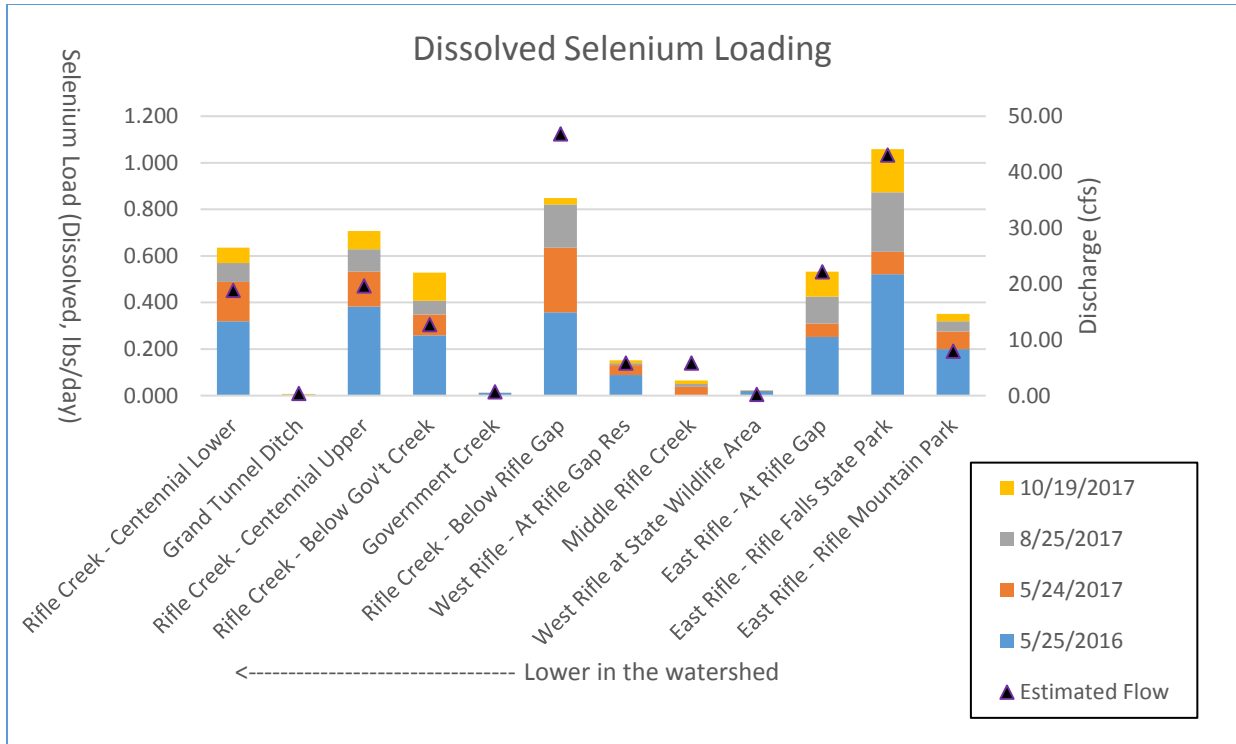


Figure 5-5. Dissolved selenium loading and median estimated discharge at all sites in the Rifle Creek Watershed. Four discharges were averaged from both BOR gage data and in situ-measurement estimate method.

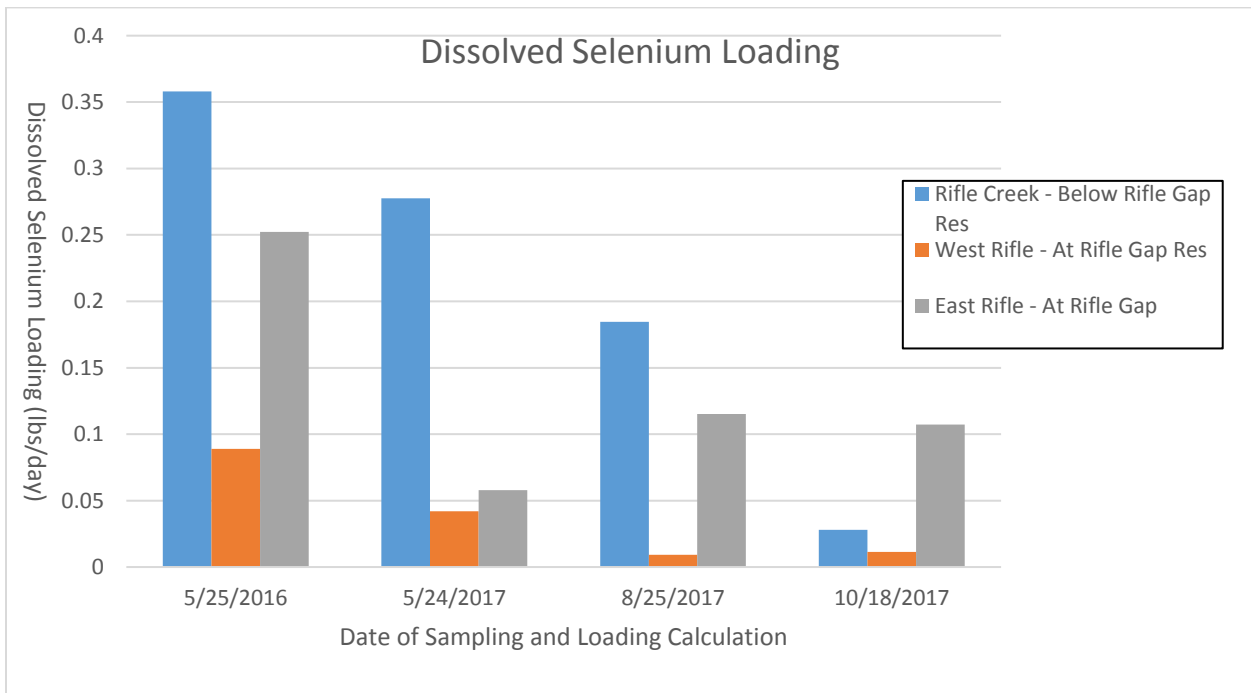


Figure 5-6. Dissolved selenium loading in East, West and Mainstem Rifle Creek (below Rifle Gap Reservoir) for four sampling events. Loading was calculated in pounds/day based on the concentration and discharge at the time of sampling on the day shown.

Discussion. Selenium was a parameter of major concern at the onset of this investigation. The results of this study indicate it to be minimal in its extent throughout the Rifle Creek watershed. All results were below the chronic aquatic life standard of 4.6 µg/L. Selenium concentration appears to increase minimally further down in the watershed, as can be seen in Figure 5-4.

Loading for selenium revealed that differences in discharge are the major factor driving loading when comparing sites (see Figure 5-5). Figure 5-6 shows that East Rifle Creek had a much larger selenium loading due to discharge. Additionally, it appears that Rifle Gap is sometimes a sink and sometimes a source of selenium, and most likely neither overall.

Selenium mobilization is often associated with deep percolation of irrigation waters via geochemical leaching and direct erosion. It is also associated with geologic formations such as Mancos Shale, a formation that bisects the Rifle Creek watershed.

EPA's current recommendations for selenium are somewhat more stringent than state of Colorado regulations. It recommends (not a mandate) a chronic water column standard of 1.5 µg/L versus the 4.6 µg/L standard that Colorado implements (EPA 2016). The EPA also recommends taking fish tissue samples to evaluate selenium levels when possible. This technique would provide better information for evaluating the risks for human consumption of fish.

5.3 Iron

Results. 16 out of 79 samples (20.3%) were above the state standard for total iron, which is a chronic standard for aquatic life. Total iron concentrations were generally elevated further downstream (Figures 5-7 and 5-14). A notable exception was the site below Rifle Gap Reservoir, which had very low iron concentrations, similar to the sites at Rifle Mountain Park and Rifle Falls. Grand Tunnel Ditch had the highest concentrations of iron. Mainstem Rifle Creek also had high concentrations of iron. West Rifle Creek, which had the highest concentrations of iron among the three forks, notably had a higher concentration of iron above the confluence with Middle Rifle Creek.

Mass loading is shown in Figures 5-8 and 5-9. Excepting the May of 2016 sampling event, East Rifle Creek consistently contributed more mass of iron than West Rifle Creek. Iron decreased considerably below Rifle Gap Reservoir when compared to the two major drainages.

Dissolved iron is not a parameter thoroughly discussed in this assessment, but is worth a brief mention. There is no listing in the Rifle Creek watershed for dissolved iron, which has a water supply standard of 300 µg/L. This is fitting since dissolved iron was found to have an average of 8 µg/L and a maximum of 79 µg/L.

Discussion. Iron was most likely low below Rifle Gap Reservoir due to settling or reduction in the lake. Iron concentrations were also low at the highest sites, Rifle Falls and Rifle Mountain Park. These low concentrations could be, but are most likely not due to dilution since the Rifle Mountain Park site did not have significantly lower flows when compared to this site (See Figure A-6 in Appendix A). Mainstem Rifle Creek drains a significant acreage of irrigated farmland which may be a contributing factor to elevated iron levels in this reach. The mechanism for increased iron is based on soil-water contact

resulting from irrigation practices. See Section 6.4 for more information on how Best Management Practices may be able to effectively lower iron content.

Loading contrasts with concentration when comparing East and West Rifle Creeks due to the difference in discharge between the basins. West Rifle Creek (including Middle Rifle Creek), drains more area than East Rifle Creek but has significantly different hydrology. The monocline known as “The Grand Hogback” separates the two drainages which have very different geology as well as elevations. See Figure A-8 in Appendix A for more information on geology. West Rifle Creek receives much less snow and generates less source water because of this. This leads to earlier peak flows and significantly lower base flows when compared to East Rifle Creek. This is a possible explanation for lower loading of iron as well as sulfate in the West Rifle Creek Drainage. It could be that West Rifle Creek contributes more iron in the early spring or winter (March-April) than East Rifle Creek.

Overall, total iron load increased downstream in the watershed. This is not surprising given that sediments also generally increase further down in the watershed (see section 5.6). These sediments are likely iron-rich. Iron load results shown in Figure 5-9 demonstrate how large influxes likely dominate the amount of total iron that enters the lower reaches of Rifle Creek.

According to these results, total recoverable iron is out of compliance with CDPHE standards in the Rifle Creek Watershed. West Rifle Creek, which is the location of the M&E listing is notably out of compliance, with 4 out of 7 concentrations exceeding the 1000 µg/L standard. It may be that this section warrants 303(d) listing.

Environmental Impact. Impacts on aquatic life by elevated iron can vary. Factors such as the form of iron, other water quality parameters, and physical stream characteristics influence its impact. Iron has been known to impact rainbow trout populations at concentrations of 1483 µg/L (Goettl and Davies 1977) or not until approximately 7500 µg/L (Steffens et al. 1993). It is impossible to say at this point whether iron is having a direct or indirect effect upon aquatic life in the Rifle Creek Watershed, but it is present at concentrations which could be adversely impacting aquatic life in West Rifle Creek.

Precipitates that smother macroinvertebrate habitat and fish spawning habitats are what have been shown to be the largest impact of elevated iron (Cadmus, et al. 2018). Given the low gradient and the fact that total iron at times decreased further downstream in West Rifle Creek, it can be inferred that iron precipitates are forming and settling in West Rifle Creek at certain times. Figure 5-7 shows that loading was actually greater overall further downstream in West Rifle Creek, thus much of the iron is being flushed into Rifle Gap Reservoir as well, most likely during precipitation events.

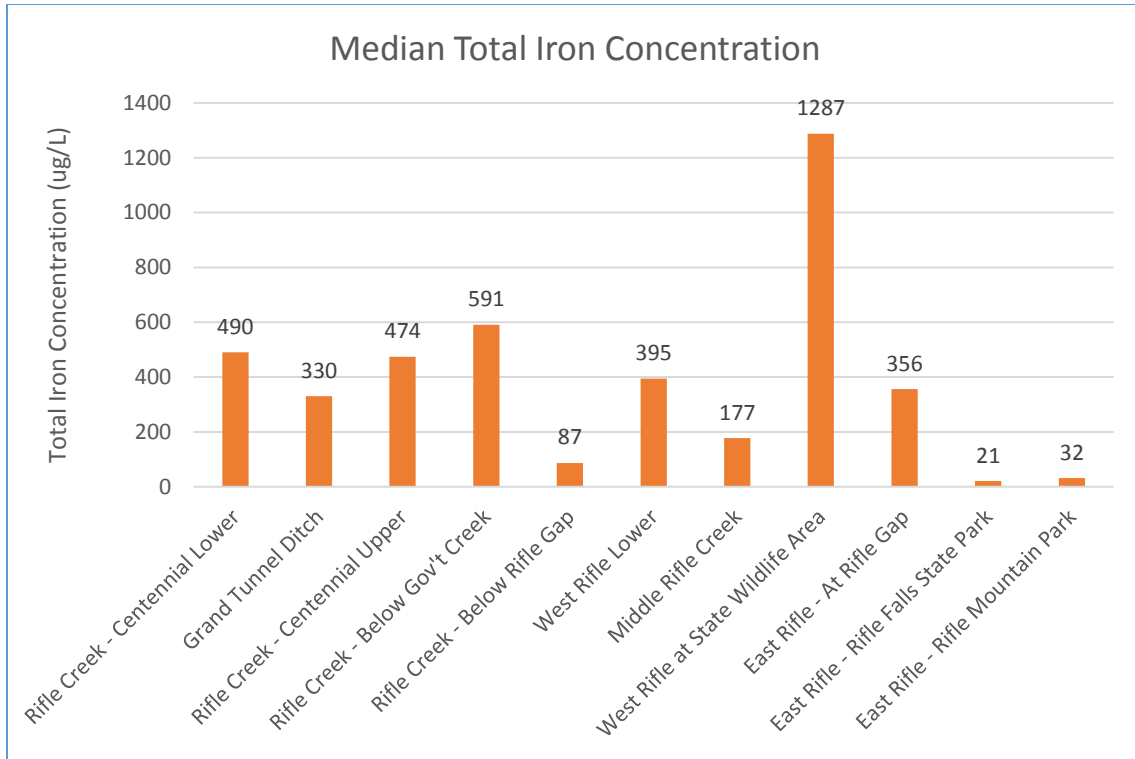


Figure 5-7. Median total iron concentrations for all sites and sampling events.

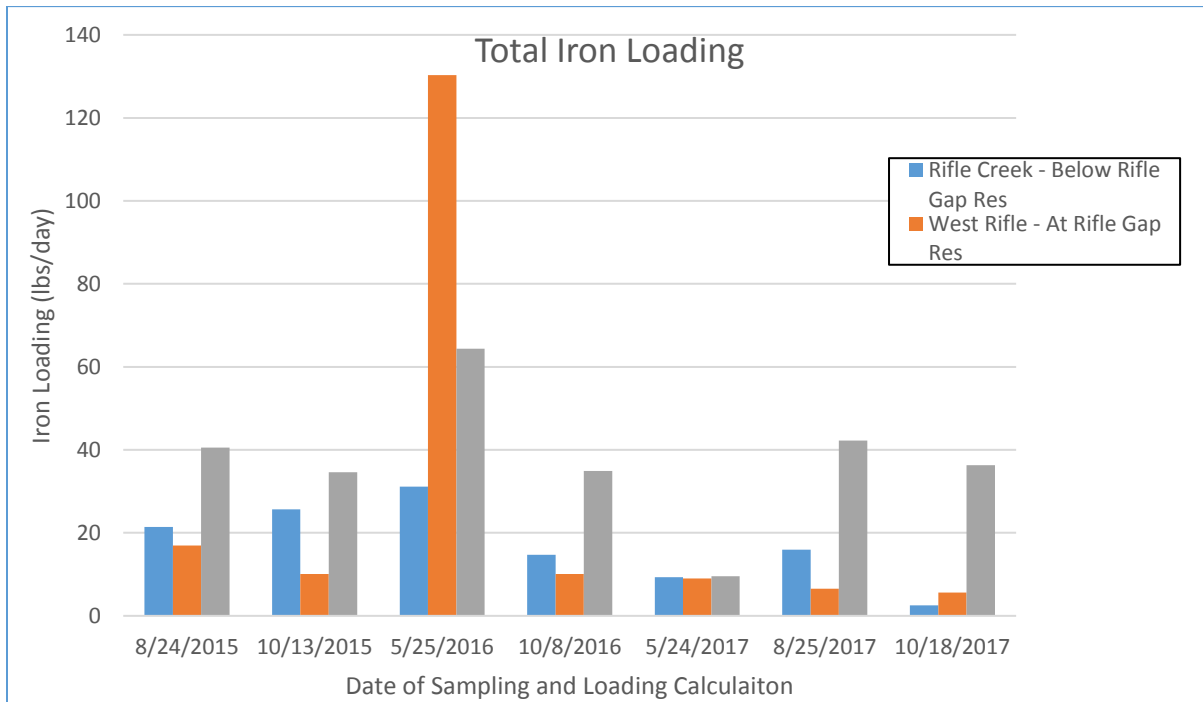


Figure 5-8. Total iron loading in East, West, and Mainstem Rifle Creek (below Rifle Gap Reservoir) for all sampling events. Loading was calculated in pounds/day based on the concentration and discharge at the time of sampling on the day shown.

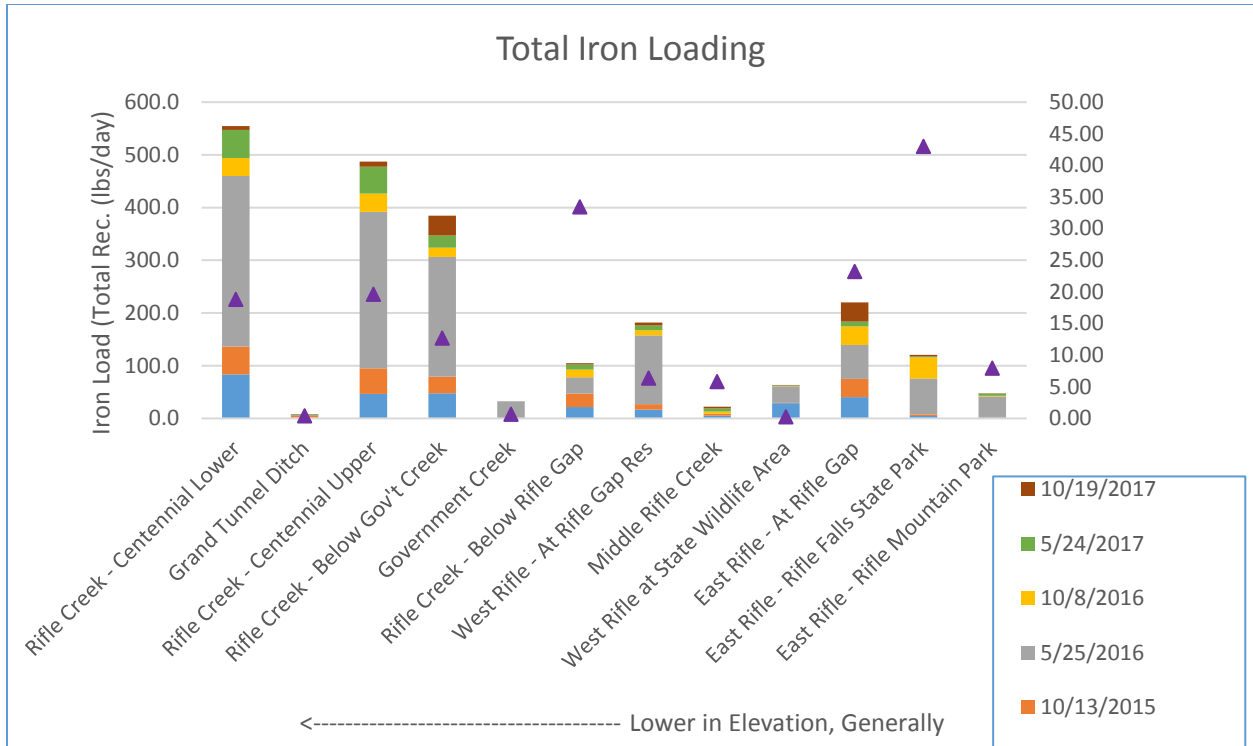


Figure 5-9. Total recoverable iron at all sampling locations in the Rifle Creek Watershed.

