MONITORING REPORT FOR 2014

CLARK FORK RIVER OPERABLE UNIT

prepared for

Montana Department of Environmental Quality
Remediation Division
Federal Superfund and Construction Bureau
P.O. Box 200901
Helena, MT 59620-0901

December 2015

RESPEC

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CLARK FORK RIVER OPERABLE UNIT

by

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EXECUTIVE SUMMARY

This performance monitoring program evaluates the progress of remedial actions in the Clark Fork River Operable Unit (CFROU) of the Milltown Reservoir/Clark Fork River Superfund sites toward meeting performance goals or identified reference values. Environmental media monitored in 2014 included surface water, instream sediment, geomorphology, vegetation, macroinvertebrates, periphyton, and fish. This report summarizes results of data collected for each of these environmental media and evaluates progress toward attainment of performance goals or reference values as of 2014.

Heavy metals originating from historic mining, milling and smelting processes associated with operations in Butte and Anaconda accumulated in the Clark Fork River streambanks and floodplain over a period of at least 100 years. The primary sources of contamination are tailings and contaminated sediments mixed with soils in the streambanks and floodplains, which erode during high streamflow events and enter the river and other surface waters. In addition to erosion, heavy metals are leached from the contaminated sediments and tailings directly into the groundwater and eventually to surface water. These contaminant transport pathways result in impacts to terrestrial and aquatic life along the Clark Fork River as described in the Record of Decision (ROD) for the site.

The Montana Department of Environmental Quality (MDEQ), as lead agency and in consultation with the U.S. Environmental Protection Agency (USEPA) and the National Park Service, oversees, manages, coordinates, designs, and implements remedial actions for the Clark Fork River site. The MDEQ coordinates with the Natural Resource Damage Program (NRDP) of the Montana Department of Justice for implementation and integration of restoration components to supplement the remedial actions. The MDEQ coordinates with the National Park Service to implement remedial actions on the Grant-Kohrs Ranch.

Data collected in 2014 represents the fifth year of monitoring in the CFROU. Remediation activities in the CFROU in 2014 included active tailings removals and floodplain reconstruction in Phases 5 and 6 and revegetation in Phase 1 of Reach A. Reach A of the CFROU, extending from the Warm Springs Creek and Silver Bow Creek confluence downstream to the Little Blackfoot River confluence, has the largest volume of streamside tailings in the CFROU.

Monitoring under this program was first conducted by MDEQ and RESPEC personnel in the spring of 2010, prior to initiation of any remediation actions within the CFROU. Since 2010, some monitoring sites have been added to the monitoring program in Clark Fork River tributaries. In addition, this monitoring program has been coordinated with long-term monitoring by the U.S. Geological Survey (USGS) to complement data collected by the USGS and minimize data duplication by each program. Monitoring methods and quality assurance protocols guiding collection and analysis of the data described in this report are summarized in the project sampling and analysis plan (SAP) and the project quality assurance project plan (QAPP).

The CFROU monitoring network in 2014 included fourteen sites; six mainstem sites and eight tributary sites. Not all sites were sampled for each environmental medium or for each analyte of each environmental medium (e.g., some surface water sites were only sampled for mercury and methylmercury rather than the full suite of analytes). Monitoring site locations were generally the same in 2014 as in 2013, although sites changed between 2012 and 2013 to provide a more detailed spatial representation of the Clark Fork River mainstem in the upstream most portion of the CFROU where active remediation is occurring. The sample site on the Little Blackfoot River, a tributary to the Clark Fork River mainstem, was relocated during the second quarter of 2014 to minimize hazards from local traffic. This sample site will be permanently relocated. For surface water and instream sediment, the monitoring program primarily monitored concentrations of metal contaminants of concern (i.e., arsenic, cadmium, copper, lead, and zinc). However, for surface water, additional data was collected including nutrient and common ion concentrations, and other field parameters (e.g., acidity). Surface water samples were collected during each calendar quarter with two additional samples collected during the spring snowmelt runoff period. Sediment samples were collected during the first and third quarters. Macroinvertebrate and periphyton samples were collected during the summer (third quarter). Fisheries data, collected by Montana Fish Wildlife and Parks, included trout population abundance at long-term reference sites and *in situ* mortality of confined fish at selected sites.

Streamflows throughout the upper Clark Fork River watershed were at or slightly above the long-term median for the period-of-record at nearly all sites during monitoring periods during 2014. Higher streamflows presumably contributed to slightly higher surface water contaminant of concern (COC) concentrations in 2014 compared to 2013.

Exceedances of performance goals were rare for all COCs in surface water except arsenic and copper. Of 30 samples collected in the mainstem Clark Fork River in 2014 (from five sites during six sample periods), no samples (0%) had zinc concentrations exceeding the performance goal, one sample (3%) had cadmium concentrations exceeding the performance goal, and four (13%) had lead concentrations exceeding the performance goal. However, arsenic commonly exceeded performance goals, particularly in Reach A. Of 24 samples collected in the Clark Fork River in Reach A (four sites during six sample periods), 96% exceeded the dissolved arsenic and 46% exceeded the total recoverable arsenic performance goals. Silver Bow Creek and the Mill-Willow Creek appear to be sources of arsenic to the Clark Fork River as 94% (17 of 18) of the samples from those sites exceeded the dissolved arsenic and 78% (14 of 18) exceeded the total recoverable performance goals in those sites. Total recoverable copper concentration exceeded the state of Montana chronic aquatic life standard (chronic ALS) in the mainstem Clark Fork River sites in 95% of the samples collected in the first and second quarters, but only at Deer Lodge in the third and fourth quarters. These results support the conclusion that copper contamination in the upper Clark Fork River is strongly related to streamflow and contaminant loading occurs primarily in Reach A.

The highest instream sediment COC concentrations in the mainstem of the Clark Fork River were typically observed in the uppermost sample sites in Reach A and the lowest concentrations were typically observed at the downstream-most site at Turah in 2014. Concentrations of arsenic, copper, and zinc exceeded the "probable effect concentration" (PEC; the higher of the two reference values for the CFROU) at all of the Clark Fork River mainstem monitoring stations during both sample periods in 2014. Among all sites in the CFROU, arsenic most commonly exceeded the PEC (88%) followed by copper (83%), lead (79%), zinc (75%), and cadmium (50%).

Geomorphology data was collected during the third quarter of 2014 in Phase 1 of Reach A in the CFROU. All monitoring metrics for channel dimension (i.e., cross-sectional area, bankfull width, mean bankfull depth, and width to depth ratio), pool density, and residual pool depth were within the specified target ranges. The secondary channel stability performance target was also met because the secondary channel did not carry more than 10% of the streamflow of the main channel when streamflows reached the design bankfull level. Performance targets that were not met included floodplain connectivity and floodplain stability. Failure to meet the performance targets for channel connectivity and floodplain stability was the result of an over-connected river channel and floodplain, which results in increased avulsion risk, rather than the disconnected pre-project channel and floodplain. Performance targets for channel slope, sinuosity, bank erosion rate, and channel migration rate were not scheduled for monitoring in Year 1 (2014) but will be evaluated in Year 5 (2018).

Vegetation monitoring data was collected during the third quarter of 2014 in Phase 1 of Reach A in the CFROU. The only vegetation monitoring metric applicable to Year 1 monitoring was for overall floodplain plant survival which was 87.7%, exceeding the performance target for Year 1 (80%). However, survival was 17.2% lower in in the floodplain riparian shrub cover type (primarily consisting of swales) compared to the other floodplain cover types and survival of planted birch trees (*Betula occidentalis*) was particularly low. Low survival in swales may have been caused by the relatively deep swale excavation in combination with prolonged flood inundation which resulted in drowning. Other monitoring metrics with Year 1 performance targets (floodplain total native cover and noxious weed cover) will be monitored in 2015. Some floodplain plant survival monitoring plots will be monitored for plant survival in 2015 in planting units that had not yet been planted at the time of monitoring in 2014.

Overall biotic integrity of the macroinvertebrate community was either “none” or “slight” at all Clark Fork River tributary and mainstem sites; overall biointegrity scores throughout the CFROU ranged from 84.1 to 90.9. For metals sensitivity, index classifications in the mainstem were “none” at all sites except at Gemback Road which was “slight”; metals sensitivity scores in the mainstem ranged from 75.0 to 87.5. Metals sensitivity index classifications in the tributary sites was “moderate” at Racetrack Creek and Warm Springs Creek, “slight” in Silver Bow Creek and the Little Blackfoot River, and “none” in Mill-Willow Creek and Lost Creek; metals sensitivity scores in the tributaries ranged from 56.9 to 88.9. Nutrient sensitivity index classifications were “none” at all CFROU sites, with scores ranging from 81.9 to 100.0.