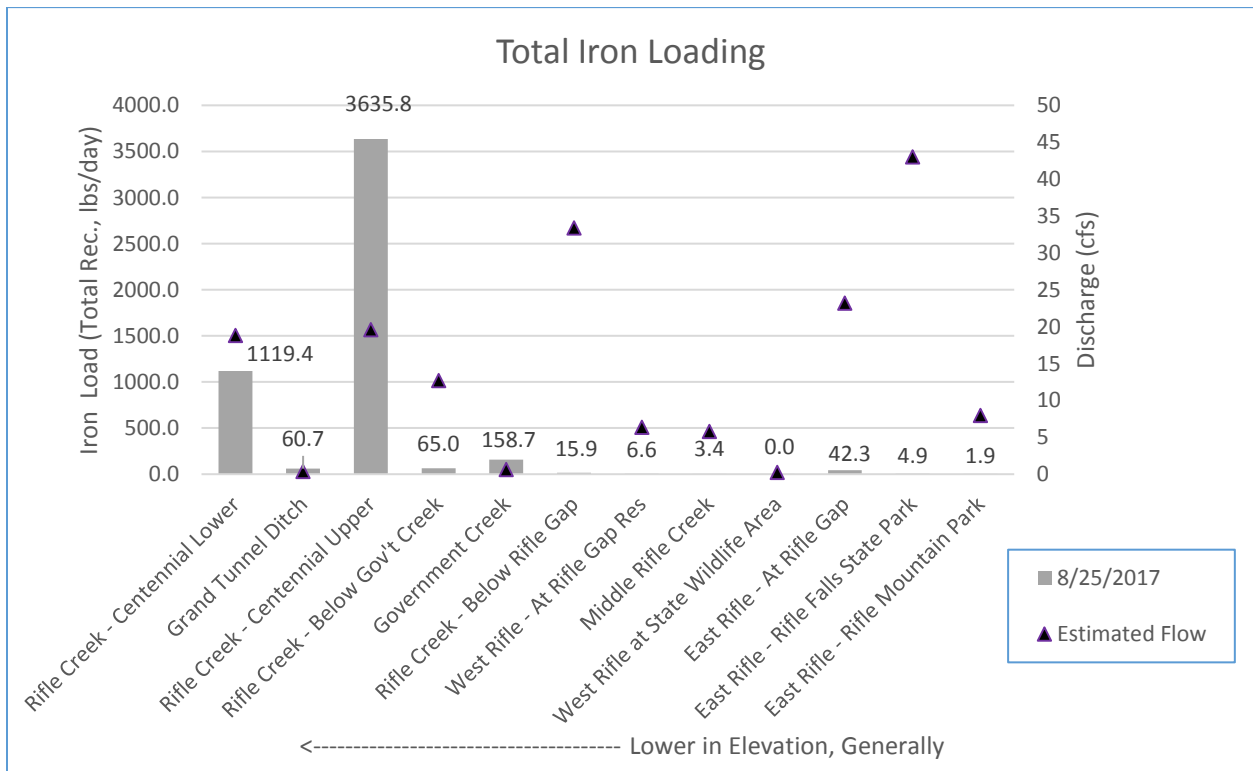


Figure 5-10. Total Iron Loading at all sampling locations on August 25th, 2017.

5.4 Sulfate

Results. Twenty-five out of 78 samples (32.1%) were above the state standard for sulfate (Figure 5-11). The highest concentration was observed at the Grand Tunnel Ditch site. West Rifle Creek at the State Wildlife Area (upper site) had the second highest average and was the highest among the three major tributaries. Sulfate was fairly widespread throughout the watershed.

As seen in Figures 5-12, 5-13 and 5-15, loading was greater below Rifle Gap than in all of the inputs into Rifle Gap Reservoir combined. East Rifle Creek had higher sulfate loading at Rifle Falls than near Rifle Gap, indicating a loss of mass between the two sites. East Rifle Creek had much higher loading of sulfate when compared to West Rifle Creek

Discussion. Loading of sulfate was very much linked to discharge, indicating that it is being consistently introduced into the system. The larger load of sulfate measured below Rifle Gap versus what is added via East, West, and Middle Rifle Creeks is interesting. It may be that this difference is due to increased flow below Rifle Gap during the time of sampling as well. Specifically, it is suspected that sulfate is added to Rifle Gap at certain times and then released at other times.

Sulfate loading decreased somewhat in both East Rifle Creek and Mainstem Rifle Creek at downstream sites. This indicates that sulfate is settling out, reducing out, or being removed from the system. These decreases still correlate with decreases in flow, therefore it would seem likely that the sulfate is being removed from the system when it is diverted.

Overall there are no significantly large spikes in sulfate concentration as was observed for iron and arsenic. Nevertheless, sulfate was often above the standard of 250 mg/L, which is a 30-day domestic water supply standard. Further consideration for listing sulfate on the 303(d) list may be warranted.

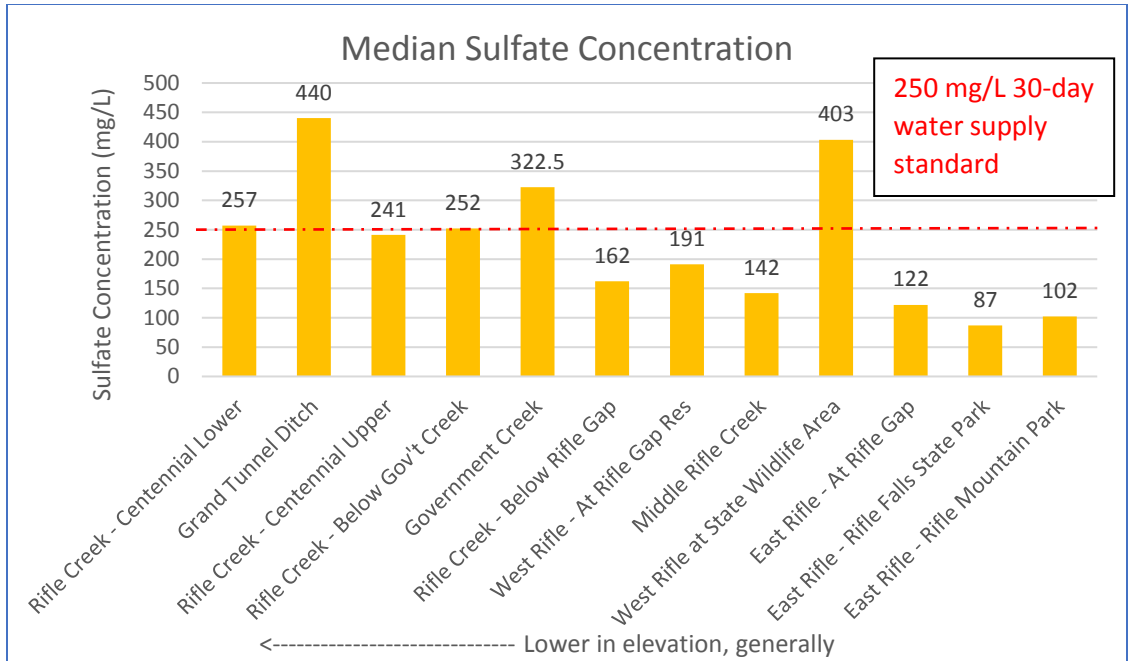


Figure 5-11. Median sulfate concentrations in mg/L at all sampling sites.

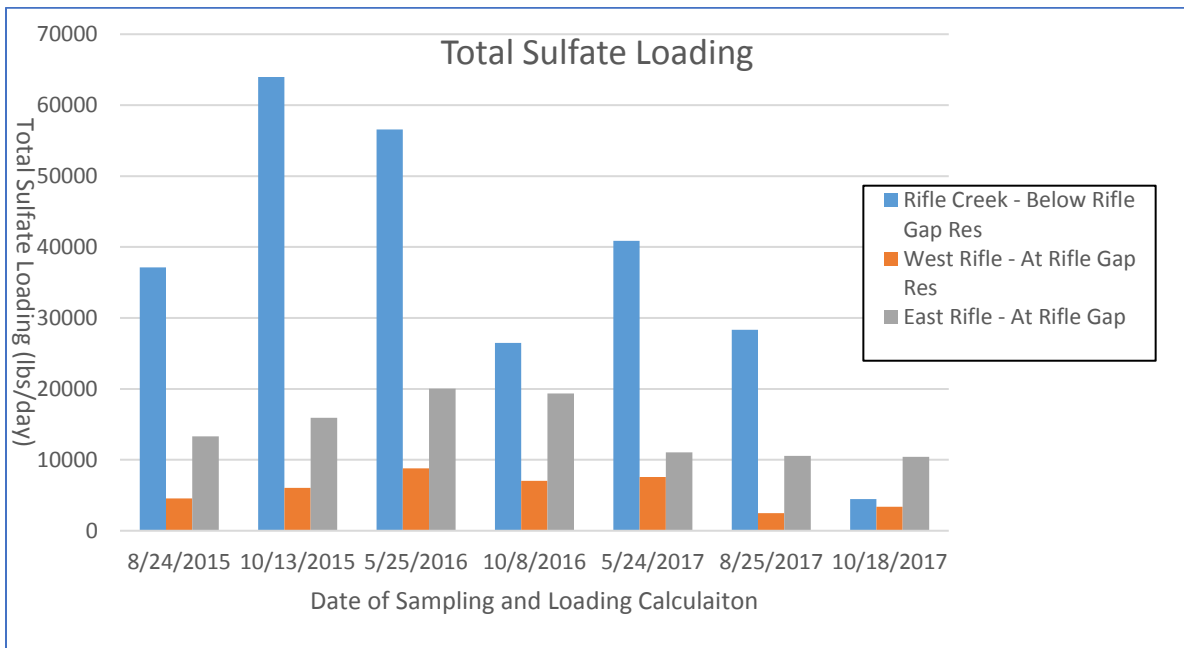


Figure 5-12. Total Sulfate loading in East, West, and Mainstem Rifle Creek (below Rifle Gap Reservoir) for all sampling events. Loading was calculated in pounds/day based on the concentration and discharge at the time of sampling on the day shown.

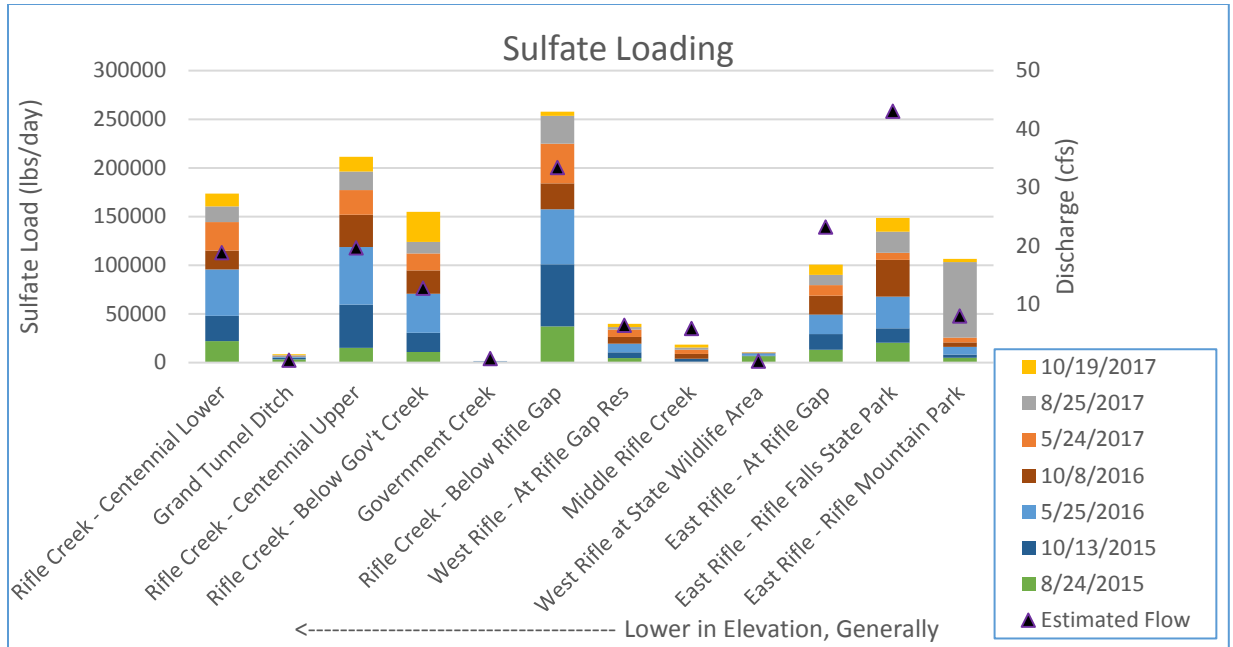


Figure 5-13. Total Sulfate loading at all sampling sites for all sampling events.

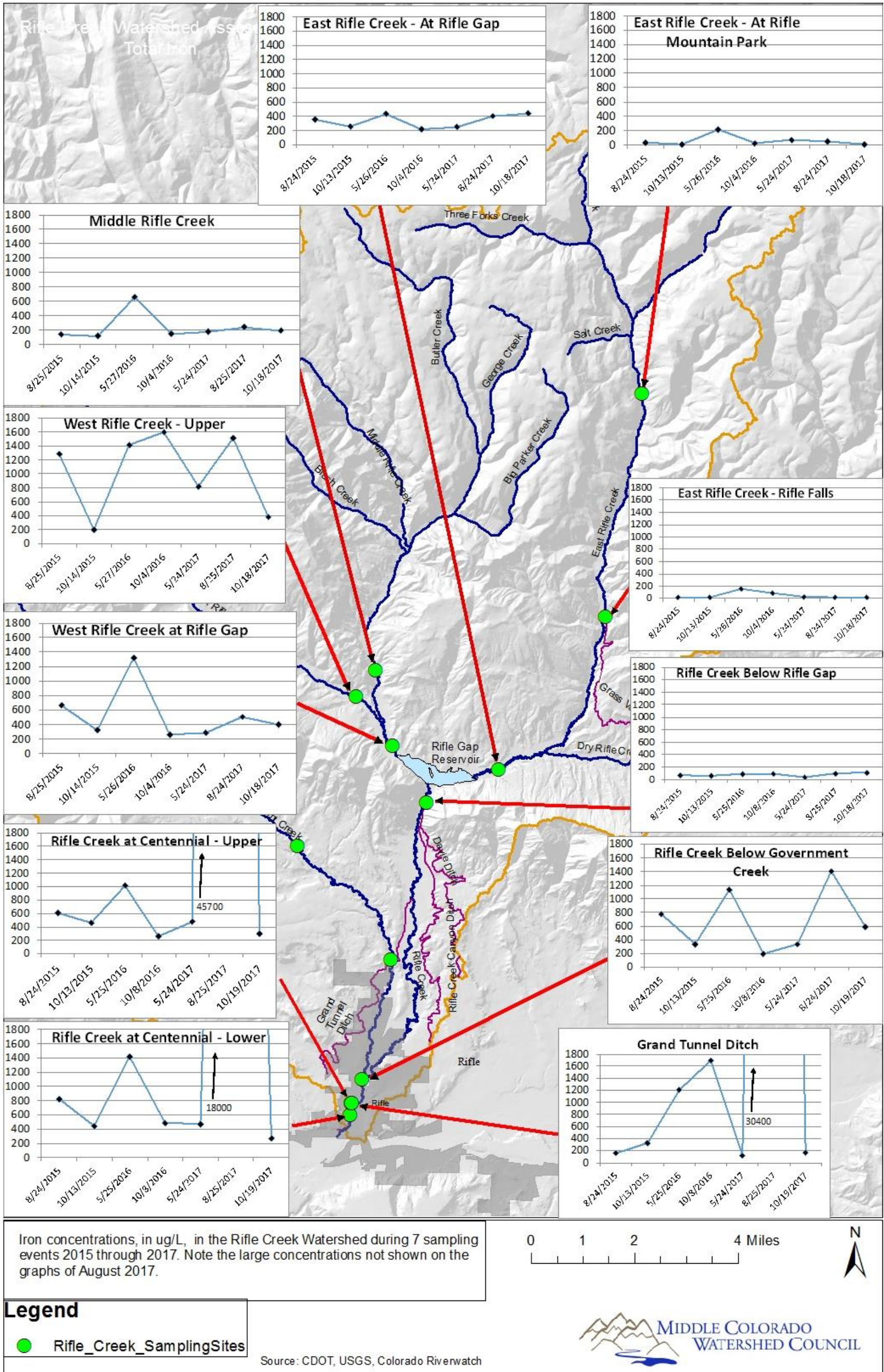


Figure 5-14. Total Iron Concentrations in the Rifle Creek Watershed during seven sampling events 2015 through 2017. Note the large concentrations in the Rifle Creek Watershed are off the graph scale for August 2017.