Periphyton monitoring results revealed that many of the non-diatom algae observed in the CFROU were tolerant to elevated nutrients, acidity, metals, or combinations of those conditions. However, diatom algae dominated the periphyton assemblage at all CFROU sites monitored in 2014 and periphyton samples were scored according to several bioassessment indices. Impairment from sediment was more likely than not (i.e., ≥51%) in three tributary sites (Mill-Willow Creek, 93%; the Mill-Willow Bypass, 77%; and Silver Bow Creek, 81%) and four mainstem sites (near Galen, 88%; at Galen Road, 57%; at Gemback Road, 79%; and at Deer

Lodge, 93%). Impairment from metals was more likely than not (i.e., ≥51%) in one tributary site (Silver Bow Creek, 74%) and four mainstem sites (near Galen, 74%; at Galen Road, 88%; at Gemback Road, 76%; and at Turah, 94%).

Based on fish population monitoring in the Clark Fork River, brown trout continue to dominate the trout species assemblage in the upper Clark Fork River. This is presumably due, at least in part, to their relatively high tolerance to metals compared to other salmonids. Brown trout populations appear to be moderately increasing since 2011 at monitoring sites in the mid- and upper-reaches of the Clark Fork River. Trout abundance in the Bearmouth reach remained low in 2014, as in prior years, relative to other reaches of the upper Clark Fork River. It is possible that above average discharge in 2011 increased the quality and quantity of brown trout spawning and rearing habitat in the upper Clark Fork River and tributaries, resulting in the modest increase in trout abundance in 2014.

Results of survival monitoring of caged juvenile brown trout indicated that, as in previous survival studies in the upper Clark Fork River, mortality rates varied among sites and among months. Most of the mortality in 2014 in the caged fish occurred in April, July, and August. This bimodal pattern was consistent with results from caged fish studies in 2012 and 2013. Mortality tended to be highest during spring runoff and on the descending limb of the hydrograph as water temperatures increased. Brown trout confined in the cages accumulated both copper and zinc in their tissues at both mainstem Clark Fork River and tributary sites. Tissue burdens of fish immediately after release from the hatchery were low compared to fish sampled from cages in the CFROU. Fish from cages in the mainstem had significantly higher metals burdens compared to fish from tributaries, but the difference was less pronounced for zinc.

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1.0 INTRODUCTION

The Record of Decision (ROD) for the Clark Fork River Operable Unit (CFROU) identified a 120-mile section of the Clark Fork River as a distinct Superfund operable unit [USEPA, 2004]. The CFROU extends from the Silver Bow Creek and Warm Springs Creek confluence to the former Milltown Reservoir site at the Clark Fork River and Blackfoot River confluence [Figure 1-1]. Historic mining, milling, and smelting activities in Butte and Anaconda resulted in heavy metal (cadmium, copper, lead, and zinc) and arsenic contamination in the floodplain soils and streambanks of the CFROU [Bartkowiak et al., 2011]. Sources of metal contaminants of concern (COCs) in the CFROU are tailings mixed with soil within the historic 100-year floodplain (primary source), contaminated surface water and shallow groundwater, contaminated instream sediments, and contaminants in irrigation ditches adjacent to the CFROU [USEPA, 2004]. In 2008, a consent decree was negotiated between the state of Montana, the U.S. Government, and the Atlantic Richfield Company for cleanup of the CFROU [Montana v. AR, 2008; U.S.A. v. AR, 2008]. The consent decree established that the state of Montana, through the Montana Department of Environmental Quality (MDEQ), would serve as lead agency to develop and implement the remedial design, remedial action, and operation and maintenance of the remedy for the CFROU [Montana v. AR, 2008; U.S.A. v. AR, 2008].

Remediation in the CFROU began in 2011 with the removal of approximately 10,000 cubic yards of contaminated soils in the “Trestle Area” in the town of Deer Lodge, Montana [Bartkowiak et al., 2012]. Remediation activities were conducted in Phase 1 of Reach A [Figure 1-2] throughout 2013 and the cleanup was mostly completed by the end of the year [Bartkowiak et al., 2013]. Approximately 330,000 cubic yards of contaminated materials were removed from the floodplain and streambanks of Phase 1 (1.6 river miles) and approximately 189,000 cubic yards of clean soil and vegetative material were used to reconstruct and revegetate the floodplain and streambanks [Bartkowiak et al., 2013]. In 2014, remediation began in Phases 5 and 6 of Reach A [Figure 1-2]. According to the remedial design for Phases 5 and 6 (4.5 river miles), 533,000 cubic yards of contaminated material will be removed, 244,00 cubic yards of clean fill material will be imported for reconstruction, and remediation will last until fall of 2015 [Bartkowiak et al., 2014]. In 2014, preliminary design plans were also underway for remediation of Phases 2, 7, 15, and 16 [MDEQ, 2014a].

Specific remediation standards were establishend in the CFROU ROD for surface water, groundwater, and vegetation but not for other environmental media [USEPA, 2004]. In lieu of specific standards, reference values have been adopted by MDEQ for instream sediment, geomorphology, periphyton, macroinvertebrates, and fish. The MDEQ has established this monitoring program to assess the effectiveness of contaminant removal from remediation on attainment of remediation standards or reference values. Data is collected to describe abiotic (surface water, instream sediment, river geomorphology) and biotic (terrestrial vegetation, periphyton, aquatic macroinvertebrate, and fish) conditions in the CFROU to evaluate if remediation standards or reference values are met and evaluate if conditions are improving over time. Data collected in 2014 represents the fifth year of data collected for this monitoring program, which began in 2010.

Figure 1-1. Remedial reaches of the Clark Fork River Operable Unit [Source: USEPA, 2004].

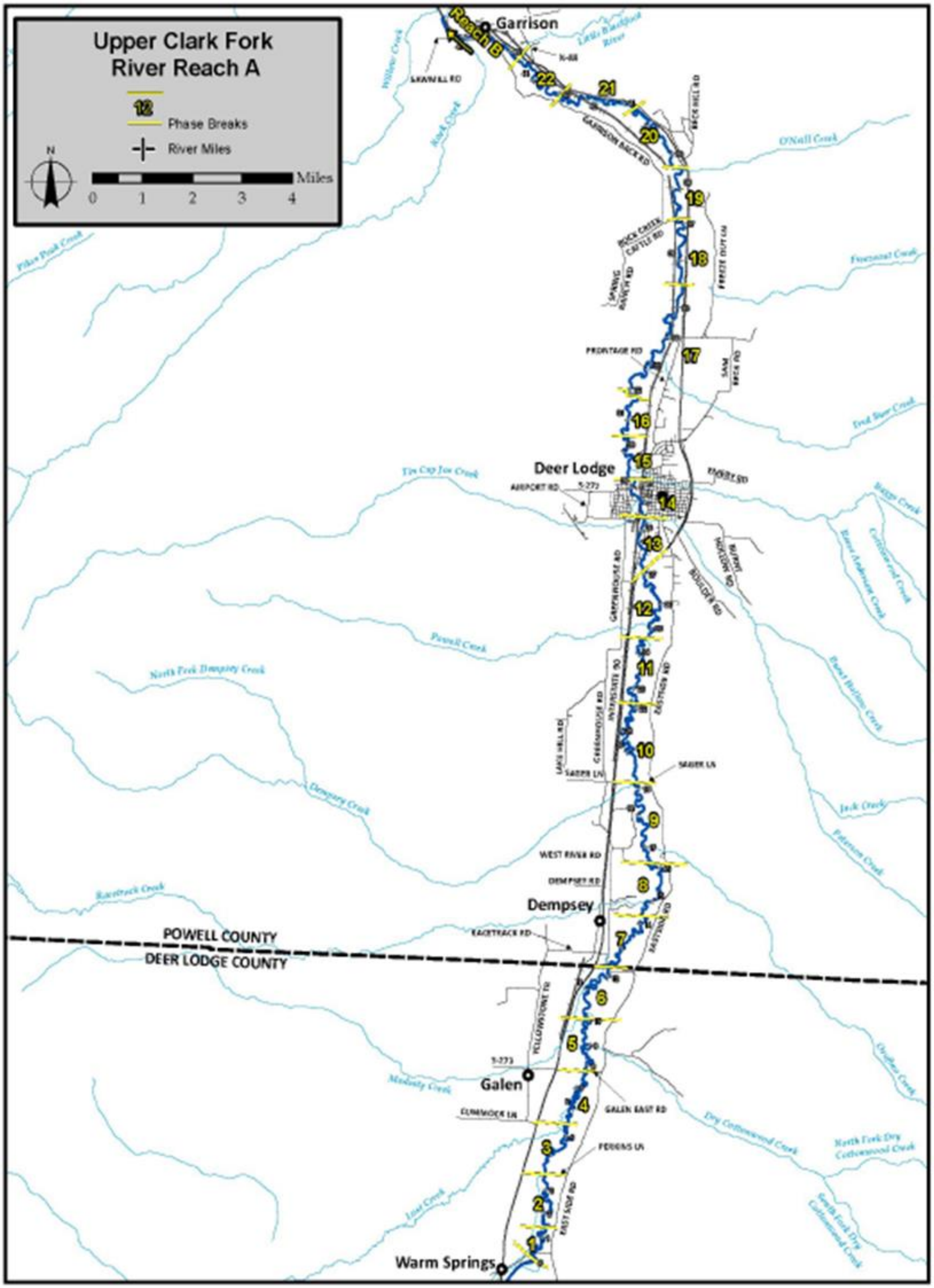

Figure 1-2. Remedial phases of Reach A in the Clark Fork River Operable Unit [Source: Bartkowiak et al., 2011].

2.0 SURFACE WATER

2.1 INTRODUCTION

Performance goals were establishend in the CFROU ROD for surface water [USEPA, 2004]. The goal for surface water quality is for concentrations of all metal contaminants of concern (COCs) to be below the concentrations identified in the CFROU ROD [Table 2-1]. The remedy for the Clark Fork River is expected to achieve these goals through the removal of contaminated floodplain soils (i.e., "slickens"), *in situ* (i.e., on site) treatment of floodplain soils with relatively low COC concentrations, and streambank stabilization. Additional removals of contaminated floodplain materials, proposed as part of remediation, may reduce arsenic concentrations as well. When the remediation activities are completed, surface water quality in the Clark Fork River is expected to fully support the growth and propagation of coldwater fishes (e.g., salmonids) and associated aquatic life. Surface waters will be monitored at specific locations along the Clark Fork River. Performance goals must be met at each location in order for the remedial actions to be considered successful.

This report evaluates progress toward attainment of surface water performance goals as defined in the CFROU ROD [Table 2-1]. Water chemistry data were collected in 2014 to evaluate COC concentrations in order to make direct comparisons to relevant performance standards. In addition to COC concentrations, data are collected to describe other water quality characteristics which influence the toxicity of metal contaminants or otherwise influence the ecology of the Clark Fork River. Other water quality characteristics described include total suspended sediments, common ion, and nutrient concentrations and other physical properties of water (e.g., acidity).

Table 2-1. Remediation performance goals for surface water in the Clark Fork River Operable Unit [USEPA, 2004].

Contaminant of Concern	Performance Standard		
	Aquatic Life Standard[1]		Human Health or Drinking Water Standard (µg/L)
	Chronic (µg/L)	Acute (µg/L)	
Arsenic	150	340	10/18[2]
Cadmium	0.25	2	5
Copper[3]	9	13	1,300
Lead	3.2	81	15
Zinc	119	119	2,000

2.2 METHODS

The purpose of the surface water monitoring program is to collect data describing the temporal and spatial variation of metal and nutrient concentrations, and other physical properties of surface water in the CFROU. These data provide a long-term record of environmental conditions in the CFROU. As of 2014, five years of CFROU surface water data (2010-2014) have been collected under this monitoring program. This long-term record provides a dataset to evaluate the effect of remediation on environmental conditions in the CFROU over time. Changes to the surface water monitoring program have occurred over time and a record of these changes is provided in the project sampling and analysis plan (SAP) [Naughton et al., 2014].

2.2.1 Monitoring Locations

Surface water was monitored at 14 CFROU sites in 2014 [Figure 2-1]. The monitoring network included six sites in the Clark Fork River mainstem and eight sites in tributary streams [Table 2-2]. The monitoring site locations in 2014 were the same as the monitoring site locations in 2013. However, monitoring sites changed between 2012 and 2013 to provide a more detailed spatial representation of the Clark Fork River mainstem in Reach A [Figure 2-1]. Additionally, some sites were removed from the monitoring network to avoid duplication of water quality sampling efforts by the U.S. Geological Survey (USGS).

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[1] The aquatic life standards for cadmium, copper, lead, and zinc vary in relation to water hardness. The values displayed in this table correspond to a water hardness of 100 mg/L.

[2] The performance standard includes both the federal maximum contaminant level (MCL; 10 µg/L; dissolved concentration) and the state of Montana standard (18 µg/L; total recoverable concentration).

[3] Based on the federal ambient water quality criteria (USEPA 1986; dissolved concentration).

2.2.1.1 Clark Fork River Mainstem

Each of the mainstem sample site locations were selected for a specific monitoring objective. The four mainstem Clark Fork River monitoring sites in Reach A (CFR-03A, CFR-07D, CFR-11F, CFR-27H) were included to provide a detailed spatial representation of conditions in Reach A [Figure 2-1]. The Reach C site (CFR-116A) represents conditions in Reach C at the downstream end of the Clark Fork River in the CFROU [Figure 2-1]. Currently, no remedial actions are planned for Reach C. One mainstem site is located downstream from the Flint Creek tributary (CFR-84F) [Figure 2-1]. Site CFR-84F is intended to assess the influence of Flint Creek inflows, which typically has elevated mercury concentrations [Langer et al., 2012; Ingman et al., 2014] on water quality in the mainstem.

2.2.1.2 Tributaries

Tributary site locations were selected to assess the significance of COC or nutrient loading from sources outside the CFROU. Each tributary has one sample site located near the tributary confluence with the Clark Fork River, with the exception of Mill-Willow Creek, which has two sites [Figure 2-1].

2.2.1.2.1 Mill-Willow Creek

Mill-Willow Creek is a tributary to Silver Bow Creek and flows into Silver Bow Creek immediately downstream from the Warm Springs Pond outfall [Figure 2-1]. The Warm Springs Pond system captures the Silver Bow Creek streamflow and routes the water through a lime treatment facility and a series of tailings ponds designed to precipitate heavy metals [see: www.cfrtac.org]. Historically, Mill and Willow Creeks conflucenced with Silver Bow Creek upstream from the Warm Springs Ponds. However, because contaminant levels in Mill and Willow Creeks were low relative to Silver Bow Creek, streamflows from Mill and Willow Creek were routed around the Warm Springs Pond system through a designed channel commonly referred to as the "Mill-Willow Bypass". The Mill-Willow Bypass was remediated between 1990 and 1995 to remove tailings and contaminated soils along the stream channel and floodplain and to reduce toxic discharges to Silver Bow Creek and the upper Clark Fork River [see: www.cfrtac.org].

Two sample sites are located in Mill-Willow Creek: MCWC-MWB and MWB-SBC [Figure 2-1]. MCWC-MWB is located at the upstream end of the Mill-Willow Bypass to demonstrate background water quality conditions in Mill-Willow Creek. MWB-SBC is located near the Silver Bow Creek confluence. Increases in contaminant concentrations between MCWC-MWB and MWB-SBC suggest that contaminant loading is occurring in the Mill-Willow Bypass reach of Mill-Willow Creek.

2.2.1.2.2 Warm Springs Creek

The Clark Fork River mainstem begins at the confluence of Silver Bow Creek and Warm Springs Creek [Figure 2-1]. Warm Springs Creek is a major tributary to the Clark Fork River in Reach A. Warm Springs Creek typically has relatively low nutrient concentrations and relatively cool streamflows. Water chemistry in Warm Springs Creek is monitored at site WSC-SBC [Figure 2-1].

2.2.1.2.3 Silver Bow Creek

The Silver Bow Creek sample site (SS-25), located immediately upstream from the Silver Bow Creek and Warm Springs Creek confluence, monitors water chemistry in Silver Bow Creek immediately downstream from the Warm Springs Ponds discharge and the Mill-Willow Bypass confluence [Figure 2-1].

2.2.1.2.4 Lost Creek and Racetrack Creek

Lost Creek and Racetrack Creek originate in the Flint Creek Range on the west side of the Deer Lodge valley [Figure 2-1]. Major portions of both watersheds are used for cattle grazing and agriculture and streamflows are heavily diverted for irrigation. Surface water monitoring in Lost Creek and Racetrack Creek was discontinued in 2013 because these tributaries had relatively low COC concentrations [Ingman et al., 2013]. Water chemistry in Lost Creek is monitored by the USGS [Dodge et al., 2014]. Instream sediments and biological monitoring were conducted at these sites in 2014. Monitoring in Lost Creek occurs at LC-7.5 and in Racetrack Creek at RTC-1.5 [Figure 2-1].