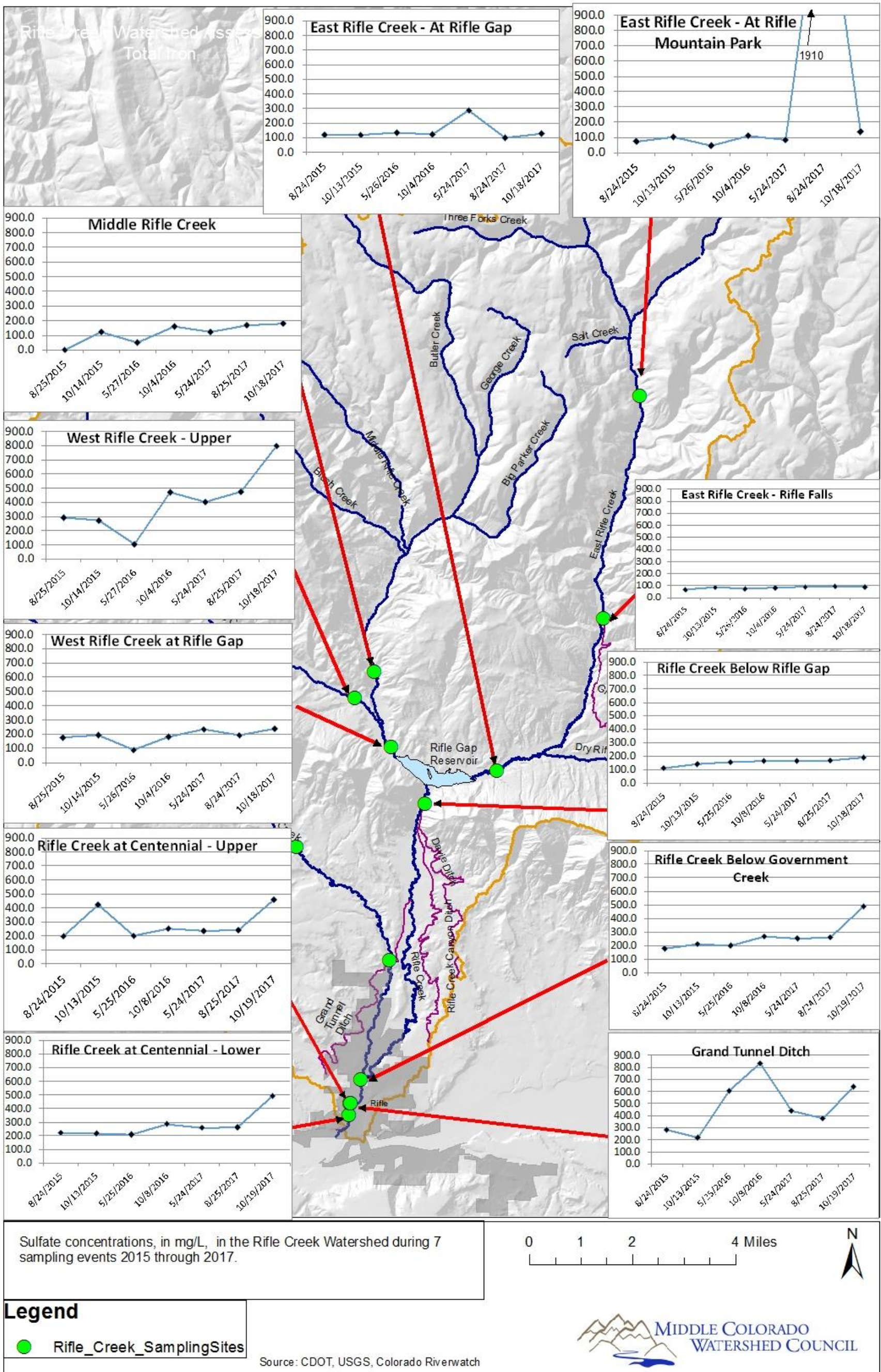


Figure 5-15. Sulfate Concentrations in the Rifle Creek Watershed during seven sampling events 2015 through 2017. Note the large concentration for East Rifle Creek at Rifle Mountain Park are off the graph scale for August 2017 was 1910 mg/L.

5.5 Specific Conductance / Salinity

Results. Specific conductance and thus salinity were highest in Grand Tunnel Ditch, followed by upper West Rifle Creek, and then the mainstem of Rifle Creek near the town of Rifle. Conductance generally increased going downstream, with West Rifle Creek being the exception (see Figure 5-16).

Discussion. As can be seen by elevated salinity in the Grand Tunnel Ditch, agriculture is likely an influence on salinity in this watershed. Agriculture has been cited as a source for one-third of the salts in the Colorado River (Gardner 1988). Other natural geologic processes are likely at play as well. Mining is an unlikely influence; there is only one mine upstream of Rifle Mountain Park that could lead to increased salinity at that site.

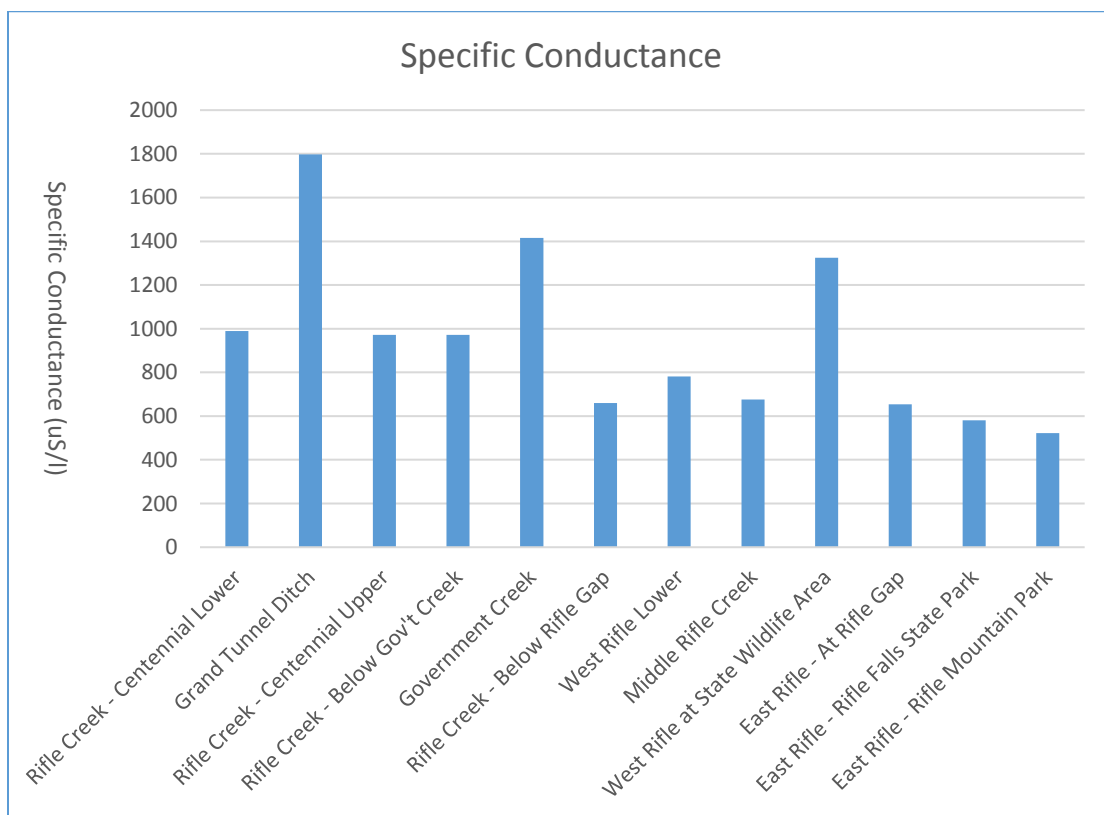


Figure 5-16. Median Specific Conductance concentrations for all sites excluding Government Creek which only had three measurements. Two at 32-mile gulch, were 1035 and 1816 uS/L on 5/26/2016 and 5/24/2017, respectively. One measurement at Hubbard Mesa OHV during 8/25/2017 area was 1415 uS/L.

5.6 Suspended Sediments

Results. According to these data, sediment loading was consistently greater in East Rifle Creek. This can be seen in Figure 5-17 below. West Rifle Creek's sediment load was much higher in the spring of 2016,

an exception to the trend. Overall, suspended sediment loading was greatest at the most downstream sites in the city of Rifle (see Figure 5-18).

Discussion. The consistent load from East Rifle Creek and sporadic load from West Rifle mimic the patterns seen with iron. East Rifle has more consistent flows that continuously transport certain constituents, including overall sediment, down through the basin. West Rifle Creek, and other basins such as Government Creek, are much more “flashy” both in terms of amount of water and the constituents that they contain. In other words, a lot of sediment will flush down West Rifle Creek during precipitation events.

Sediment deposition is undoubtedly occurring in Rifle Gap Reservoir. Though a measure of suspended solids does not include all particles that could be deposited, it does measure all suspended particles, essentially everything silt-sized or smaller. Comparing inputs to outputs allows for an estimation of how much suspended material is deposited; this study calculated deposition of suspended solids between 79 lbs/day and 12,533 lbs/day in Rifle Gap. Across the 7 sampling events, the median deposition was 2805 lbs/day.

The sediment event in August of 2017 showed that certain locations can receive large inputs after rain events. This has already been discussed in the arsenic and iron sections. It should be noted again how these constituents, as well as nutrients, are directly linked to sediment. Therefore, any reductions in total arsenic, total iron, and nutrients could be achieved alongside a reduction in overall sediment load.

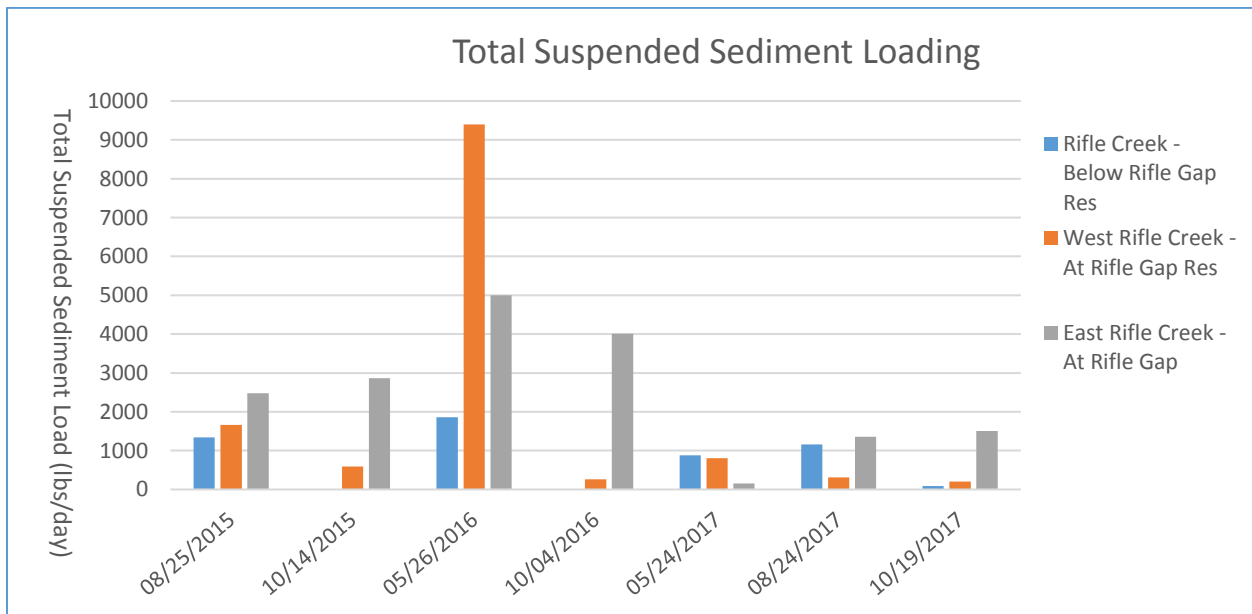


Figure 5-17. Total Suspended Sediment loading in East, West, and Mainstem Rifle Creek (below Rifle Gap Reservoir) for all sampling events. Loading was calculated in pounds/day based on the concentration and discharge at the time of sampling on the day shown.

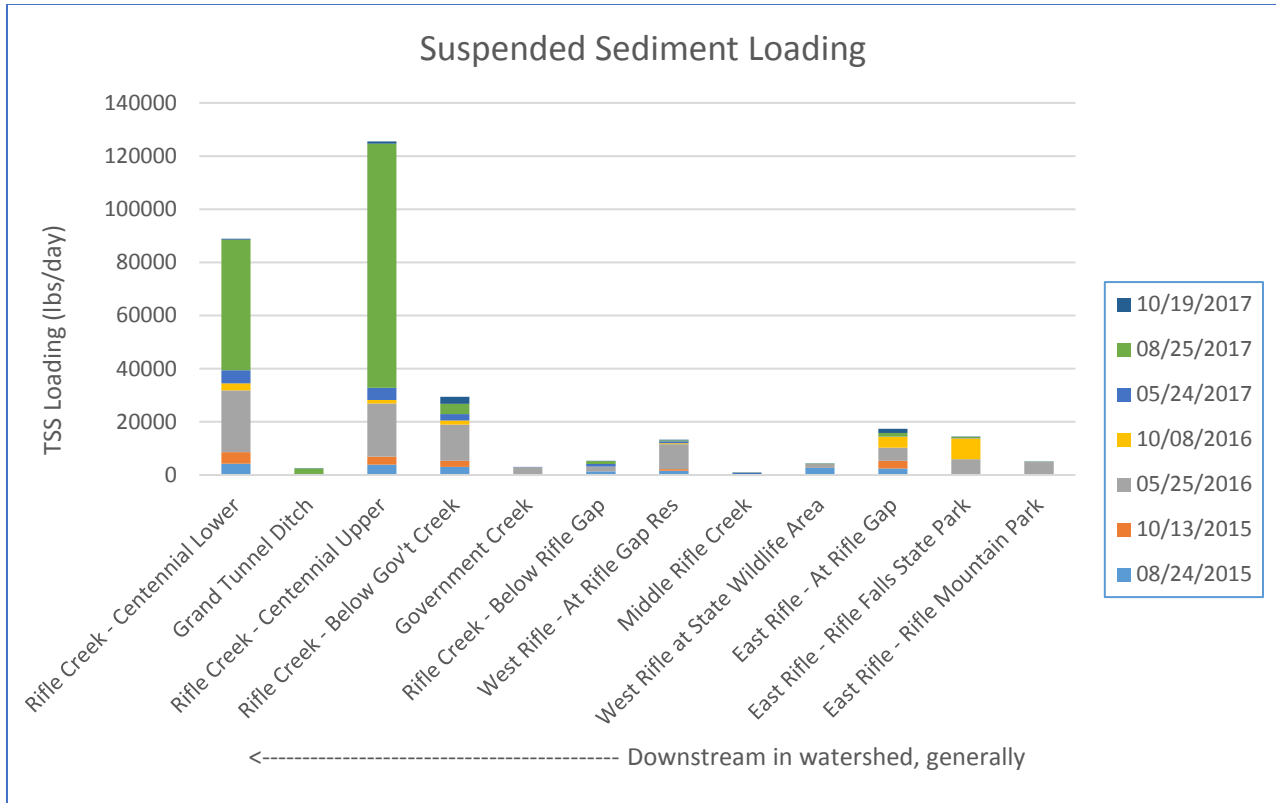


Figure 5-18. Total Suspended Sediment loading in for all sites and all sampling events. Loading was calculated in pounds/day based on the concentration and discharge at the time of sampling on the day shown.

5.7 Nutrients

Nitrogen.

Results. Drinking water standards for nitrate and nitrite are 10 mg/L and 1 mg/L, respectively, which is the strictest standard applied for all uses. Since the River Watch lab does not test separately for nitrate and nitrite, but reports it as a combined concentration, it is impossible to know if standards are being exceeded. However, since nitrate contributes a much higher percentage of the combined total of the two, it can be inferred that the nitrite standard was not exceeded (see Figure 5-19). However, a spike of 4-5 mg/L was measured during May 2017 at three sites: Grand Tunnel Ditch, Rifle Falls State Park, and Above Rifle Mountain Park.

Discussion. The spike recorded in May of 2017 may not have been uncommon for this system. The locations of the elevated nitrogen are interesting considering that there is no irrigated agriculture as high in the basin as Rifle Mountain Park. There are two plausible sources for this result – livestock manure from cattle high up in the forest or natural ground water. In either case, spring runoff generally has higher concentrations of nutrients (USU 2017) and is a possible explanation. Rifle Falls State park is immediately below the CPW Rifle Fish Hatchery, but this is an unlikely source given that elevated concentrations were already present upstream of this facility.

Impacts. According to the Utah State University Extension (USU), nitrate concentrations of 10 ppm (mg/L), can be harmful to babies, and 100 ppm (mg/L) is toxic to livestock. No concentrations were measured in this range, but further monitoring would be beneficial to gain confidence that water quality standards are continually being met.

See the section below on phosphorus and impacts of elevated nutrients to aquatic environments.

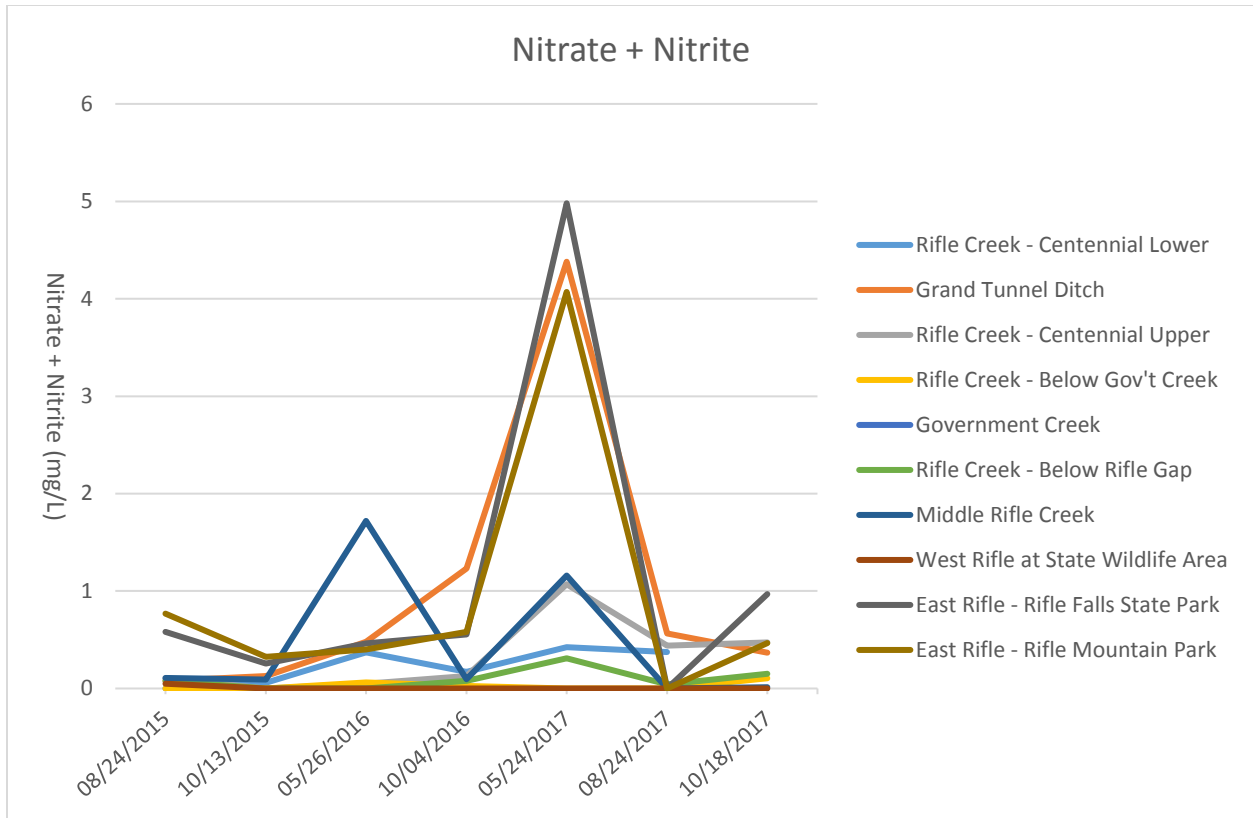


Figure 5-19. Combined nitrate and nitrite concentrations for all sampling sites in the Rifle Creek Watershed.