2.2.1.2.5 Little Blackfoot River

The Little Blackfoot River is a major tributary to the Clark Fork River. The Little Blackfoot River and Clark Fork River confluence is located at the boundary between CFROU Reach A and Reach B [Figure 2-1]. Water quality and quantity in the Little Blackfoot River may be influenced by a variety of land uses including agriculture and irrigation in lower portions of the watershed and abandoned mining in headwater portions of the watershed [Montana Engineer's Office, 1959; Lyden, 1987; Ingman, 2002; MDEQ and USEPA, 2011; 2014c].

Water chemistry, instream sediment and aquatic biota in the Little Blackfoot River are monitored in the Little Blackfoot River. For the first three sample periods of 2014, water quality in the Little Blackfoot River was monitored at site LBR-CFR [Figure 2-1]. However, the site was moved upstream approximately four miles for the last three sample periods of 2014 to minimize safety hazards from road traffic during high streamflow periods when sampling from the road bridge at LBR-CFR is necessary [Table 2-2].

2.2.1.2.6 Flint Creek

Flint Creek enters the Clark Fork River near the boundary between Reach B and Reach C [Figure 2-1]. Flint Creek is a major source of mercury to the Clark Fork River [Langer et al., 2012; Ingman et al., 2014]. Site FC-CFR monitors water chemistry in Flint Creek [Figure 2-1].

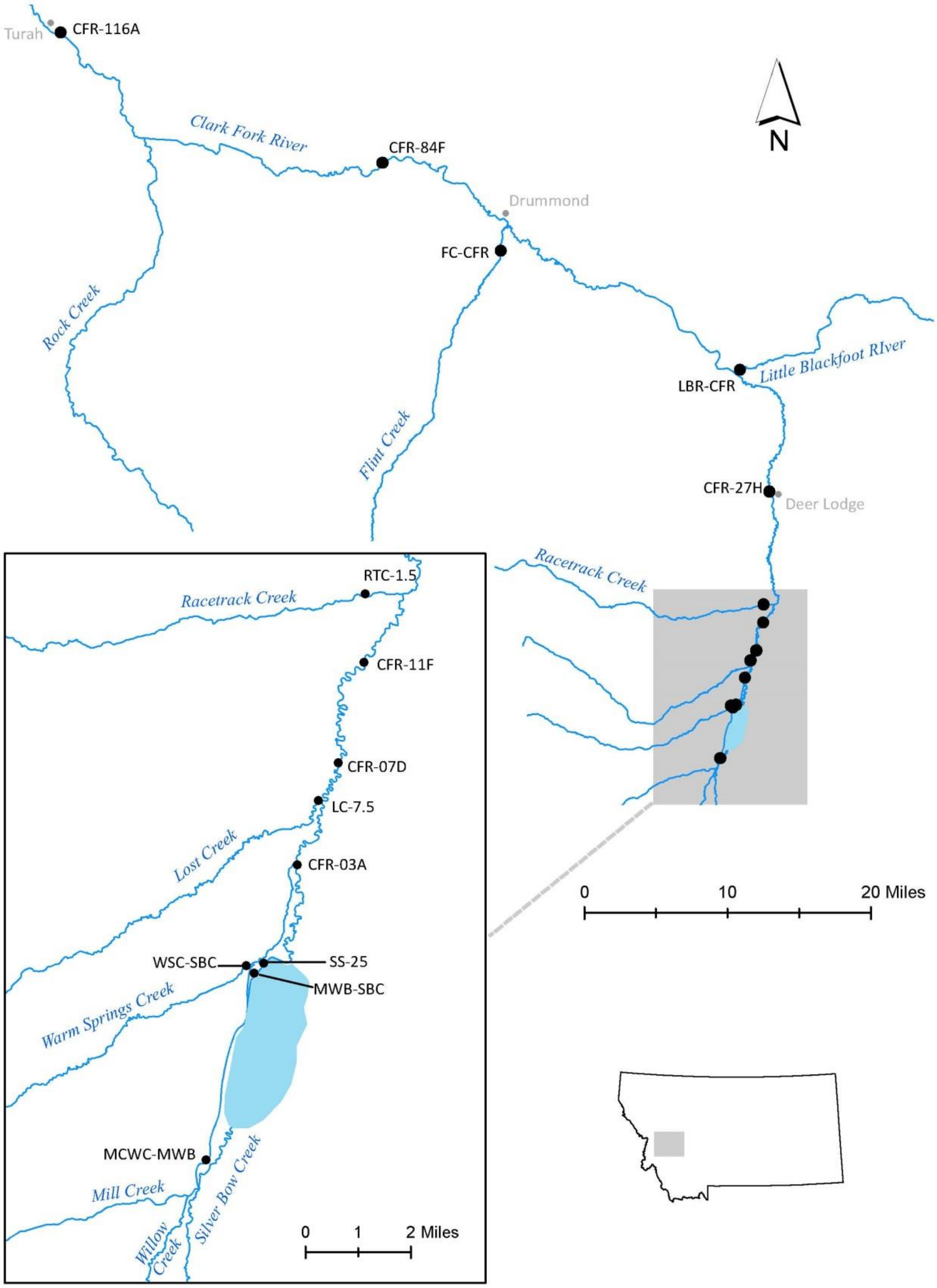

Figure 2-1. Surface water sampling locations in the Clark Fork River Operable Unit, 2014.

Table 2-2. Surface water sampling locations in the Clark Fork River Operable Unit, 2014. Streamflows were measured at all sites which did not a have co-located USGS streamflow gauge.

Site ID	Site Location	Co-located USGS Streamflow Gauge	Location (GPS coordinates, NAD 83)	
			Latitude	Longitude
Mainstem Sites				
CFR-03A	Clark Fork River near Galen	12323800	46.20877	-112.76740
CFR-07D	Clark Fork River at Galen Road	none	46.23725	-112.75302
CFR-11F	Clark Fork River at Gemback Road	none	46.26520	-112.74430
CFR-27H	Clark Fork River at Deer Lodge	12324200	46.39796	-112.74283
CFR-84F	Clark Fork River near Drummond	12331800	46.71204	-113.33137
CFR-116A	Clark Fork River at Turah	12334550	46.82646	-113.81424
Tributary Sites				
SS-25	Silver Bow Creek at Warms Springs	12323750	46.18123	-112.77917
MCWC-MWB	Mill-Willow Creek at Frontage Road	none	46.12649	-112.79876
MWB-SBC	Mill-Willow Bypass near mouth	none	46.17839	-112.78270
WSC-SBC	Warms Springs Creek near mouth	12323770	46.18041	-112.78592
LC-7.5[4]	Lost Creek near mouth	12323850	46.21862	-112.77384
RTC-1.5[5]	Racetrack Creek near mouth	none	46.28395	-112.74921
LBR-CFR[6]	Little Blackfoot River near Garrison	12324590	46.51964	-112.79312
FC-CFR	Flint Creek near mouth	12331500	46.62891	-113.15151

2.2.2 Monitoring Schedule

At least one monitoring event occurred during each calendar quarter of 2014. Each quarterly monitoring event occurred near the end of each quarter. The first monitoring event (Q1) occurred in the late winter, prior to spring runoff, from March 18-19. Three monitoring events were conducted in the second quarter (Q2) to capture the rising (Q2-Rising), peak (Q2-Peak), and falling (Q2-Falling) portions of the spring runoff hydrograph. The Q2 monitoring events were conducted on May 13-14 (Q2-Rising), June 10-11 (Q2-Peak), and June 24-25 (Q2-Falling).

[4] In 2013, LC-7 (GPS Location: 46.22665, -112.76017) was replaced LC-7.5. Site LC-7 was replaced because it appeared to be located within the Clark Fork River floodplain.

[5] In 2013, RTC-1 (GPS Location: 46.28406, -112.74484) was replaced by RTC-1.5. Site RTC-1 was replaced because IT appeared to be located within the Clark Fork River floodplain.

[6] Site LBR-CFR was replaced by site LBR-CFR-02 (GPS Location: 46.53710, -112.72443) on June 24, 2014.

The late summer (Q3) monitoring event was scheduled during low streamflow conditions on September 16-17. The late fall (Q4) monitoring event occurred on December 1-2.