Phosphorus.

Results. Figure 5-20 below shows that most phosphorus results were below the interim cold water standard of 0.11 mg/L. CDPHE has adopted interim phosphorus criteria until standards are formally adopted in 2027. The three samples that significantly exceeded this standard were collected 8/25/17: Rifle Creek at Centennial 1 was 0.522 mg/L, Grand Tunnel Ditch was 1.38 mg/L, and Centennial 2 was 1.54 mg/L. Results at all sites appeared to rise and fall seasonally together, indicating that phosphorus sources are spread throughout the watershed on most occasions.

Discussion. The spike in phosphorus during August 2017 was detected only immediately within the lower portion of the city of Rifle as it was not present at the site on Rifle Creek below Government Creek. There is not a large distance between the Government Creek confluence and Centennial Park, therefore there are a limited number of possible sources. Notably, this sampling event saw spikes in arsenic and total iron as well. It was a sampling event that followed a rain event. It is therefore likely that these elevated phosphorus concentrations were caused by fertilizer runoff from lawns and parks in and around Rifle.

Note that phosphorus attaches to sediments, which could offer an explanation as to why we saw a spike in phosphorus but not in other nutrients.

Impact. Phosphorus is a vital nutrient to plants and is thus a large component of fertilizers that are applied to crops as well as lawns. In waterways, phosphorus, as well as nitrogen, are the most common causes of eutrophication. Eutrophication leads to algal blooms that can kill fish and shift the aquatic environment away from normal conditions, thus negatively impacting native species. Drinking water supplies can also become unpalatable (Kotak et al., 1994). Though there was only one time where elevated phosphorus was detected, it can be inferred that phosphorus may occur at elevated levels as it is mobilized during storm events. As phosphorus enters the Colorado River, there is a potential to contribute to eutrophication in that system, negatively impacting native and endangered fish populations.

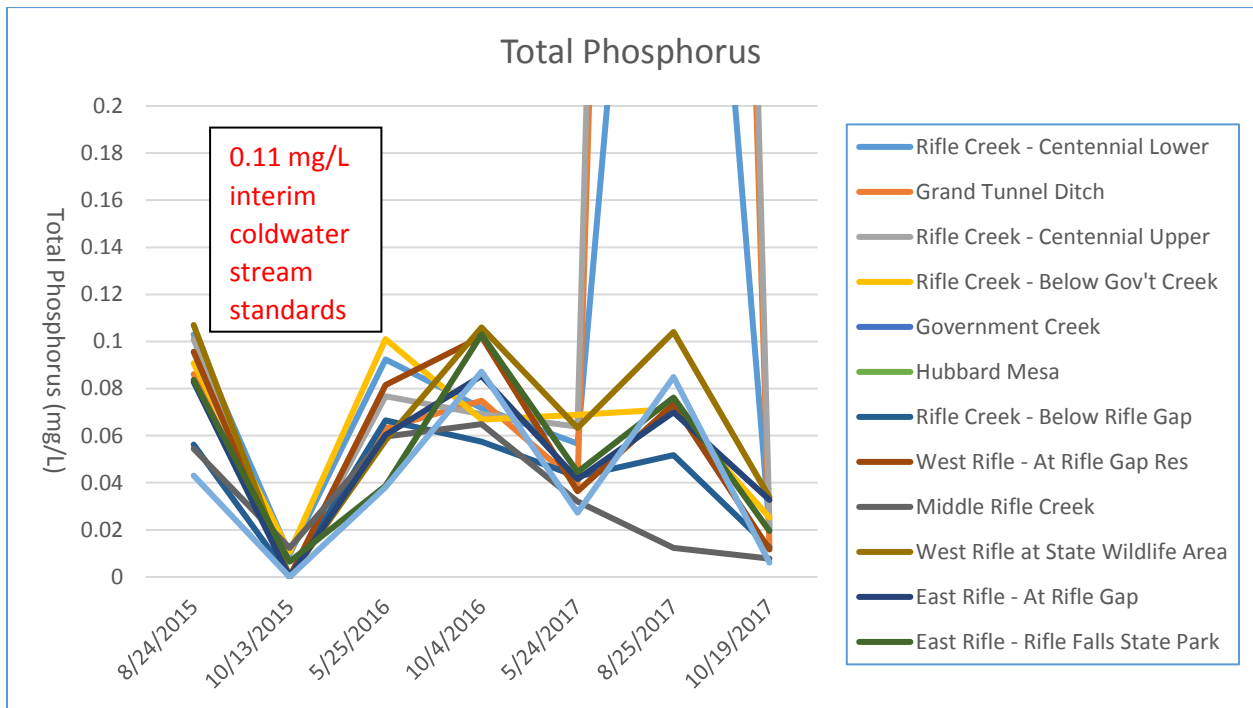


Figure 5-20. Total Phosphorus concentrations at all sites in the Rifle Creek Watershed. Off the chart values on 8/25/17 were: 0.522mg/L at Centennial Lower, 1.38 mg/L at Grand Tunnel Ditch, 1.54 mg/L at Centennial Lower.

Chloride. Figure 5-21 below shows chloride concentrations at all sites well below the chronic standard of 250 mg/L. The highest concentrations of chloride were observed in the Grand Tunnel Ditch, which was 82.6 mg/L. No especially interesting findings are associated with chloride; it is perceived to not be a major concern and is most likely natural.

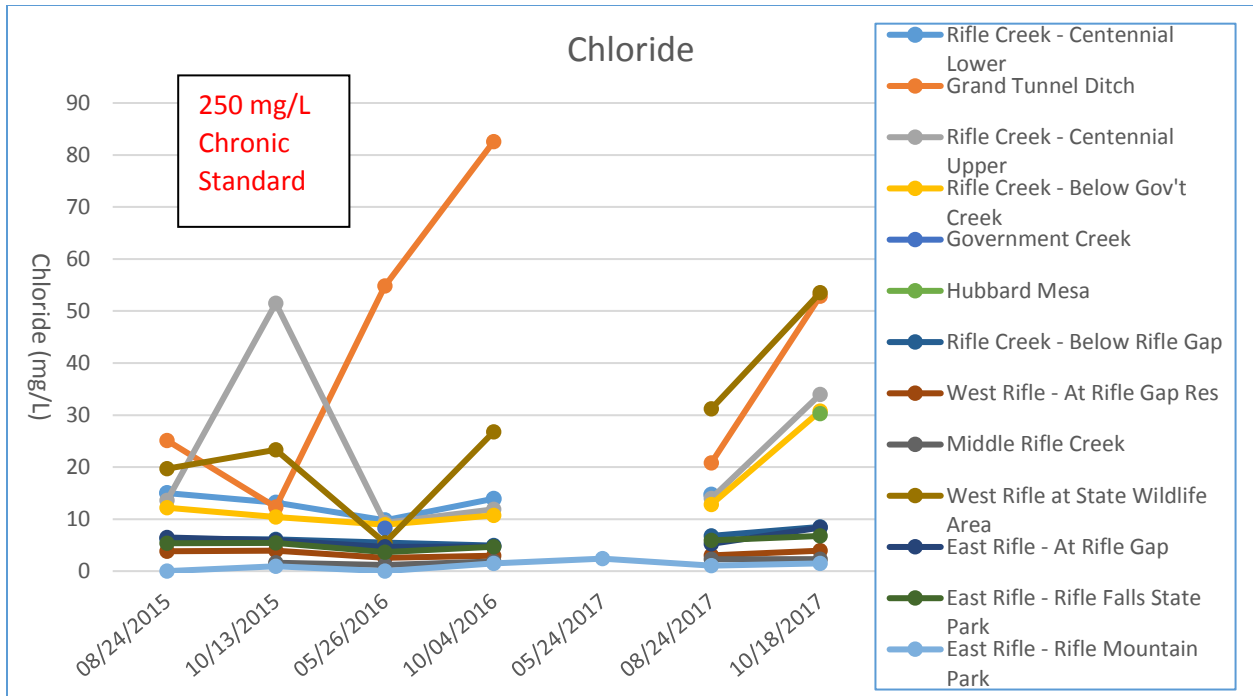


Figure 5-21. Chloride concentrations at all sampling sites in the Rifle Creek Watershed.

5.8 pH

pH affects what can live in water. The optimal range for aquatic life is between 6.5 and 9.0 which corresponds to the range specified as the standard. Outside of this range, pH can adversely affect organisms at various life stages (i.e. adolescence) and increase the toxicity of metals.

Factors that can influence pH include natural processes such as respiration and photosynthesis, buffering capacity, and geology. Anthropogenic sources can include acid rain, municipal runoff, agricultural runoff, and mining.

The pH in the Rifle Creek Watershed generally ranged between 8 and 8.5, as shown in Figure 5-22. Middle Rifle Creek had the highest average pH of 8.53.

Discussion. Results show that the Rifle Creek basin is fairly basic from top to bottom. This is most likely due to the geology and alkaline elements associated with it. There were no observed dramatic changes in pH that would indicate a large acidic or basic pollutant influx.

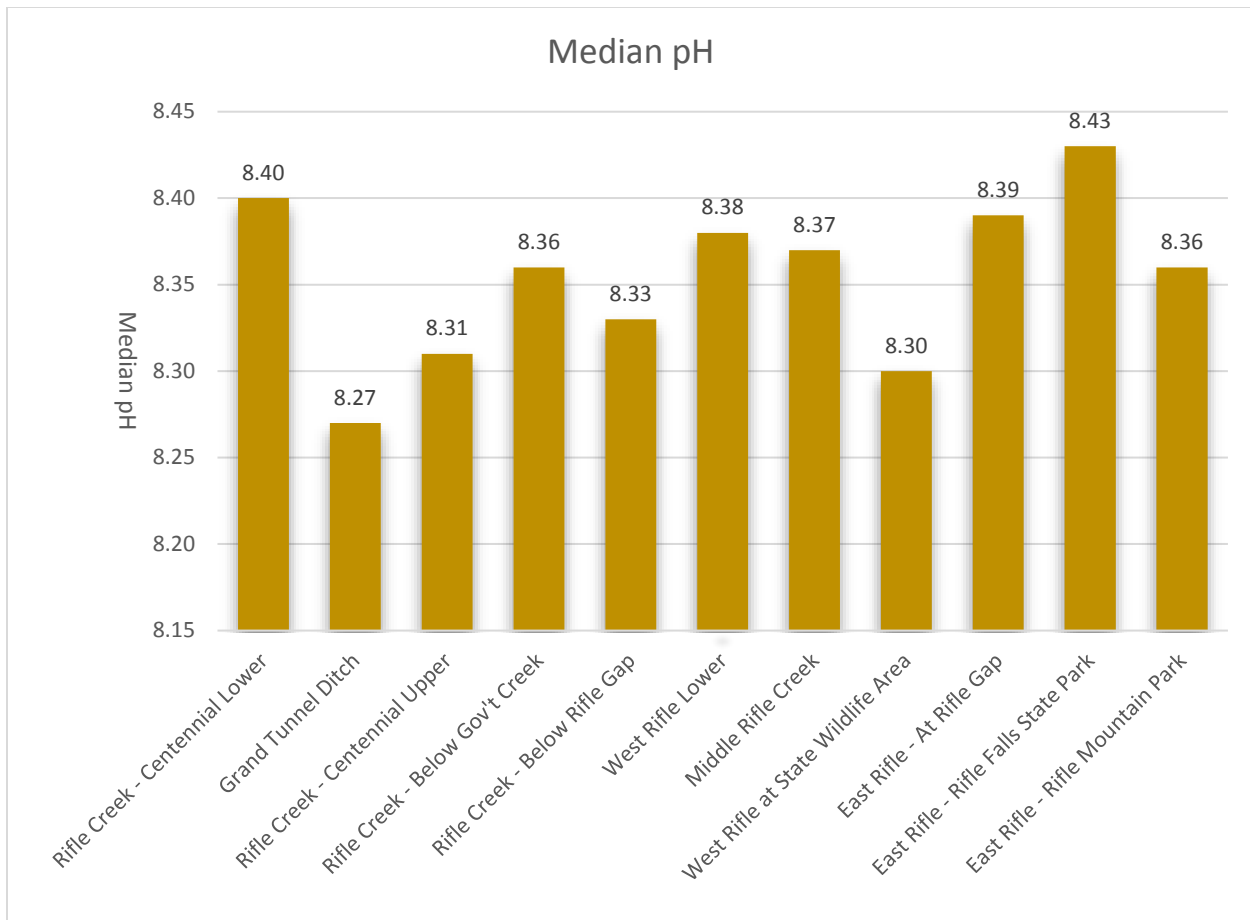


Figure 5-22. Median pH for all sampling sites and all seven sampling events in Rifle Creek Watershed.

5.9 Alkalinity

Alkalinity is the amount of carbonate and bicarbonate in the stream. It is often described as the “buffering capacity” of a stream. High alkalinity mitigates the impacts of influxes of acidic elements. This mitigation is accomplished by the carbonate and bicarbonate bonding with acids, rendering them unavailable.

Geology is generally the main influence on alkalinity, followed by precipitation and climate. Human influences can include acid rain and runoff from industry, agriculture, or cities. Although alkalinity doesn't have a set recommended range, generally an alkalinity in the range of 100-200 $\mu\text{g/L}$ is able to effectively buffer a stream (City of Boulder, 2007). An alkalinity of 10-20 $\mu\text{g/L}$ is often used as a minimum for aquatic life.

Results. Median alkalinity at a given site ranged from 176 $\mu\text{g/L}$ above Rifle Mountain Park to 377 $\mu\text{g/L}$ in the Grand Tunnel Ditch, as shown in Figure 5-23.

Discussion. Areas above Rifle Mountain Park have the lowest alkalinity given their position high in the drainage, providing less time for carbonate-rich rock and soil to incorporate. This site is also upstream of an area of exposed limestone, a rock type that is mainly composed of carbonate. All of the sites'

alkalinities seem sufficient to provide adequate buffering capacity to the streams in the Rifle Creek watershed.

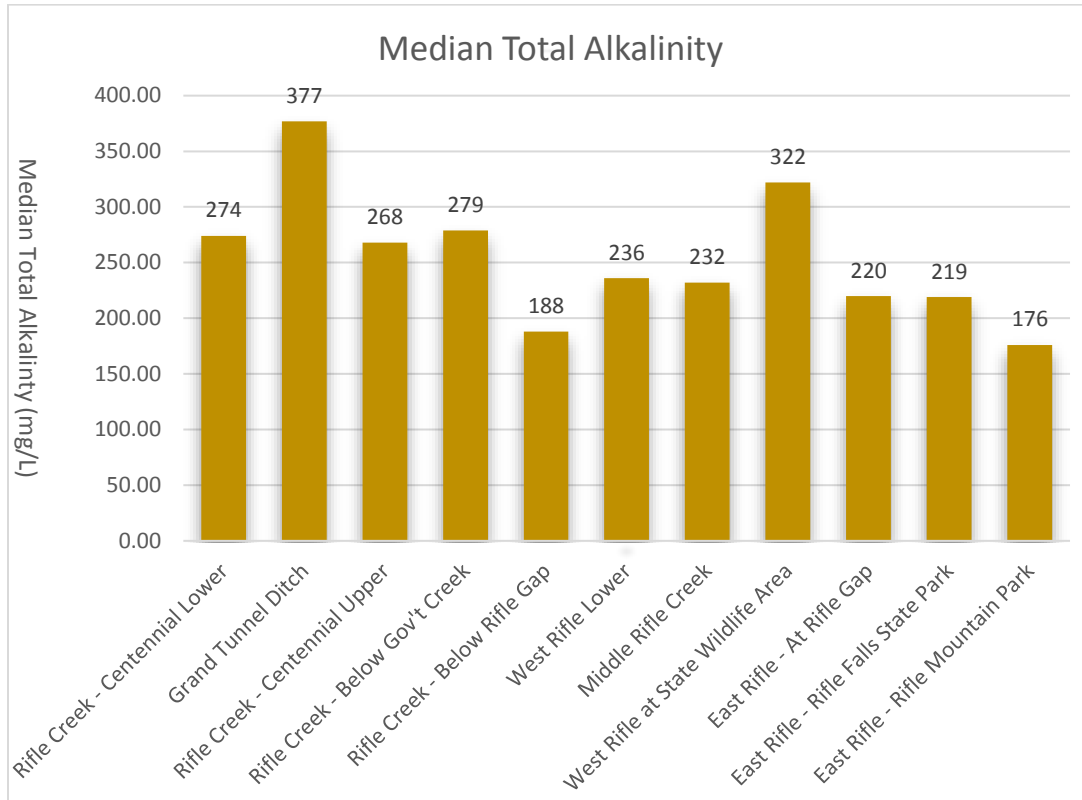


Figure 5-23. Median alkalinity for all sampling sites in Rifle Creek Watershed.

5.10 Hardness

Hardness, which is mainly controlled by calcium and magnesium concentrations, also buffers a stream in a way similar to alkalinity. Studies have shown that streams of high hardness support more aquatic life (River Watch 2016). In fish, for example, hardness protects gill sites from harmful elements through preferential bonding. Hardness has been shown to affect the toxicity of heavy metals (Besser et al. 2001).

Additionally, hardness can contribute to dietary calcium and magnesium, which are the main elements contributing to hardness. Negative effects of hardness can include “scale buildup” of these elements inside pipes and other infrastructure causing decreased water flow.

Climate, precipitation, and human influences all play a role. Human influences are mostly land use such as agriculture, mining, and other industry. As with other chemical properties, actions which increase soil-water contact and thus increase opportunities for calcium and magnesium incorporation into water are likely to increase hardness.

General guidelines used presented by USGS are:

	Value
Soft (not hard)	0-60 mg/L
Moderately Hard	60-120 mg/L
Hard	120-180 mg/L
Very Hard	>180 mg/L

Results. Hardness was in the Very Hard category throughout the watershed; ranging from 227 mg/L above Rifle Mountain Park to 551 mg/L in the Grand Tunnel Ditch (Figure 5-24). Hardness generally increased going downstream.