2.2.3 Monitoring Parameters

Surface water samples were analyzed for the parameters and analytes listed in Table 2-3. Parameters and analytes were the same at all sites with the exception of FC-CFR and CFR-83F. At site FC-CFR, mercury and methylmercury concentrations were analyzed in addition to all other analytes. At site CFR-84F, a surface water sample was collected but only analyzed for mercury and methylmercury concentrations.

Eight of the 14 monitoring stations in the MDEQ Clark Fork River monitoring network were co-located with active USGS streamflow gauging stations [Table 2-2]. USGS streamflow records were accessed and included in this report. Streamflows at monitoring stations without co-located USGS gauges were measured manually.

Table 2-3. Sampling parameters and analytes for surface water monitoring of the Clark Fork River Operable Unit, 2014.

Parameter	Analytes
Metal concentrations (total recoverable and dissolved)[7]	Arsenic, cadmium, copper, lead, zinc, mercury, methylmercury
Nutrient concentrations	Nitrogen (total nitrogen, nitrate plus nitrite, ammonia), phosphorus (total), and carbon (dissolved organic; DOC)
Common ion concentrations (total)	Sulfate, alkalinity, bicarbonate
Field parameters	Total suspended sediment (TSS) concentration, hardness, water temperature, pH, specific conductivity, dissolved oxygen (DO) concentrations, turbidity

2.2.4 Sample Collection and Analysis

Sample collection, analysis, and quality assurance procedures were described in the quality assurance project plan [DeArment et al., 2013]. Methods generally followed standard operating procedures (SOPs) developed for the Clark Fork River [AR, 1992]. Field sampling procedures were in accordance with MDEQ [2012a] and followed "clean hands/dirty hands" procedures to minimize sample contamination as described in USGS [2006][8]. Composited surface water samples were collected using width-depth integration according to methods described in USGS [2006]. When streamflows were high and samples could not be collected by wading, samples were collected with the aid of a crane mounted D-95 sampler operated from road bridges. Field parameters (water temperature, pH, dissolved oxygen concentration, and conductivity) were

[7] At CFR-84F, no nutrient or metal concentrations were be measured except mercury and methylmercury. At FC-CFR, mercury and methylmercury were measured in addition to all other analytes.

[8] We deviated from the USGS [2006] protocols to minimize sample contamination (Section 4.0.2) in two regards. First, we did not collect samples sequentially in the order of least to greatest potential for contamination. Second, samples were processed outside the sampling vehicles, rather than within an enclosed space.

measured during each monitoring event with a field multimeter (YSI Professional Plus). Turbidity was measured with a field turbidity meter (Hach Model 2100P Portable Turbidimeter). Streamflows were measured using a portable electromagnetic streamflow meter (Marsh-McBirney Flo-Mate 2000). Calibration methods for field meters, data recording and handling methods, and quality assurance and quality control procedures are described in the quality assurance project plan [DeArment et al., 2013]. Samples were analyzed by Energy Laboratories (Helena, Montana). Requested laboratory analysis procedures for each analyte are presented in Table 2-4.

Table 2-4. Analytes and methods for surface water samples in the Clark Fork River Operable Unit, 2014. All samples were analyzed by Energy Laboratories in Helena, Montana.

Parameter	Category	Method
Arsenic (dissolved and total recoverable)	Contaminants of Concern	E200.8
Cadmium (dissolved and total recoverable)		E200.8
Copper (dissolved and total recoverable)		E200.8
Lead (dissolved and total recoverable)		E200.8
Mercury (dissolved and total recoverable)		E245.1
Methylmercury		E1630
Zinc (dissolved and total recoverable)		E200.8
Calcium	Common ions and suspended sediment	E200.7
Magnesium		E200.7
Sulfate		E300.0
Total Alkalinity, as $CaCO_3$		A2320 B
Bicarbonate Alkalinity, as HCO_3		A2320 B
Hardness, as $CaCO_3$		A2340 B
Total Suspended Sediment		A2540 D
Carbon (dissolved organic)	Nutrients	A53310 C
Nitrogen, Ammonia		E350.1
Nitrogen, Nitrate plus Nitrite		E353.2
Nitrogen, Total		A4500 N-C
Phosphorus, Total		E365.1

2.2.5 Data Analysis

Data analysis included description of spatial trends and temporal (quarterly and annual) trends in analyte (metals and nutrients) concentrations and physical properties. Attainment of performance goals was assessed by comparing analyte concentrations at specific sites to remedial performance goals. Assessment of nutrient monitoring results also included comparisons of total nitrogen and total phosphorus concentrations to numeric water quality standards for the Clark Fork River (ARM 17.30.631).

Evaluation of some performance goals from data collected in this report requires an assumption that the measured analyte concentrations are consistent over time. For example, the chronic aquatic life standard (ALS) is typically based on 96-hour mean concentrations [MDEQ, 2012b]. Similarly, the acute ALS are typically based on a 1-hour mean concentration [MDEQ, 2012b]. However, in this monitoring program analyte concentrations are measured at a specific point in time and mean concentrations over time are not available. Therefore, all assessments of ALS exceedances assume that the measured concentration was representative of the required mean concentration.

Compliance ratios were computed by dividing each total recoverable arsenic concentration during the MDEQ monitoring period in the CFROU 2010-2014 by the respective performance goal or applicable water quality standard. Compliance ratio results are presented as line graphs on a semi-logarithmic scale ranging from 0.01 to 100, with a value of 1.0 corresponding to 100% of the performance goal or water quality standard. Values exceeding 1.0 represent exceedances of the performance goal or water quality standard.

2.2.6 Data Validation

Data quality objectives (DQOs) were established in the CFROU monitoring project quality assurance project plan (QAPP) for data “representativeness”, “comparability”, “completeness”, “sensitivity”, “precision”, “bias”, and “accuracy” [DeArment et al., 2013]. Methods for field and laboratory quality assurance and quality control (QA/QC) procedures are also described in detail in the project QAPP. A completed QA/QC checklist, summary tables of field duplicate and field blank results, and assessments of data quality objectives are included in Appendix A.

2.3 RESULTS

2.3.1 Streamflows

Streamflows in the upper Clark Fork River watershed were normal or above normal at all sites during almost all monitoring periods in 2014. Streamflows during the Q1 monitoring event were near normal for those dates based on long-term USGS streamflow gauging station records. Streamflows had recently receded following elevated streamflows during the first week of March in association with an abrupt melt of low elevation heavy snowpack. The three Q2 monitoring events were intended to target the rising limb of the spring runoff hydrograph, near peak streamflow, and the falling limb of the runoff hydrograph. The three sampling events were performed on May 13-14, June 10-11, and June 24-25, 2014. Streamflows during the Q2 monitoring events varied from slightly above normal to near normal for those dates. The intended peak flow event on June 10-11 missed the spring runoff maximum streamflow by approximately two weeks (May 28). Streamflows during the Q3 monitoring event were above normal for mid-September, while streamflows during the Q4 monitoring event were normal or slightly above normal.

Streamflows at the CFROU monitoring stations during the 2014 calendar year are depicted in hydrographs for USGS gauging stations Silver Bow Creek at Warm Springs (USGS

12323750) [Figure 2-2], Clark Fork River near Galen (USGS 12323800) [Figure 2-3], at Deer Lodge (USGS 12324200) [Figure 2-4], near Drummond (USGS 12331800) [Figure 2-5], and at the Turah Bridge (USGS 12334550) [Figure 2-6].

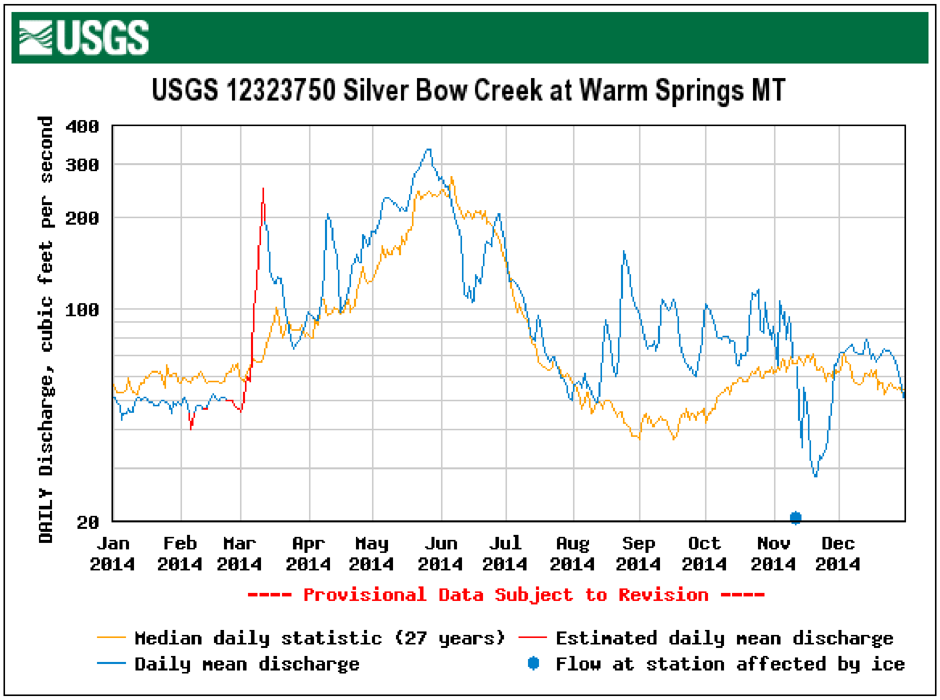

Figure 2-2. Hydrograph for Silver Bow Creek at Warm Springs, 2014.