Discussion. This stream appears to be well buffered from acidic influences such as acid mine drainage. Those residents in the area who are using well water are undoubtedly experiencing negative effects due to scale buildup.

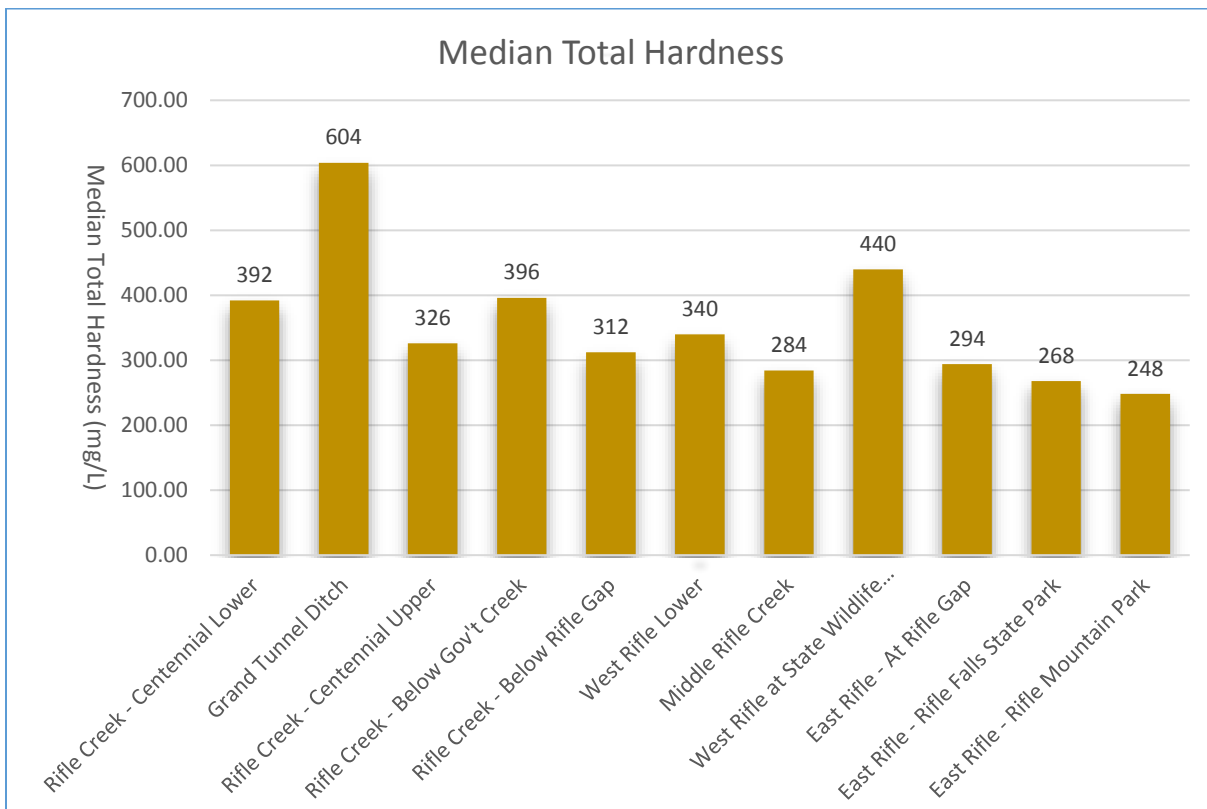


Figure 5-24. Median hardness for all sampling sites in the Rifle Creek Watershed.

5.11 Dissolved Oxygen

Dissolved oxygen (DO) is a measure of oxygen readily available to aquatic organisms (i.e. dissolved). It is affected by temperature, altitude, geomorphology, and biological processes. Within the biological processes category, humans can decrease DO by adding organic wastes from agricultural runoff, urban stormwater, waste water and industrial discharge. This organic waste leads to increased numbers of bacteria which consume DO.

As an example, brown trout prefer DO in the 9-12 mg/L range, but are tolerant of values 3-25 mg/L.

Average dissolved oxygen ranged from 7.97 to 10.07 mg/L as shown in Figure 5-25 below. The site above Rifle Mountain Park had the highest levels of DO. This is not surprising since the water is colder and more agitated by steeper gradients higher up in the watershed. Actual values ranged from 5.4 mg/L at Grand Tunnel Ditch to 12.0 mg/L above Rifle Mountain Park.

CDPHE has a standard of a minimum 6 mg/L for Rifle Creek. This standard was exceeded (values fell below 6 mg/L) for 3 samples out of 79: one at the Grand Tunnel Ditch site, one in West Rifle Creek at the State Wildlife Area, and one in Government Creek.

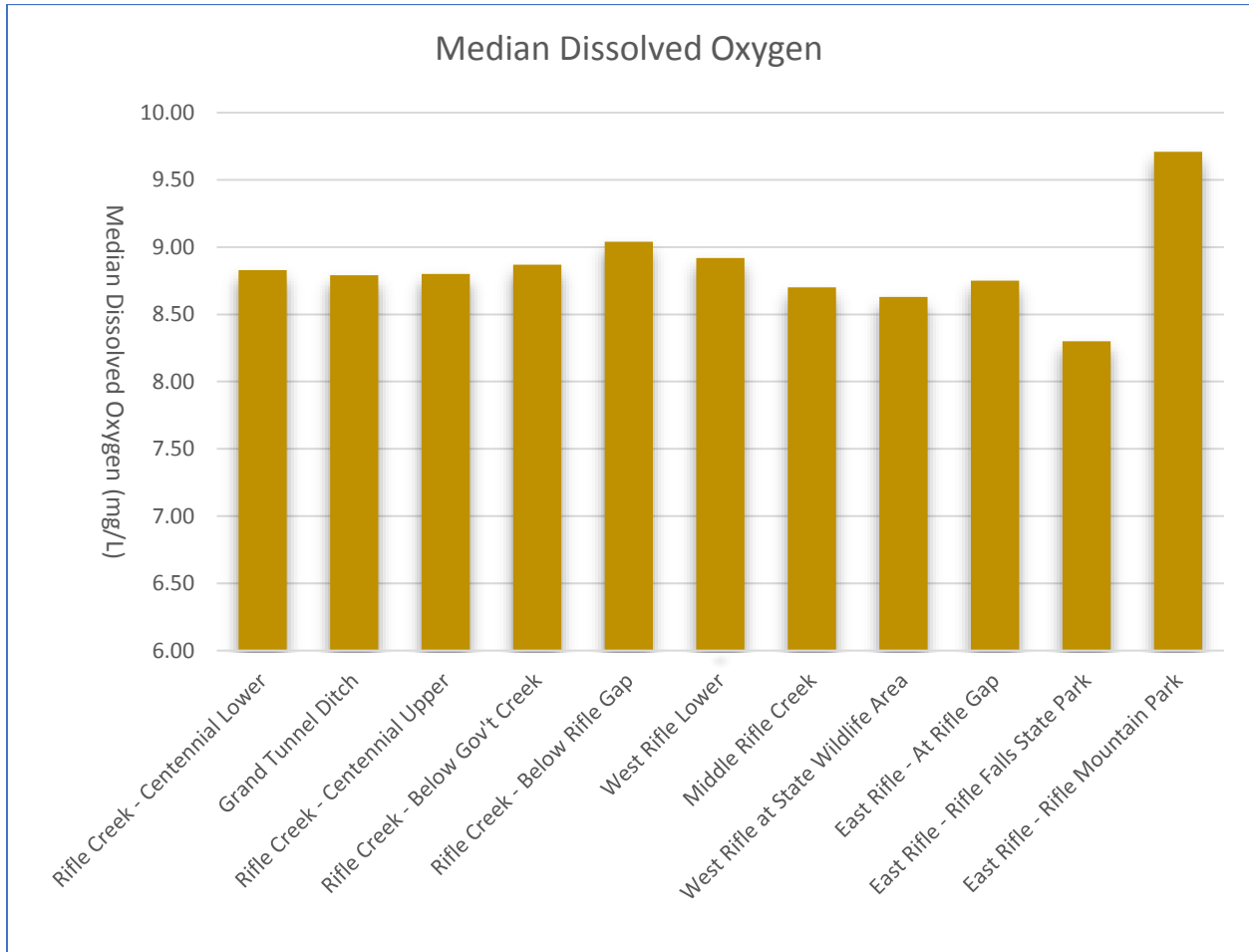


Figure 5-25. Median dissolved oxygen in the Rifle Creek Watershed. Government Creek site (two data points), not depicted.

5.12 Comparison of Current to Historical Data

Results. A comparison of historical (1981-2014) and recent (2015-2017) averages for arsenic, selenium, iron, sulfate, and salinity are shown in Table 5-4. Historic medians were much higher for all parameters except specific conductance. These historical and recent medians considered all values, regardless of whether it was above or below the MDL.

Table 5-4. Comparison of historical data (1981-2014) and recently collected data (2015-2017) in the Rifle Creek Watershed. Historic data collected by River Watch of Colorado and USGS, downloaded from CDSN. Number of exceedances was determined using 2018 standards.

Parameter	Total Count		<MDL Count		Median		Maximum		Number of Exceedances	
	Pre-2015	2015-7	Pre-2015	2015-7	Pre-2015	2015-7	Pre-2015	2015-7	Pre-2015	2015-7
Arsenic (Total) (µg/L)	7	79	0	33	2.1	0.6	12	222	7 (100%)	46 (62.2%)
Selenium (Dissolved) (µg/L)	77	79	4	29	1.8	1	4.8	2.5	2 (2.7%)	0
Iron (Total) (µg/L)	73	79	3	0	820	299	50000	98100 0	29 (39.7%)	16 (20.3%)
Sulfate (mg/L)	47	78	0	0	270	192.5	750	1910	26 (55.3%)	25 (32.1%)
Specific Conductance (µS/L)	200	80	0	0	668.7	814	2960	2441	N/A	N/A

Medians for all parameters listed on 303(d) and M&E lists were lower from this study than in pre-2015 data. Interestingly, specific conductance was higher for recent data. This is also the only parameter that had more data points historically, these two facts may be correlated. Nevertheless, at a glance it would appear that water quality is improving, which is especially apparent when comparing the percentage of exceedances in Table 5-4.

Discussion. It is suspected that, historically, only higher concentrations were reported, thus skewing median data to be higher. This is evidenced by there not being nearly as many measurements less than MDL in the historical data set when compared to recent data. This effect is also likely due to improvements in laboratory analysis methods that allow for lower concentrations to be detected more accurately.

Maximum values were higher for several parameters in the 2015 to 2017 time range. This is attributed to the larger data set and subsequent increased probability of encountering outliers, particularly during precipitation events.

5.13 Government Creek

Government Creek is different from the other major tributaries in that it has intermittent flows. It drains a large swath of area, however, about 45 square miles, or 22 percent of the watershed. It can be a significant influence on water quality downstream of its confluence with the mainstem of Rifle Creek.

Since this stream was only sampled on two occasions, the data was not always included in tables or figures. Concentrations for two parameters of special interest in this study, arsenic and iron, were found to be considerably higher in Government Creek than the other sites. Table 5-5 shows all four of the parameters of special interest in this study in Government Creek when compared to the rest of the sites during the May 2016 and August 2017 sampling event.

Table 5-5. Concentrations of four parameters of interest in Government Creek compared to the median of the remainder of sites during the only dates for which there is data in Government Creek, May 2016 and August 2017.

Parameter	Government Creek At 32 Mile Gulch 5-25-16	Government Creek At Hubbard Mesa 8-25-17	Rest of Sites - Median
Arsenic, Total ($\mu\text{g/L}$)	4.6	222	0.5
Iron, Total ($\mu\text{g/L}$)	4750	981000	280
Selenium, Dissolved ($\mu\text{g/L}$)	1.6	2	0.9
Sulfate, Total (mg/L)	187	458	193

Government Creek is a waterway that warrants further study. It is a possibly a major source of nonpoint source pollution in the Rifle Creek Watershed during precipitation events. Within the lower reaches of this stream there is OHV use directly in the stream channel as well as non-native tamarisk present in the riparian area. Loading is generally very low in Government Creek as discharge is generally low, but this trend can be reserved during large runoff events.

5.14 August 25, 2017

August 25th, 2017 was a sampling day that yielded unique results. Arsenic and iron concentrations were, in particular, very high. Government Creek was flowing at Hubbard Mesa OHV area but not at the 32-mile Gulch site a little higher in the drainage. The creek at Hubbard Mesa was chocolate-milk colored and not flowing a lot. It was sampled effectively, however, and the results indicate that the spikes of iron and arsenic that were detected downstream in mainstem Rifle Creek were most likely coming from Government Creek. Specifically, the water was originating somewhere between the Hubbard Mesa OHV area access and 32-mile gulch.

Though the exact extent of this drainage’s impact is not known, it can be seen that it has a potential to be acutely impactful. The total arsenic concentration on August 25th was 222 $\mu\text{g/L}$ at Hubbard Mesa, approximately 11,000 times the strictest CDPHE standard for arsenic (Water + Fish) in this basin. However, this total is still below the acute aquatic life standard of 340 $\mu\text{g/L}$. Total iron was 981,000 $\mu\text{g/L}$, which is 981 times the total iron standard in this basin (Figure 5-10).

NOAA recorded climate observations do in fact show that there was precipitation recorded at multiple locations in the Rifle, CO area. This explains why there was any water flowing in Government Creek, an intermittent stream, in August, and suggests that acute influxes of constituents of interest may be a common occurrence during rain or melted snow events.

5.15 Other Results

Though this study focused mainly on a few parameters that are known or suspected issues pertaining to water quality, this study included data for 46 different parameters, including both dissolved and total metals. Additional parameters not yet mentioned, but that have a standard in Rifle Creek, include the following:

- Aluminum (total)
- Cadmium (dissolved)
- Copper (dissolved)
- Lead (dissolved)
- Manganese (dissolved)
- Zinc (dissolved)

All of the parameters listed above were all within accepted standard ranges for all sampling events and are not deemed to be a concern at this time.

6.0 Conclusions and Recommendations

6.1 Water Quality Conclusions

This study, initiated in 2015, was developed to evaluate the health of the Rifle Creek Watershed using water quality as the primary indicator. The data set is too small for a robust statistical analysis, but basic observations regarding median concentrations, loading amounts, and spatial trends can be drawn. Additional sampling and analysis may be warranted to either support or refute the state's 303(d) listings.

Selenium. All concentrations of selenium at all sites were below the state chronic standard for aquatic life, a finding that supports the State's delisting of this analyte in 2016. This study confirmed that selenium is not a major water quality concern in the Rifle Creek watershed. Selenium loading was fairly evenly distributed throughout the watershed.

Arsenic. All arsenic concentrations were well above the recently implemented, more stringent water quality standard for water + fish. Concentrations were generally higher downstream in the watershed and were highest in West Rifle, Government Creek and mainstem Rifle Creek. West Rifle's elevated arsenic is most likely due to the unique geology of that drainage. Agriculture and pesticides may play a lesser role. These conclusions are supported by the observation that there is no historic mining in that area and the geology is very different from Middle and East forks which showed less arsenic. Overall loading of arsenic fluctuated significantly, even within individual tributaries, indicating that arsenic is being continuously added to and removed from the water column.

Iron. Sixteen out of 79 samples (20.3%) were above the state standard for total iron. Iron followed a pattern similar to arsenic. It was highest in West Rifle and Mainstem Rifle. Therefore, as with arsenic, it is likely that geology and agriculture are contributing to elevated iron concentrations at these sites. Government Creek should be studied in more detail to determine its role in iron loading to the lower sections of Rifle Creek and eventually the Colorado River. Iron concentrations may be high enough to result in detrimental impacts to aquatic life in certain areas.

Sulfate. Twenty-five out of 78 samples (32.1%) were above the state standard for sulfate. Sulfate followed the trend that was observed for arsenic and iron. Geology, agriculture and residential runoff are suspected to be causes of elevated sulfate, especially in West Rifle and mainstem Rifle Creek. Agricultural and lawn fertilizers are a potential cause that could be investigated further.

Nutrients. Nitrate, nitrite, and chloride were in compliance for all samples in this study. One sampling event, August of 2017, showed phosphorus concentrations at the downtown Rifle sites that greatly exceeded the state standard. Based on these results, phosphorus is a nutrient that is entering this system in high concentrations during precipitation events in the city limits.

Overall Water Quality. An overall increase in specific conductance can be seen in Table 5-2 when comparing current study results with data before 2015. This does not directly compare the same sites, however, and suspended solids (directly related to conductance) were seen to fluctuate largely based on site location. Figure 5-18 shows this relationship as well; sediment loading is much higher lower in the basin. East Rifle Creek consistently contributes larger loads of most parameters due to higher flow volume, but West Rifle Creek experiences spikes during runoff events.

6.2 Natural Versus Human Influences

It is undoubtedly the case that constituent concentrations and loads in this system are due to both natural and anthropogenic influences. In this complex system it is difficult to tell which is playing a larger role and sources are most likely parameter specific. In the case of selenium, underlying geology is the main source. Arsenic, iron, and sulfate are all most likely heavily influenced by geology, hardness, and anthropogenic causes, mainly increased soil-water contact via land disturbance and irrigation.

6.3 Best Management Practices

Key objectives of this study were to determine the sources of water quality impairments, identify where the sources are located, and recommend Best Management Practices (BMPs) for source control. Now that water quality impairments have been further characterized, we can identify specific next steps that might be used to mitigate water quality issues. The cumulative use of BMPs should have a positive impact on water quality in the basin.

Grazing Management. Grazing is ubiquitous on the western slope of Colorado and has implications in terms of water quality (NRCS 2003). Grazing practices can expose soils, increase erosion, increase soil compaction, encourage invasion by undesirable plants, destroy fish habitat, and degrade streambank integrity and floodplain vegetation that is important for wildlife habitat, water filtration, and stream shading. Certain improvements can be implemented to minimize the impact of grazing on water quality. These include:

- rotating livestock and limiting the amount of time they graze in a certain area;
- switching to an animal species better suited to the terrain (such as sheep or buffalo);
- reducing number of livestock;
- fencing off sensitive riparian areas; and
- providing adequate water troughs for livestock to offset the need for stream access.

Organizations such as NRCS can help agricultural producers with funding for the implementation of such BMPs. More information on funding assistance can be found in Appendix B. Those seeking additional information on Grazing Management should reference NRCS's "National Range and Pasture Handbook",

chapter 5 “Management of Grazing Lands”. A number of funding sources exist to assist with range improvements, see the table in Section 6.6. For technical expertise, NRCS and the Bookcliff Conservation District are excellent sources.

Off-Highway Vehicle (OHV) Management. OHVs can cause significant ground disturbance, particularly where users have created ad-hoc roads. For example, the Hubbard Mesa OHV area, an area designated by BLM explicitly for the purpose of OHV use, contains an extensive network of user-created roads. Closing steep terrain and riparian areas off from OHVs use and encouraging the use of less sensitive areas could improve water quality in Government Creek and ultimately the mainstem of Rifle Creek through the City of Rifle. Limiting use in areas not designated for use by OHVs by closing user created trails may improve water quality as well.

Detention Ponds and Wetlands. The building of on-channel detention ponds could serve to mitigate impacts to water quality by allowing sediment and constituents such as iron and other metals to settle out if they are in the total recoverable state or reduce out if they are in the dissolved state. Settled material would need to be removed periodically to maintain pond capacity. These ponds could be designed with wetland “forebays” where certain elements like selenium and nutrients could be biologically transformed by the wetland vegetation, effectively removing them from the system. In a sense, Rifle Gap Reservoir probably functions like a detention pond now, trapping and storing possible pollutants transported by East, Middle and West Rifle Creeks. The lower portion of the watershed, below Rifle Gap Reservoir, would be a more logical section of the basin to locate these types of features.

Diversion Structure Improvements. Diversion structures, depending on their design, can be an impediment to fish passage and detrimental to water quality (Baker et.al, 2010 and USDA 2013). Upgrading and improving old structures can minimize localized erosion and associated water quality degradation.

Efforts are underway at the BLM to inventory these structures to determine which may be good candidates for redesign. Private lands ditches and diversions are being inventoried by local Conservation Districts in conjunction with the Integrated Water Management Plan that is currently being conducted by the Conservation Districts and Middle Colorado Watershed Council.

Stream / Riparian Restoration. Restoration of the stream corridor is an appealing choice overall when looking to improve water quality. Riparian vegetation is a well-proven asset in terms of its water filtering and erosion reduction capabilities. Removal of invasive species, direct seeding, planting of whips/poles, and planting of rooted material are all options.

It is important to water quality to protect wetland areas (CSU Extension, 2010) as these are the best habitat types for filtration.

Beaver dams are in effect small-scale detention ponds. They serve to trap sediments, slow velocity, and thus reduce sediment loading. Reintroduction of beavers to an area is an option to be considered in order to improve water quality. Construction of “beaver dam analogs” can be used to encourage beavers to construct dams and the analogs themselves can create ponds that encourage riparian vegetation growth.

Nutrient Limitation. With the exception of one sampling event for phosphorus, nutrients were present only in low amounts in the Rifle Creek Watershed. This sampling took place after a precipitation event,

therefore it is likely this influx is occurring during other such events. Dissolved phosphorus has been known to be directly tied to soil phosphorus levels in agricultural fields (Sharpley 1995). However, for this study, the presence of high phosphorus occurring only at sites in the town of Rifle suggests that the source of phosphorus is lawn fertilizers from local residences and/or parks. One way to limit this influx is through education and outreach. Water quality-related campaigns are in use by several municipalities throughout Colorado. A regional campaign is currently under development in the Roaring Fork Valley, middle section of the Colorado River, and in the Eagle River valley: the Keep It Clean partnership. Keep It Clean is focused on stormwater education, letting residents know that what they put on the ground is not treated and goes directly into the river. More information can be found at: <https://www.keepitcleanpartnership.org/>.

Irrigation Water Management. Efficient management of irrigation can result in less water being diverted as well as improved quality of water returned to the stream. By minimizing the amount of irrigation water applied, water users are able to limit the amount of nutrients, soil sediments, and other associated constituents associated with tailwater runoff. Instead, these constituents remain in the fields (Colorado Ag Water Quality 2018). Switching to more arid-adapted crops and efficient delivery systems would have this effect. Additional practices including minimizing tillage and leaving ground cover intact can also minimize surface runoff.

In residential areas, “zero-scapes” or “xeriscapes” that require little or no additional watering are recommended. These landscaping options often utilize native vegetation that is well adapted to Colorado’s climate and soil. By reducing requirements for supplemental irrigation and fertilization, this landscaping option would help to reduce contamination via surface runoff as well as deep percolation.

Erosion Control Techniques. A number of techniques exist that have been proven to limit soil erosion. These practices include: conservation tillage, use of cover crops, grassed waterways, contour farming, and many more. A full list of these techniques can be found at the [Colorado Ag Nutrients Clearinghouse](#) website, a Colorado State University Extension outreach project. As with efficient irrigation management, these techniques help keep soil particles and associated constituents in the fields and not in the streams (Colorado Ag Water Quality 2018). In the case of Rifle Creek, there is no doubt that erosion is a naturally occurring phenomena; however, limiting human acceleration of this process is in the best interest of water quality.

6.4 Project Recommendations

This assessment has given insight into the current water quality condition of the Rifle Creek Watershed. Another main objective of this study is to identify potential projects that could improve the water quality of this system.

This study indicates that most constituents, especially those of identified concern (arsenic, iron, sulfate, salinity, and sediment) were generally present in greater masses in the lowest elevation sites of Rifle Creek – i.e. at the city sites. Therefore, it makes sense to target this area for high restoration value. Notwithstanding, it makes sense to consider projects in all areas, including headwaters tributaries, as these areas may have more manageable and cost-effective restoration and remediation needs. Table 6-

1 highlights several project options, some of which may already be underway; multiple options for action may exist at a given site.

All of the projects listed in Table 6-1 would serve to improve water quality in the Rifle Creek Watershed. Most of these projects are centered on restoration or enhancement of the riparian corridor to create a more resilient and effective water quality buffering system. These projects have been scoped, with all showing some promise. Figure 6-1 shows the location of these potential projects. Additional details including site photos are available by request.

One main factor affecting feasibility is the willingness of land owners/managers and other partners. Without buy-in from the land owner, none of these projects can progress. Of the projects listed in Table 6-1, Rifle Creek Ranch, Bryce's Valley Ranch, and West Rifle Creek State Wildlife area have the most enthusiastic land managers. For this reason, these sites should be prioritized. Other obvious factors affecting prioritization include funding availability, project complexity, and the need for and ability to conduct long-term site maintenance.

Sites that can be easily remedied by little action and cost are a high priority. Restoration in Government Creek is relatively easy to approach given the low density of invasive species, but the OHV use is a complex social issue and perhaps less easily fixed. At ranches such as Bryce's Valley and Rifle Creek Ranch, management changes are somewhat easily enacted since the land managers are cooperative. Both areas are highly visible and could serve as local demonstrations for water quality improvement restoration projects. Other areas such as West Rifle Creek SWA require additional assessment before it is known how complex restoration might be.

Long-term maintenance is always a concern. Once again, participating and engaged land managers are key. In areas where invasive species are present, there needs to be a plan in place for ongoing control of initial and secondary invasives.

Table 6-1. Identified BMP implementation project sites.

Name	Size	Ownership & Size	Stage	Project Description	Next Steps
Bryces Valley Ranch Riparian Restoration Project	558 Acres, approx. 2 stream miles	Bryces Valley Holdings, LLC (based in New York City) – Managed by Nathan Bell	Concept	Several options exist at this project location. These include: - Fencing of important riparian areas to limit livestock impact - Construction of a new diversion structure for the Wisdom Ditch - Implementation of a stream restoration plan, one that encourages lateral channel migration, overbank flooding to disperse sediment, nutrients, and other constituents. - Grade controls that could include beaver dam analogs or other structures to limit accelerated down-cutting.	Additional site assessment. Seek out funding collaboration with land manager and private land owner.
Rifle Creek Ranch Riparian Restoration	123 acres	Private Owner	Planning	The Colorado National Heritage Program (CNHP) has initiated riparian restoration planning, following years of ecological inventory on this property (called BioBlitz’s). Riparian restoration ideas currently include increasing stream vegetation “buffer zones” and reintroduction of native vegetation.	Provide assistance to CNHP (Lisa Tasker) with restoration activities.
City of Rifle Parks Native Vegetation Restoration		City of Rifle	Concept	The City of Rifle currently eradicates certain non-native species on park properties. These efforts could be expanded and paired with native vegetation reintroduction in order to increase the ecological and recreational value of streamside city properties.	Continue to suggest native revegetation strategies to replace Russian Olive.
West Rifle State Wildlife Area Hydrological Assessment and Remediation	1016 acres	Colorado Parks and Wildlife	Planning	The West Rifle SWA is an area that has experienced severe down-cutting and erosion. Though overall water quality concerns are somewhat mitigated by the presence of Rifle Gap, there is still reason to improve this property for the benefit of waterfowl, amphibians, and fish populations. Currently conversations are underway with CPW on ways to conduct a geomorphological assessment of this property in order to better understand its current status and remediation potential.	Collaborate with CPW to secure funds to pay for a hydrological assessment.
Government Creek	N/A	Bureau of Land Management	Concept	The BLM manages a decent amount of the riparian area in the Government Creek basin, including the Hubbard Mesa OHV area. This basin contains little water on most days, but is perceived to be a significant source of sediment and many other constituents during	Advocate to BLM and OHV recreation community for the restriction of OHV

				<p>runoff events. There are actions that could be taken to mitigate for these influxes. Current ideas include:</p> <ul style="list-style-type: none"> - Retention/Detention Ponds. These could trap sediments that the stream picks up. Maintenance of such structures is a concern. - Invasive species management. Tamarisk is present along this creek in several locations. Eradication of these species would improve conditions for native riparian species since tamarisk heightens soil salinity levels. - OHV management changes. This drainage contains extremely erodible soils. Current management of the Hubbard Mesa OHV area allows for vehicles to drive directly in the streambed and on the banks. By limiting access to these sensitive riparian areas, erosion and thus sedimentation could be greatly reduced in the Government Creek basin. 	<p>use in riparian areas using this study as a citation.</p>
Outreach and Education	N/A	Middle Colorado Watershed Council	Underway	<p>One of the goals of the Rifle Creek Assessment is to educate local stakeholders on water quality issues and opportunities for local stewardship. This includes actions such as lawn care, pet waste disposal, and proper vehicle maintenance. The Keep It Clean Partnership is an established education effort that does just this and is currently being promoted for use in the region. It is recommended that the City of Rifle engage in the regional effort underway as a way of making the community aware of the value of clean water while supporting water quality improvements at the grassroots level.</p>	<p>The Middle Colorado Watershed Council is creating an interpretive center at the Office at 200 Lions Park Circle in Rifle. This can be used as a central base for outreach efforts pertaining to water quality and restoration.</p>

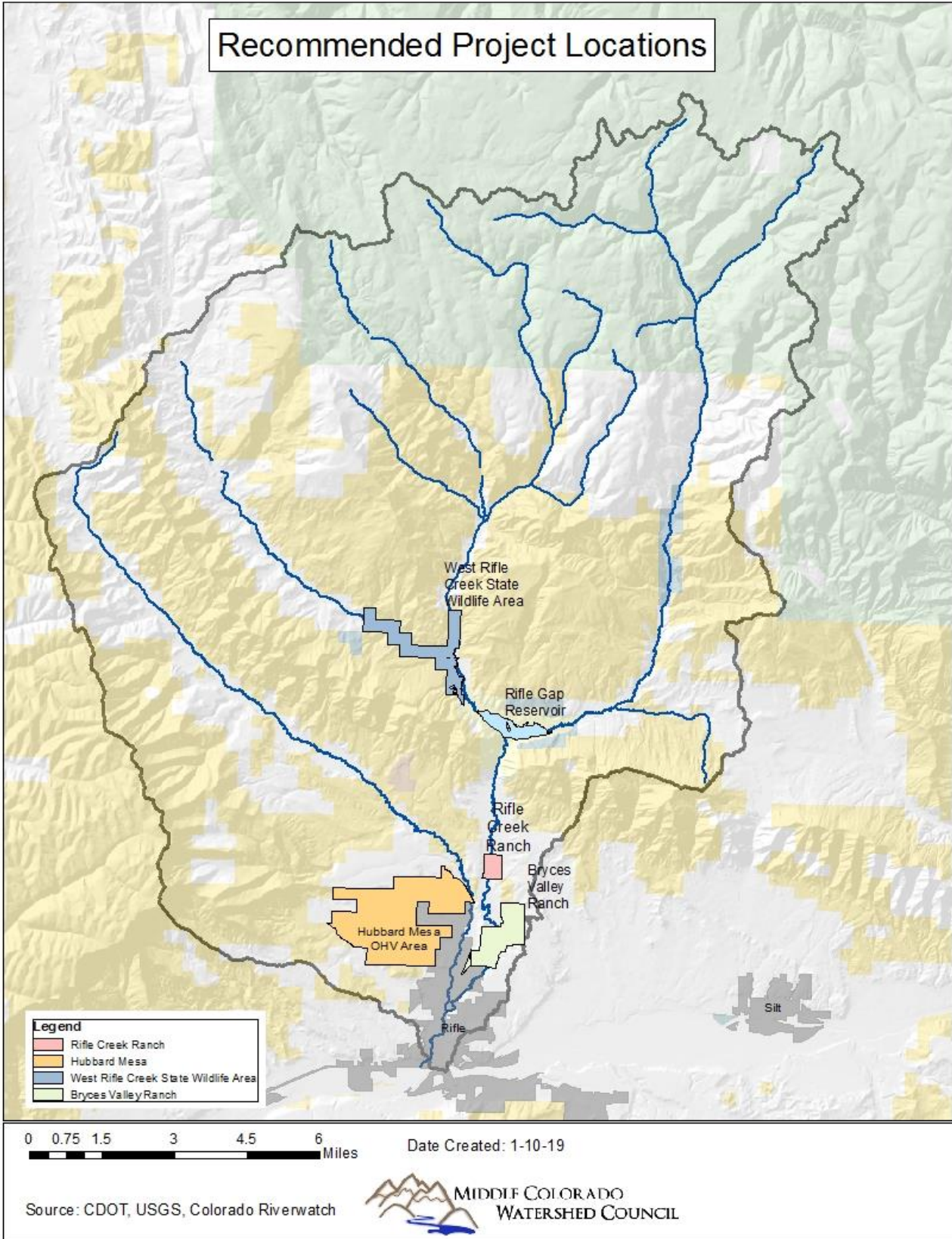


Figure 6.1. Location of projects suggested for BMP implementation.

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Appendix A

Table A-1. Sampling site descriptions and locations.

Site ID #	Description	Waterbody Name	Notes	Latitude	Longitude
923	Rifle Creek at Centennial Park Lower	Rifle Creek	Rifle Creek in Centennial Park below the confluence with Grand Tunnel Ditch	39.5345	-107.7856
924	Grand Tunnel Ditch at Rifle	N/A	Grand Tunnel Ditch in Centennial Park	39.5380	-107.7852
925	Rifle Creek at Centennial Park Upper	Rifle Creek	Rifle Creek in Centennial Park above the confluence with Grand Tunnel Ditch	39.5378	-107.7849
926	Hubbard Creek at Rifle	Hubbard Creek	On BLM land upstream of USFS Ranger Station	39.5622	-107.8143
927	Rifle Creek below Government Creek Confluence	Rifle Creek	At Rifle Skate Park	39.5447	-107.7815
928	Government Creek at 32 Mile Gulch	Government Creek	Off BLM Road 8051, on south side of Hwy 13 SE of Rifle Arch Trailhead	39.6096	-107.8075
939	Hubbard Mesa	Government Creek	On BLM land just off Hwy 13 at Hubbard Mesa OHV area access point	39.5791	-107.7717
929	Rifle Creek below Rifle Gap Reservoir	Rifle Creek	On Rifle Creek on State Park land at the Christo Day Use Area	39.6229	-107.7613
930	West Rifle Creek at Rifle Gap Reservoir (lower)	West Rifle Creek	Park at the swim beach and walk along service road west approximately 1/2 mile to reach West Rifle Creek	39.6386	-107.7741
931	Middle Rifle Creek above Rifle Gap Reservoir	Middle Rifle Creek	On BLM land 1 mile north of Rifle Correctional Facility	39.6597	-107.7813
932	West Rifle Creek at West Rifle Creek SWA (upper)	West Rifle Creek	Spur road on south side of Hwy 252 approximately 1/2 mile west from the intersection with Hwy 219, access gate to the SWA	39.6517	-107.7882
935	East Rifle Creek at Rifle Gap Reservoir	East Rifle Creek	At the pedestrian bridge in Rifle Gap State Park	39.6326	-107.7353
936	East Rifle Creek at Rifle Falls State Park	East Rifle Creek	In channel directly downstream of Rifle Falls before diversion	39.6767	-107.6983
937	East Rifle Creek above Rifle Mountain Park	East Rifle Creek	Access from USFS Kiosk north of Rifle Mountain Park	39.7396	-107.6879

Table A-2. Description of all active discharge permits in the Rifle Creek Watershed on file with the Colorado Department of Public Health and Environment. Note that Rifle Creek is not necessarily listed as the receiving water.

Permittee	Facility Name	Permit Sector	General Permit Type	Permit ID	Issue Date	Facility Address	Receiving Water	Stream Segment
CDNR CPW	Rifle Falls State Fish Hatchery	Commerce and industry	COG130000-Aquatic animal production	COG130011	2011-04-01	11466 CO SH 325	East Rifle Creek	COLCLC10
Swallow Oil Co	Bookcliff 66	Construction	COG315000-Remediation activities discharging to surface water	COG315517	2018-04-04	134 W Centennial Pkwy		COLCLC01
6 & 13 Quick Mart LTD	6 & 13 Quick Mart	Construction	COG315000-Remediation activities discharging to surface water	COG315518	2018-04-04	101 Railroad Ave		COLCLC01
John W Savage	Homestead at Rifle PUD	Construction	COR030000-Stormwater discharge associated with construction activities	COR033618	2007-07-01	1340 Firethorn Dr	Colorado River	COLCLC01
Hubbard Gulch Development LLC	Hwy 13 Fairway Ave	Construction	COR030000-Stormwater discharge associated with construction activities	COR03H590	2011-04-26	Hwy 13 and Fairway Ave	Colorado River	
Stampfel Construction Co	Rifle Animal Shelter	Construction	COR030000-Stormwater discharge associated with construction activities	COR03P895	2016-08-03	CR 265 and CR 244	Rifle Creek, Colorado River	COLCLC10
Questar Pipeline Co	Mainline 68 Rifle 2017 Pipeline Replacement Project	Construction	COR030000-Stormwater discharge associated with construction activities	COR03R203	2017-04-26	Acacia Ave and Creekside Dr	Colorado River	COLCLC10
American Metal Climax Inc	Garfield Mine	Commerce and industry	COR040000-Metal mining stormwater	COR040215	2006-10-01	1.5 mi S of Rifle Falls	Dry Rifle Creek	COLCLC10
Savage Services Corp	Savage Services Rifle	Commerce and industry	COR900000-Industrial stormwater	COR901276	2015-05-27	21520 Highway 6 and 24	Colorado River	COLCLC10
Union Pacific Railroad Co	UPRR Rifle, CO Yard	Commerce and industry	COR900000-Industrial stormwater	COR901438	2018-01-31	28484 Centennial Pkwy	Colorado river	COLCLC01
CDOC	Rifle Correctional Center	Public and private utilities	COX-Individual permit	COX046060	2001-06-11	200 CR 219	Groundwater	Groundwater
Pete Lien and Sons Inc	Rifle Quarry	Commerce and industry	COG500000-Sand and gravel mining process water and stormwater combined	COG501810	2017-06-06	SH 325/Fish Hatchery	Rifle Creek	COLCLC10

Figure A-1. Sampling site locations and land ownership in the Rifle Creek Watershed.