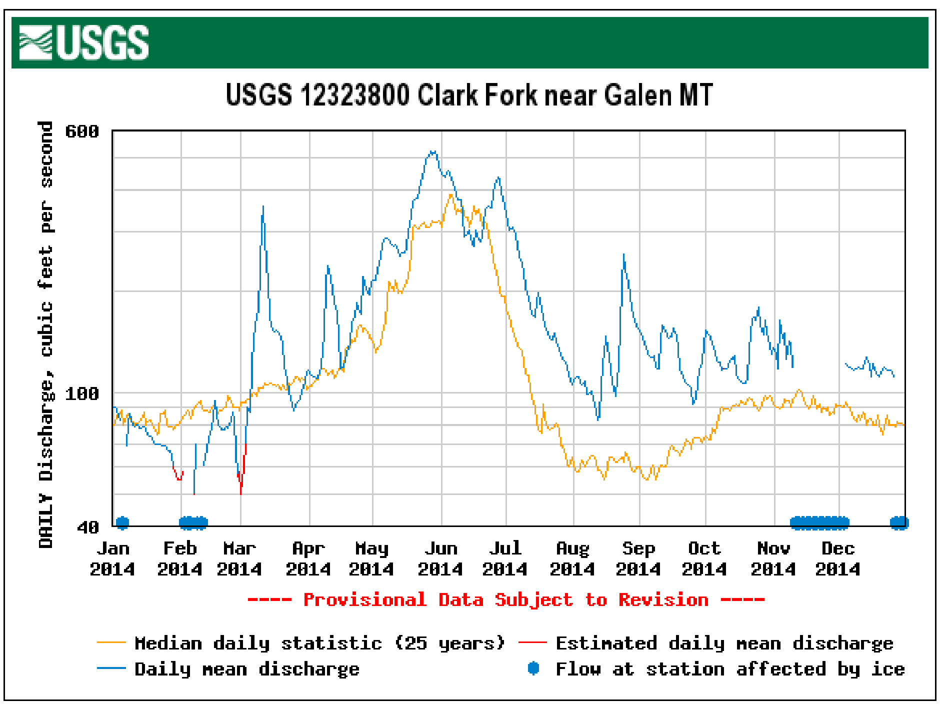

Figure 2-3. Hydrograph for Clark Fork River near Galen, 2014.

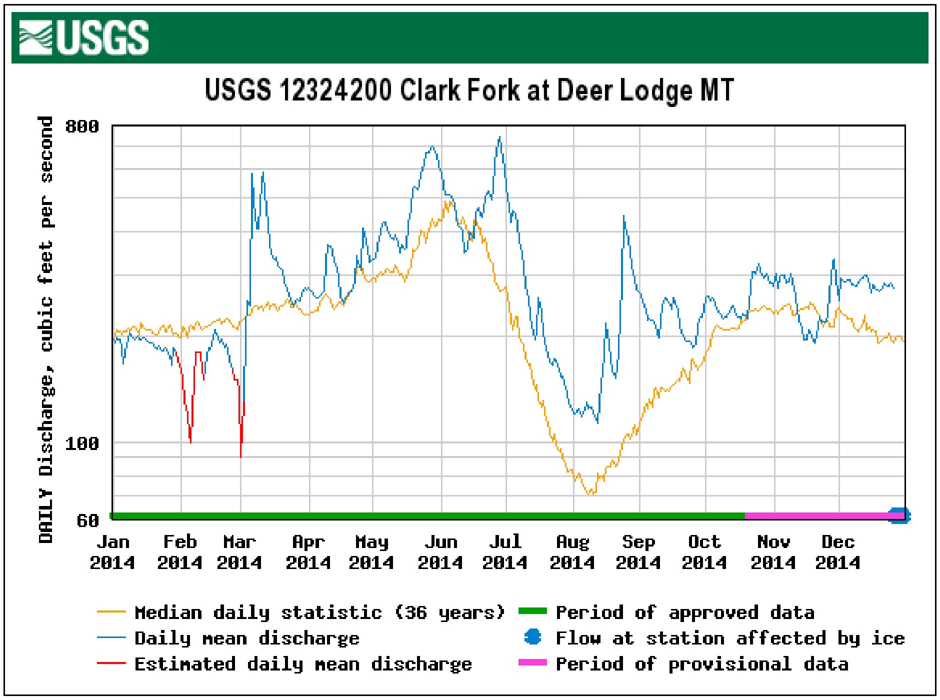

Figure 2-4. Hydrograph for Clark Fork River at Deer Lodge, 2014.

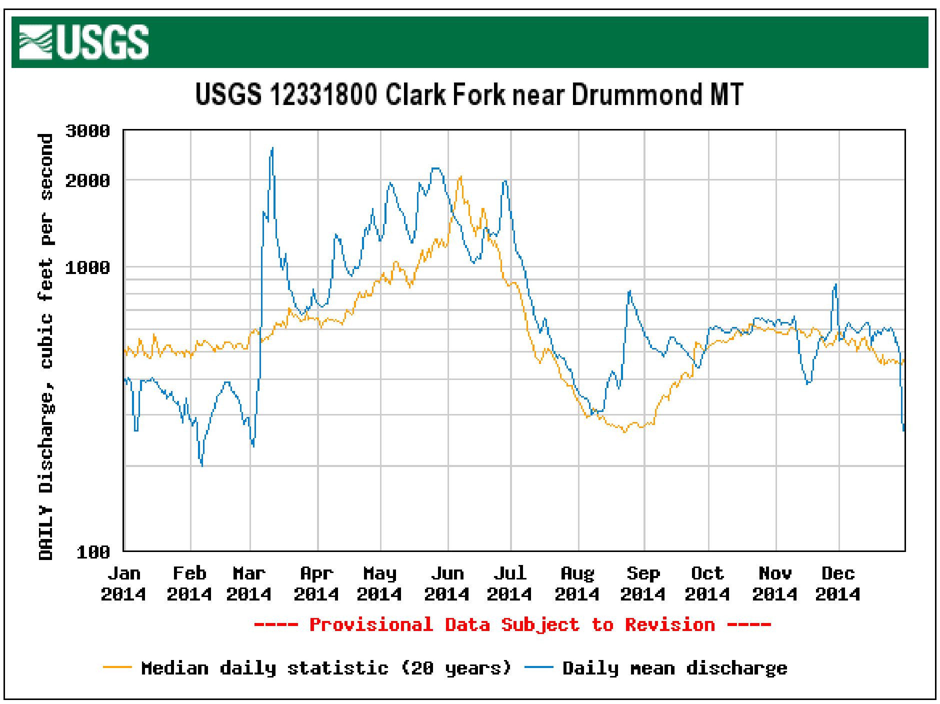

Figure 2-5. Hydrograph for Clark Fork River near Drummond, 2014.