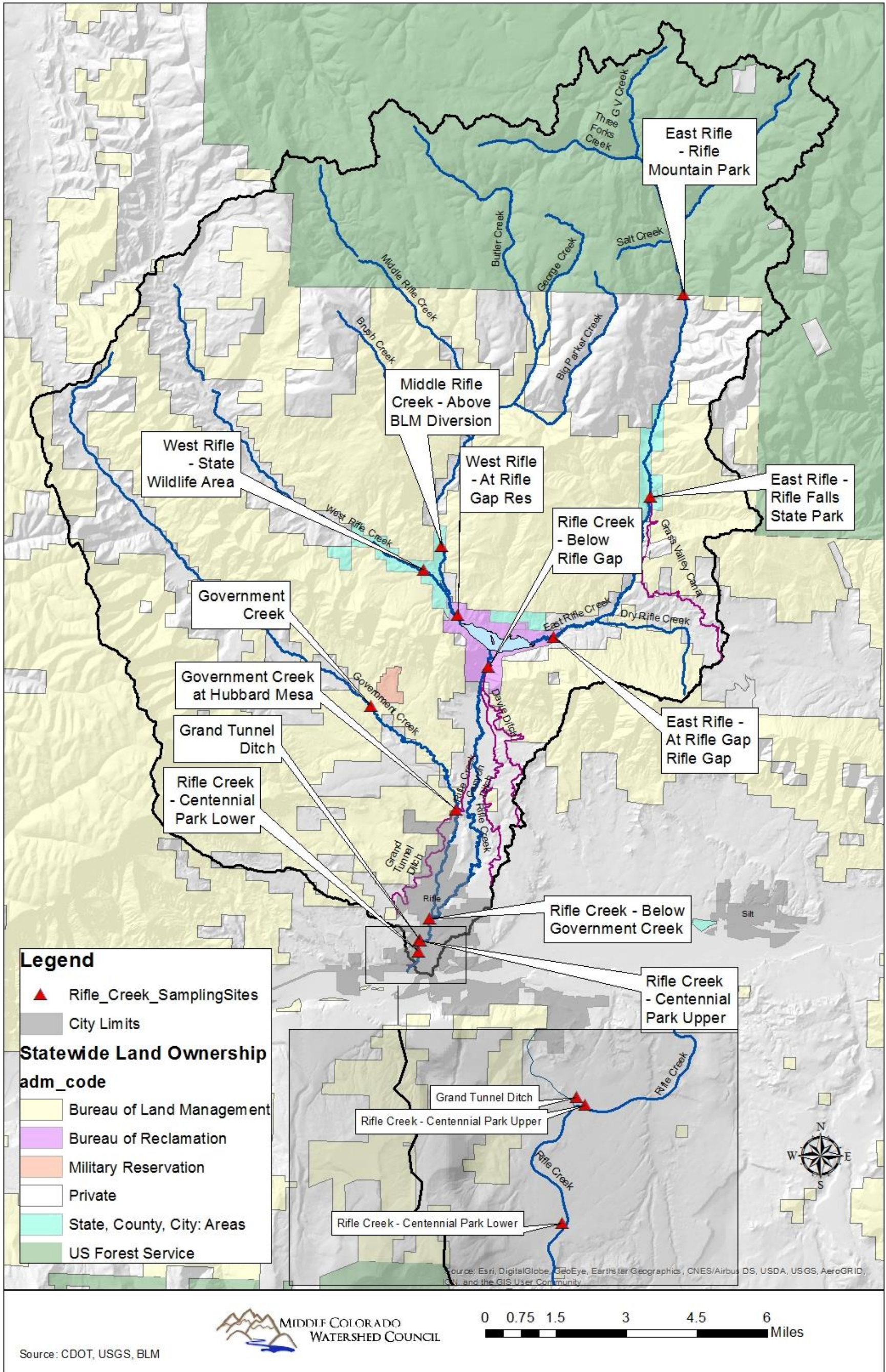


Figure A-2. 2018 impaired streams of the Rifle Creek Watershed and their listing parameters.

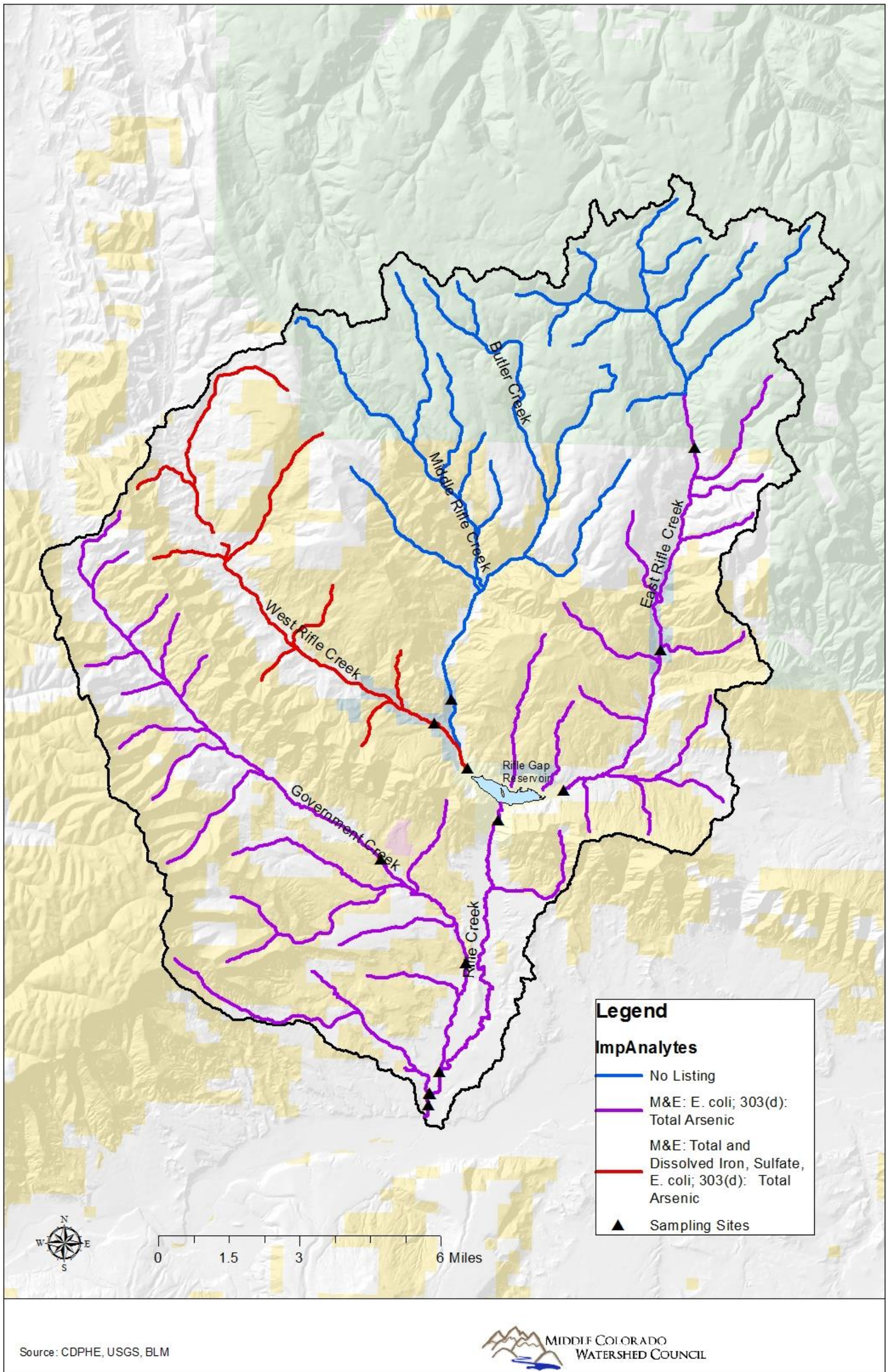


Figure A-3. Active Discharge Permits in the Rifle Creek Watershed as of 8-6-18. Source: CDPHE.

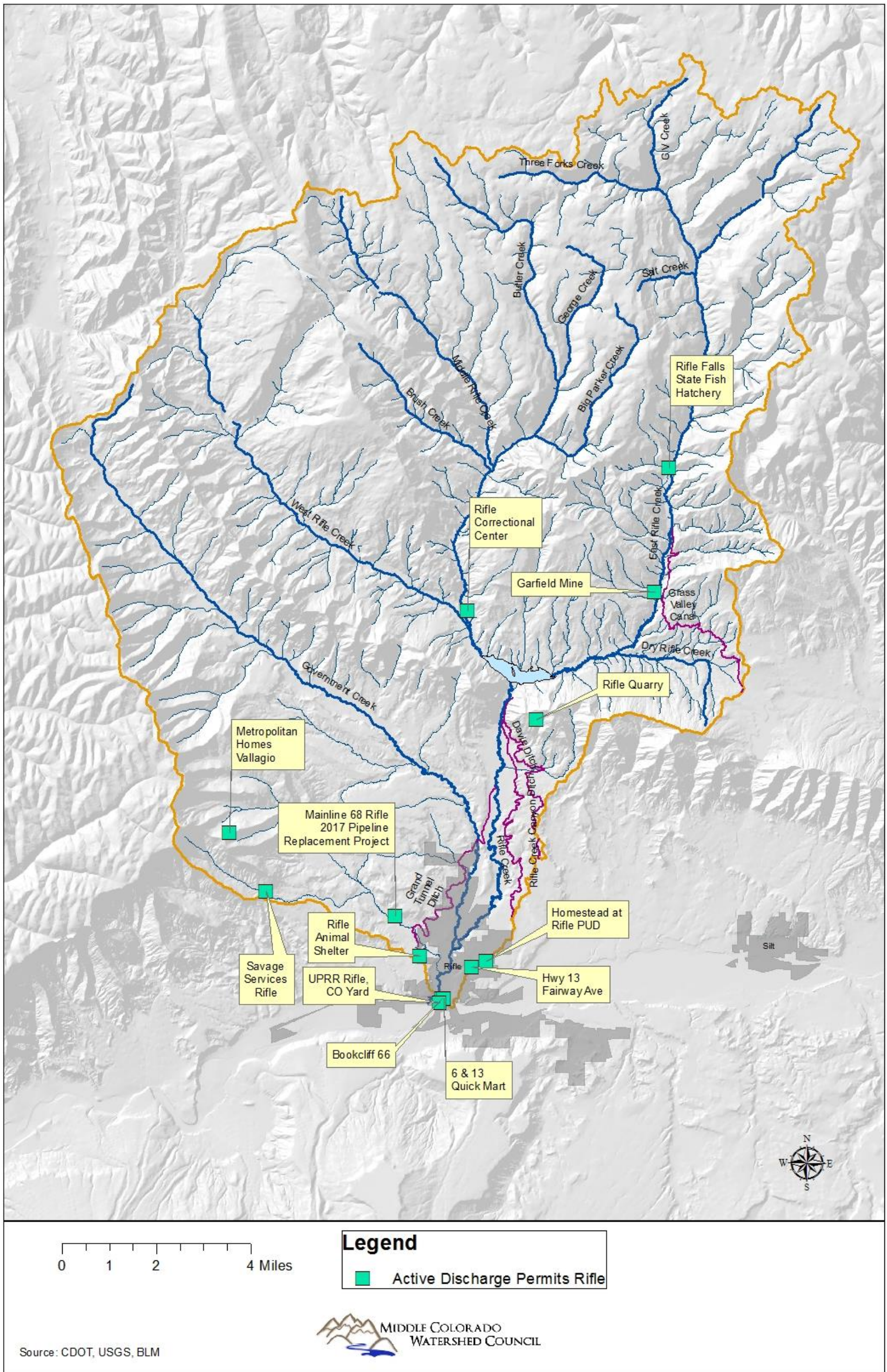


Figure A-4. Hydrology, agriculture, and National Heritage Program biodiversity.

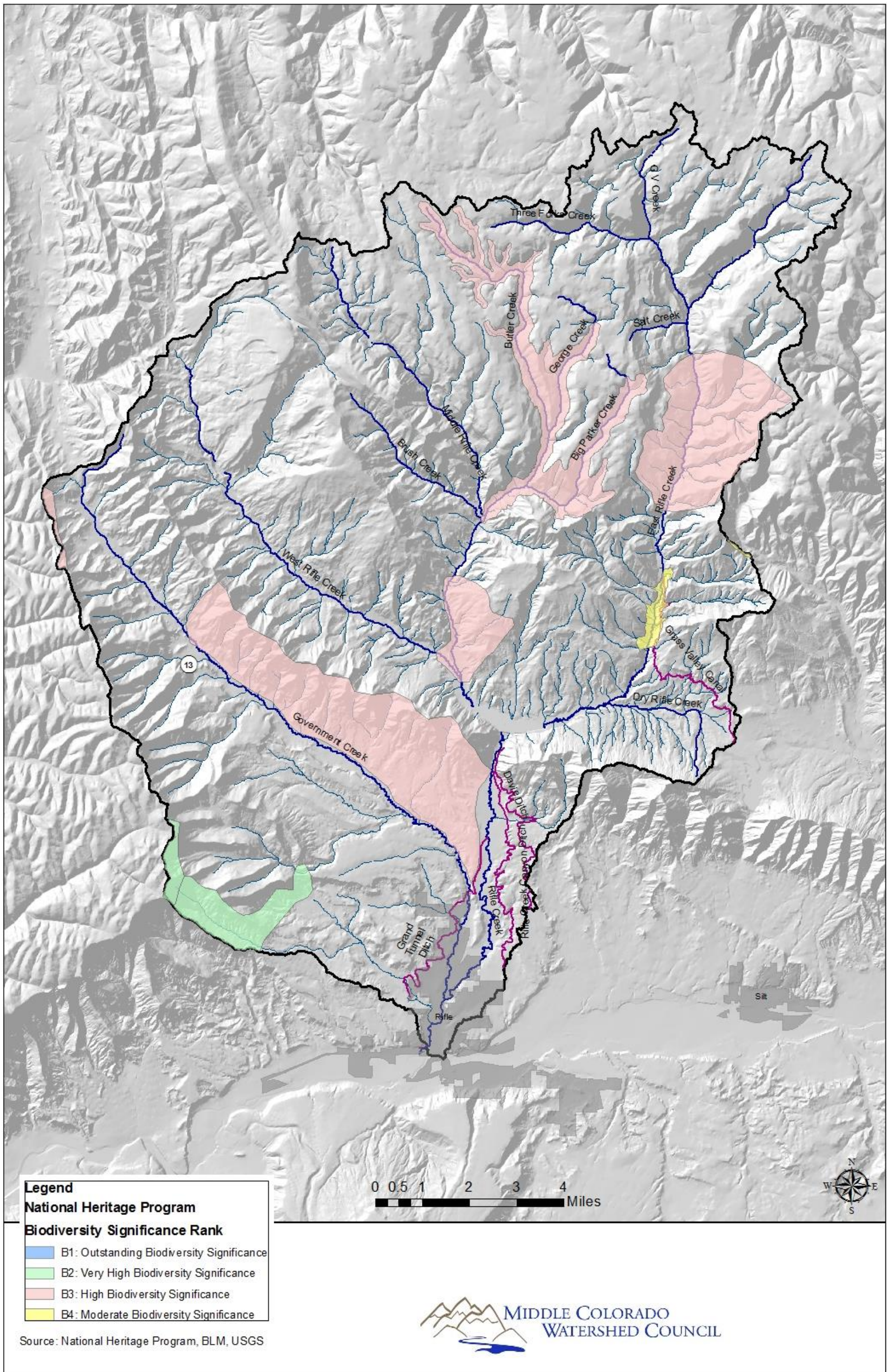
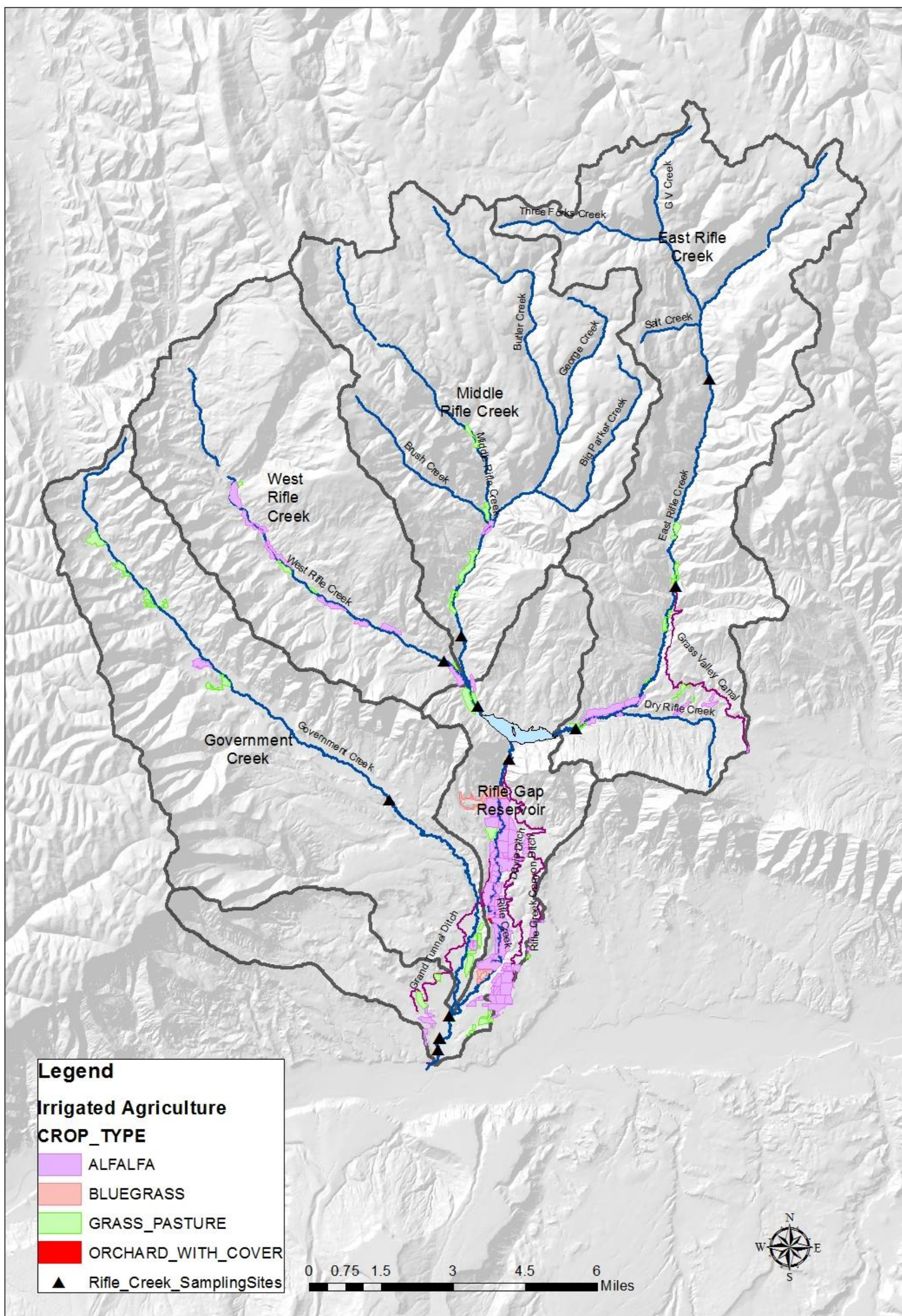


Figure A-5. Agriculture and sampling sites.