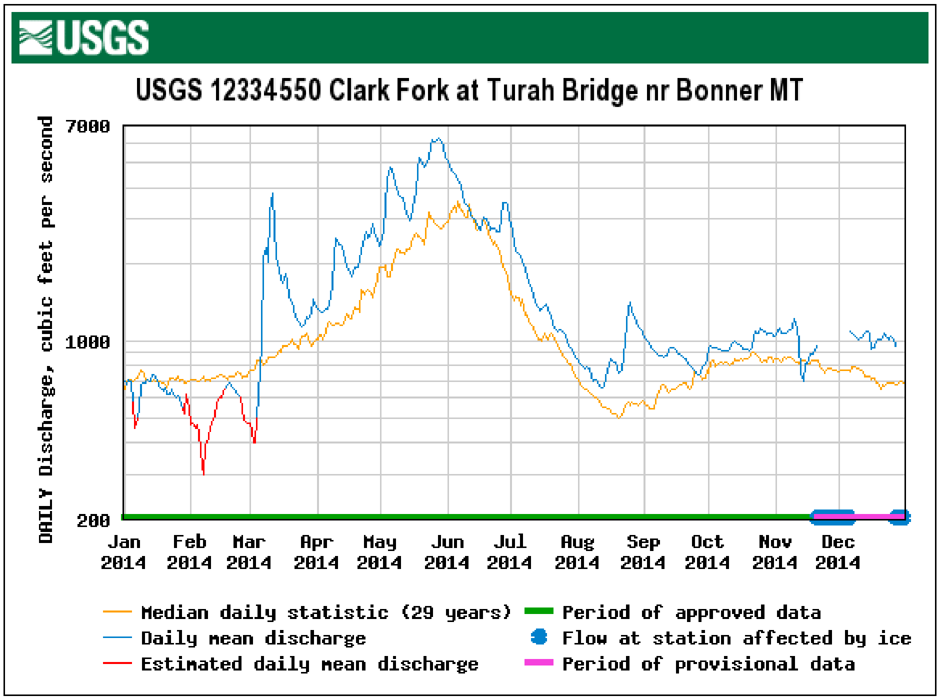

Figure 2-6. Hydrograph for Clark Fork River at Turah Bridge, 2014.

2.3.2 Field Parameter

2.3.2.1 Water Temperature

Water temperatures at CFROU sites in 2014 indicated modest seasonal and spatial variation that was generally within the preferred range of cold water organisms such as trout [Figure 2-7; Figure 2-8]. Maximum water temperatures at most of the CFROU monitoring stations during the six monitoring events in 2014 were observed during the Q2-Falling monitoring event, when temperatures at some sites slightly exceeded the 12–14 C optimal temperature range for trout. The exceptions were the Clark Fork River at Deer Lodge and the Little Blackfoot River near mouth, which had the highest water temperature during the Q2-Peak monitoring event. The maximum water temperature (16.9 C) was measured at the Clark Fork River at Deer Lodge site. The lowest water temperatures were measured during Q4 and ranged from 0-2.1 C.

There was no clear spatial trend in water temperature at the mainstem Clark Fork River sites in 2014. Water temperature differences between sites during any single monitoring event were generally small and were somewhat affected by the time of day monitoring was conducted at any given station. Water temperatures at CFROU mainstem monitoring stations during 2014 monitoring events were generally within the range of temperatures recorded during the 2010-2013 monitoring years. The tributary monitoring site on Warm Springs Creek near its mouth showed the lowest and least variable water temperatures of all sites during the six 2014 monitoring events.

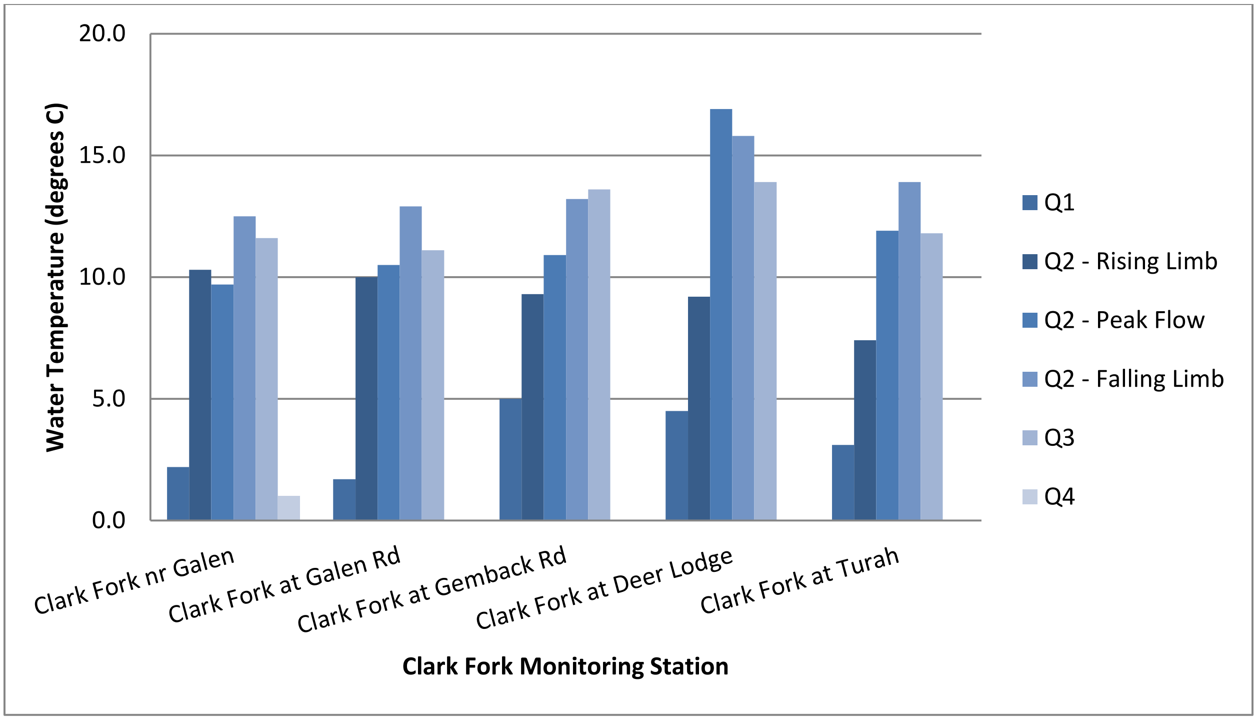

Figure 2-7. Surface water temperatures at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

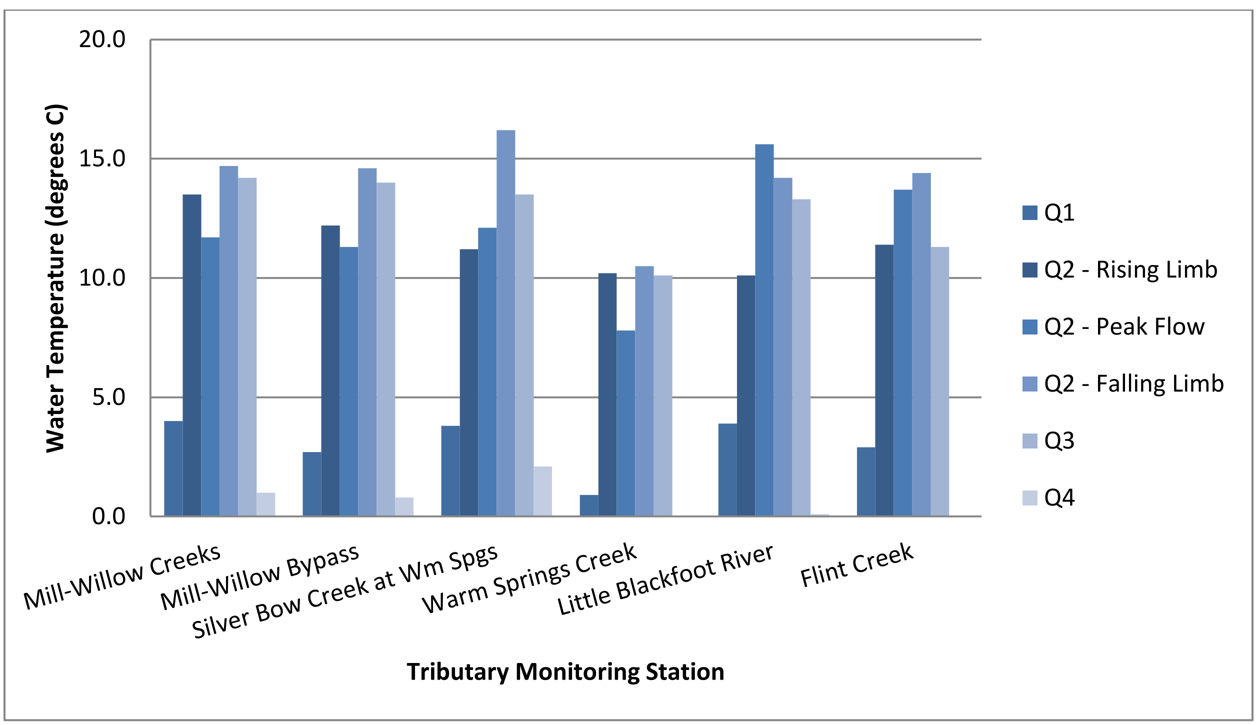

Figure 2-8. Surface water temperatures at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.2.2 Acidity