Legend

Irrigated Agriculture

CROP_TYPE

- ALFALFA
- BLUEGRASS
- GRASS_PASTURE
- ORCHARD_WITH_COVER
- Rifle_Creek_SamplingSites

0 0.75 1.5 3 4.5 6 Miles



Source: CDOT, USGS, BLM



Figure A-6. Average discharge in all streams sampled in the Rifle Creek Watershed. All diversions that occur on BLM.

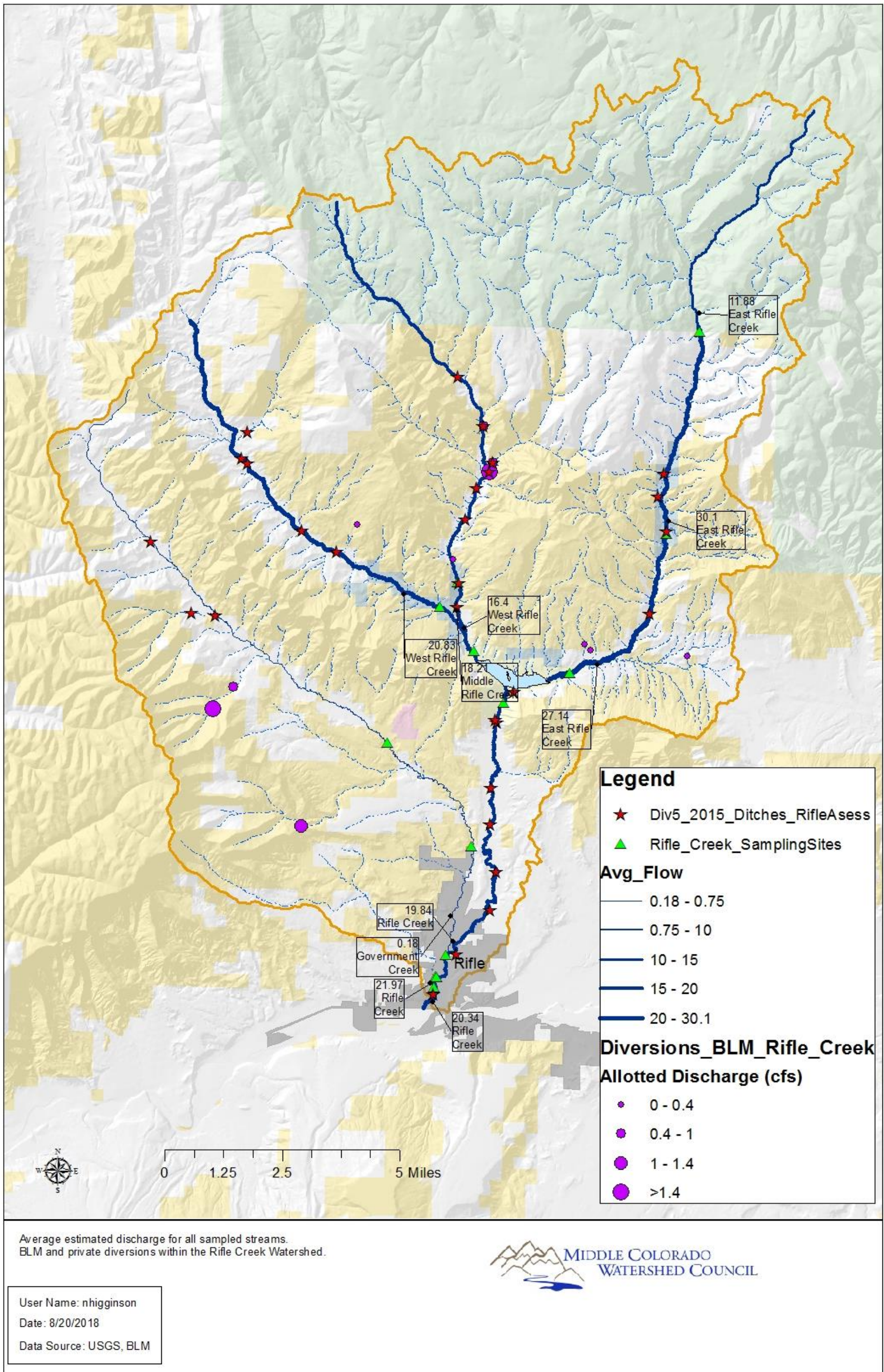


Figure A-7. All mining activities in the Rifle Creek Watershed, as recorded by USGS's Mineral Resource Database System.

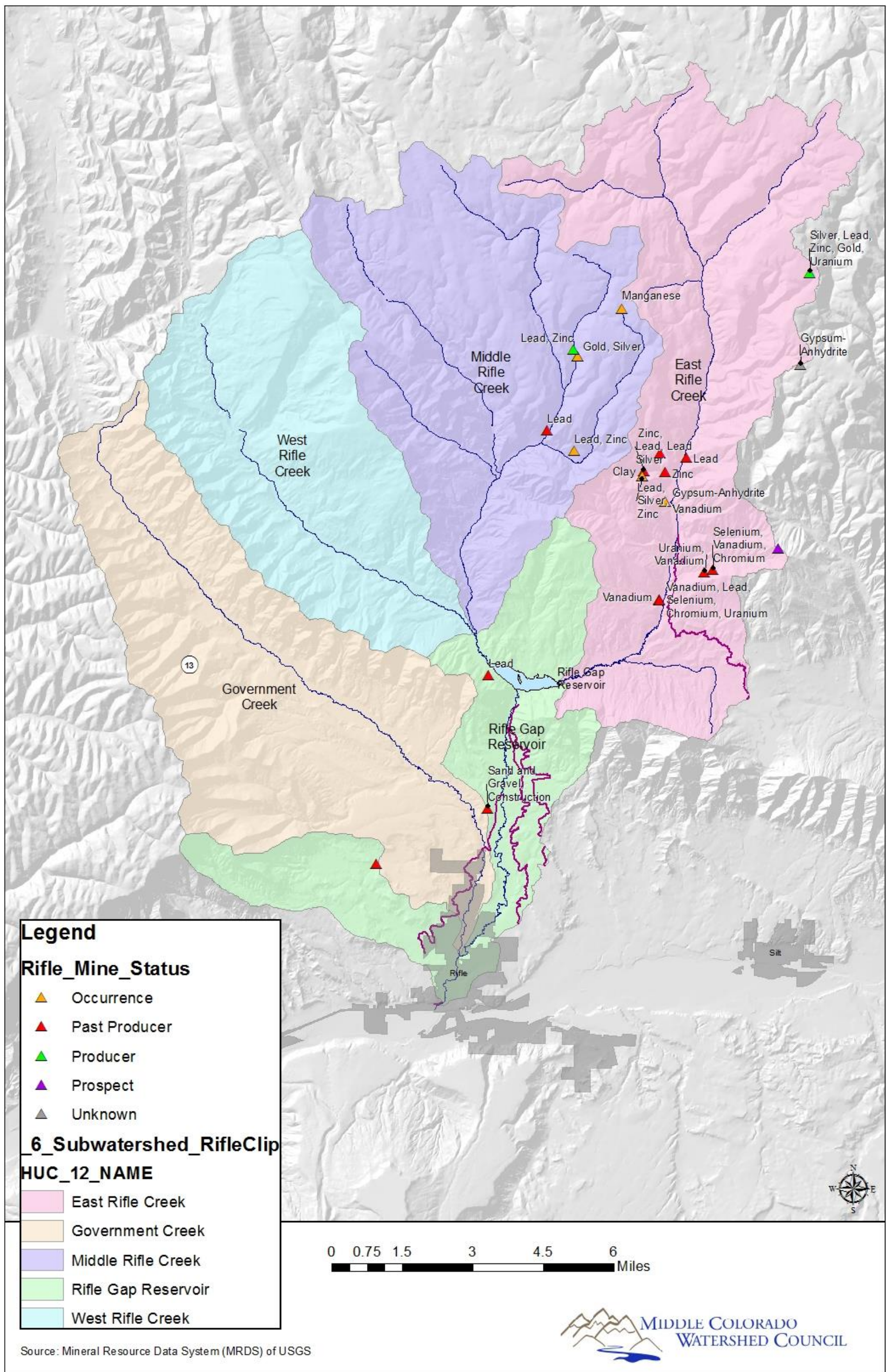


Figure A-8. Geology.

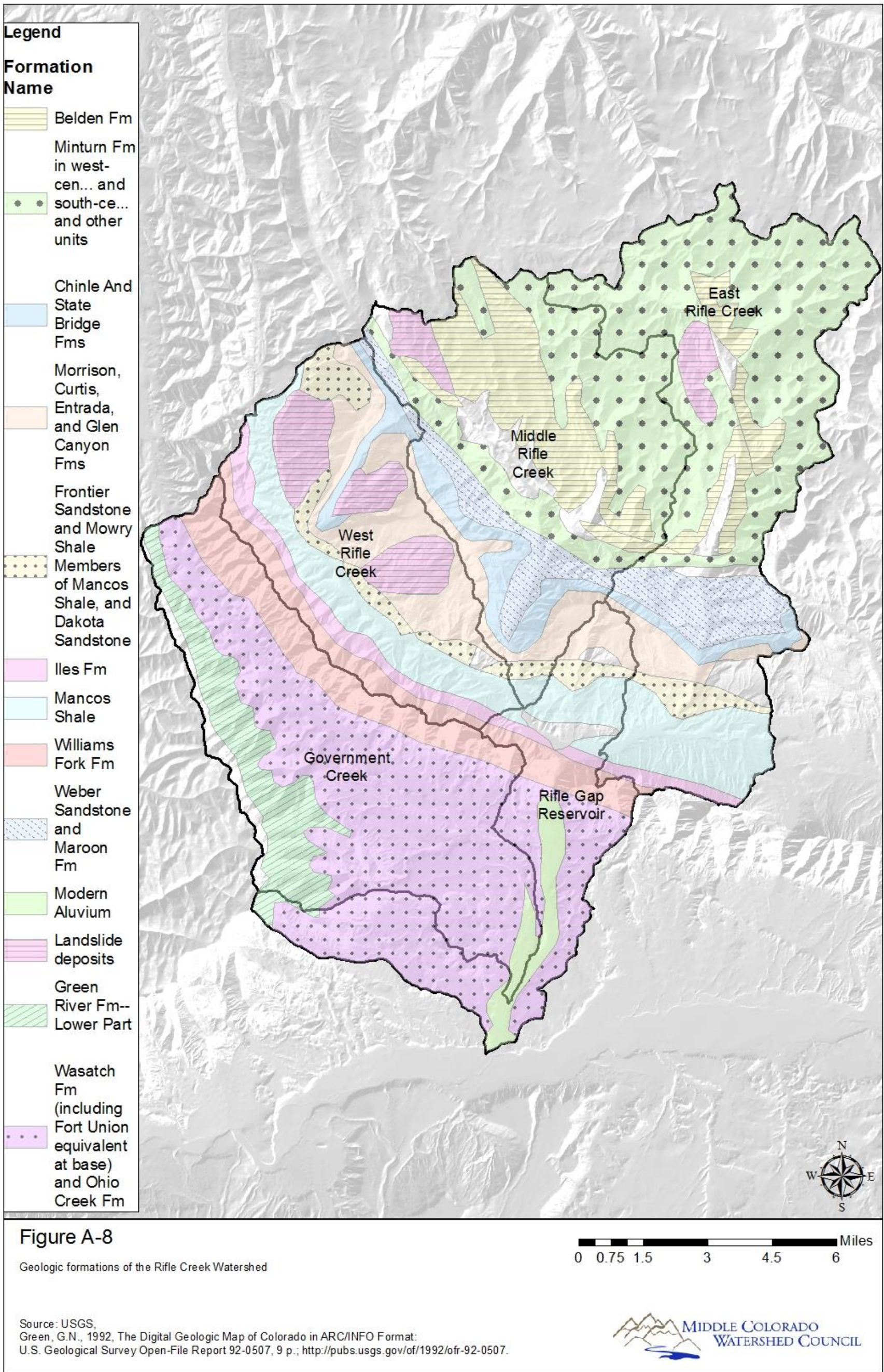
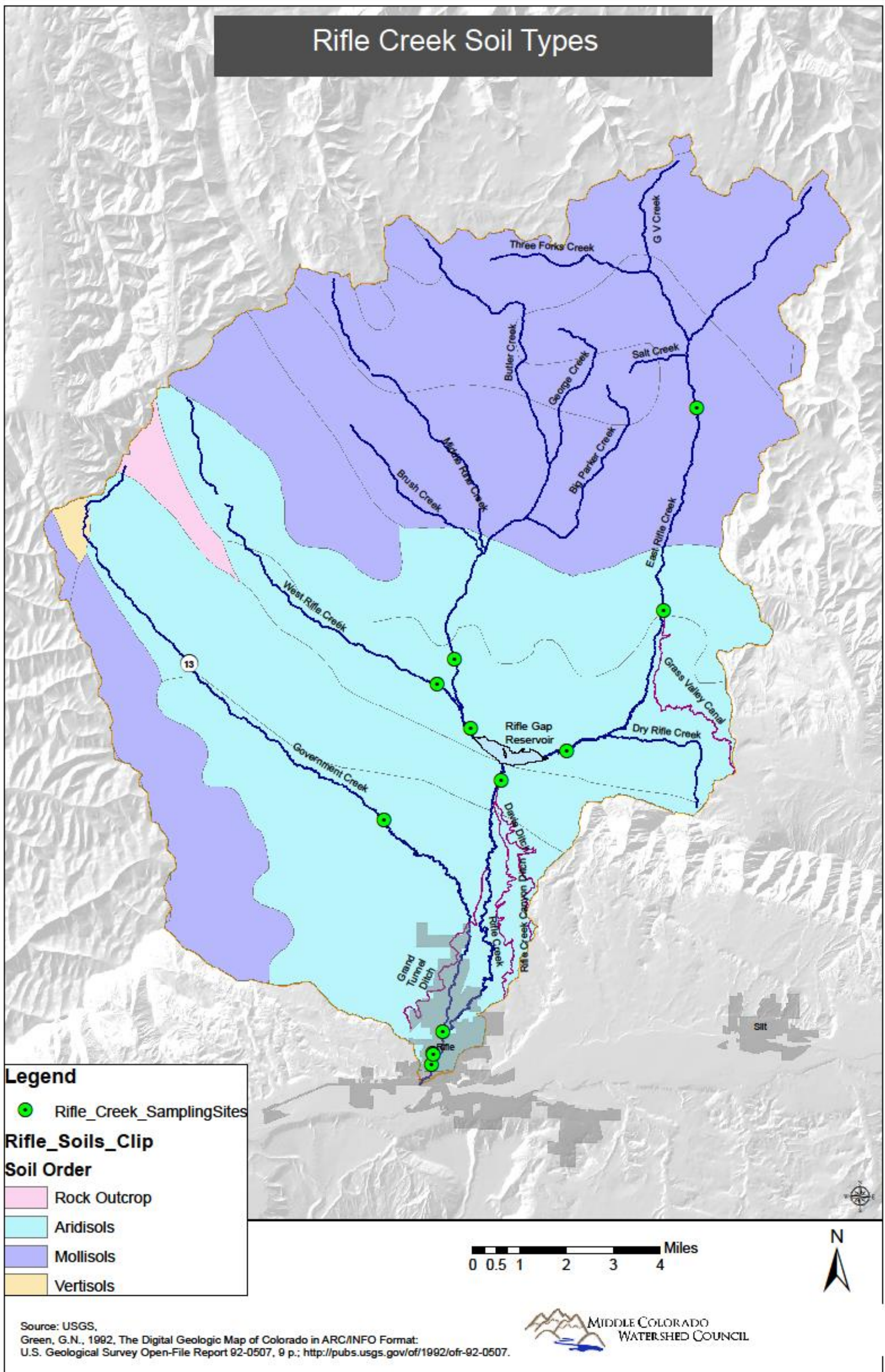


Figure A-9. Soil types of Rifle Creek.



Appendix B: Additional Resources & Tools

Funding Sources

Agency	Program	Eligible Parties	Use	Website
Natural Resource Conservation Service	Environmental Quality Incentives Program	Private land owners	Salinity Control, Air Quality	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/
Natural Resource Conservation Service	Conservation Stewardship Program	Private land owners	Improve agriculture yields, range improvements, improve wildlife habitat	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cstp/
Natural Resource Conservation Service	Easement Programs	Private land owners	Environmental Protection	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/
Colorado Water Conservation Board	Various Grants	Water providers, non-profits, and others	Water efficiency, supply, and infrastructure, fish and wildlife, invasive species control, water planning, etc.	http://cwcb.state.co.us/LoansGrants/Pages/LoansGrantsHome.aspx
South Side, Mount Sopris, and Bookcliff Conservation Districts	Conservation Cost Share Program	Private land owners	Irrigation and range conservation improvement	http://www.mountsopriscd.org/Programs
Bureau of Reclamation	WaterSMART Water and Energy Efficiency Grants	Irrigation districts, tribes, states, and other entities	Water Conservation, hydropower, mitigate risk of water conflict, improve water supply	https://www.usbr.gov/watersmart/weeg/index.html

Tools

CLEAN Nutrient Dashboard Tools – CDPHE - <https://www.erams.com/cdphe>

For watershed managers to review possibilities for implementing nutrient requirements from Regulation 85 - Nutrients Management Control Regulation. (Low flow, Reg. 85, Storet, stream segments, fish tissue).

eRAMS – Colorado State University - <https://erams.com/>

Provides web services for sustainable management of land, water, and energy resources to assist strategic and tactical decision-making at multiple scales. Includes mapping and other content management systems.

Watershed Rapid Assessment Program (WRAP) – Colorado State University - <https://erams.com/wrap/>

This tool is used to extract, organize, and analyze water data and information. Organized by watershed HUC codes.