In 2014, pH in the upper Clark Fork River mainstem monitoring stations ranged from 7.65-9.06 [Figure 2-9]. Tributary monitoring stations had a slightly greater pH range: 7.82-9.48 [Figure 2-10]. Two measurements each from Clark Fork River and Silver Bow Creek stations had pH values outside the optimal range for the protection of aquatic life (6.5-9.0). These included the Clark Fork River near Galen in Q3 (9.04), the Clark Fork River at Gemback Road in Q3 (9.06), and Silver Bow Creek at Warm Springs in each of Q2-Falling and Q3 (9.38 and 9.48, respectively). There was no readily apparent seasonal pattern in pH in 2014, although highest pH values tended to be measured in Q3. Spatially, the highest pH values tended to occur in the upstream sites including Silver Bow Creek and the Clark Fork River near Galen sites. Lime additions to Silver Bow Creek at the Warm Springs Pond inflow were likely a contributing cause of the higher pH levels in lower Silver Bow Creek and the upper Clark Fork River stations. The pH levels at several CFROU monitoring stations in 2014 were higher than any of the previous measurements observed from 2010-2013. These sites included Silver Bow Creek at Warm Springs, and the Clark Fork River near Galen, at Galen Road, at Gemback Road, and at Deer Lodge.

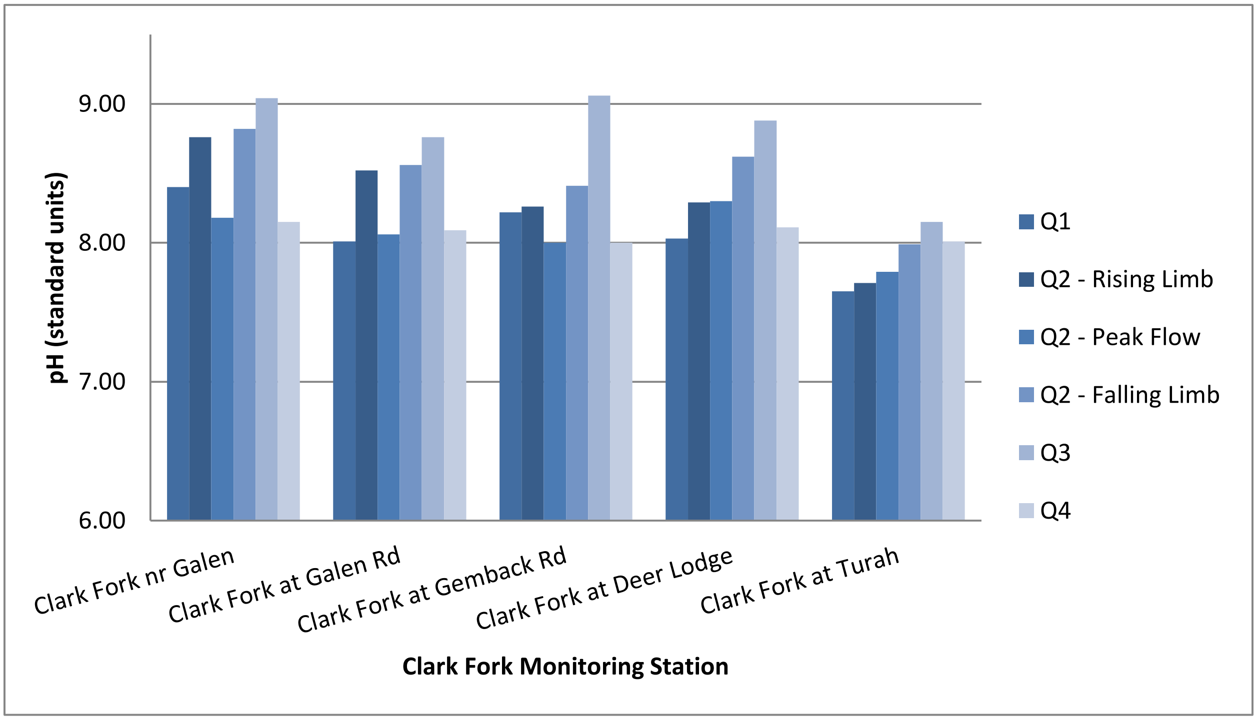

Figure 2-9. Surface water pH at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

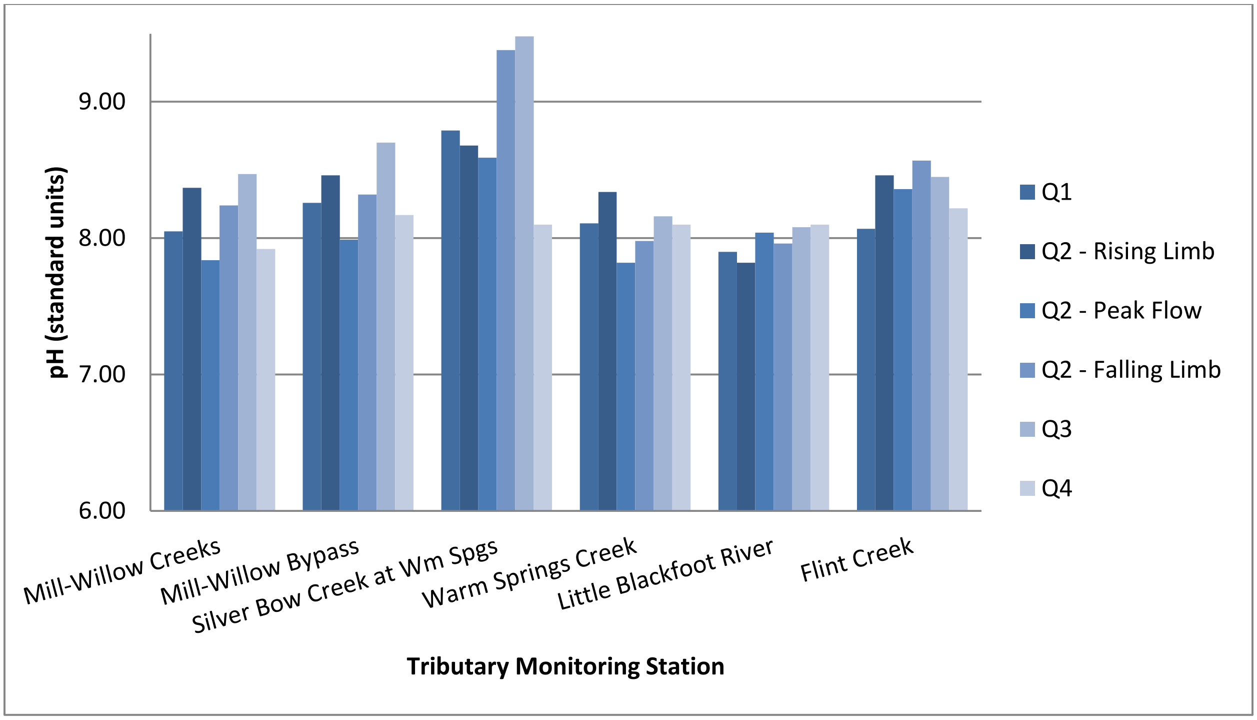

Figure 2-10. Surface water pH at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.2.3 Conductivity

The highest conductivities at most of the CFROU monitoring sites occurred in Q1 and Q4 when streamflows were lowest. The lowest conductivities occurred during the Q2 monitoring events. Conductivity in the mainstem Clark Fork River tended to progressively increase from the headwaters station near Galen downstream to Gemback Road, then stabilize or decrease slightly at the Deer Lodge station. In the mainstem, conductivity was always lowest at Turah, downstream from the Rock Creek confluence. Conductivity at CFROU stations in 2014 ranged from 103.6-593.5 µS/cm [Figure 2-11]. Conductivity increased substantially between the Mill-Willow Creek and Mill-Willow Bypass sites, particularly in Q1, Q3, and Q4 [Figure 2-12]. The lowest conductivity occurred in Mill-Willow Creek at the Frontage Road during the Q2-Peak monitoring event. The highest conductivity occurred in the Mill-Willow Bypass in Q4. The conductivity range at CFROU monitoring stations in 2014 (103.6-593.5) was slightly greater than in 2013 (111-560 µS/cm), 2010 (176-466 µS/cm), 2011 (113-439 µS/cm), and 2012 (138-456 µS/cm).

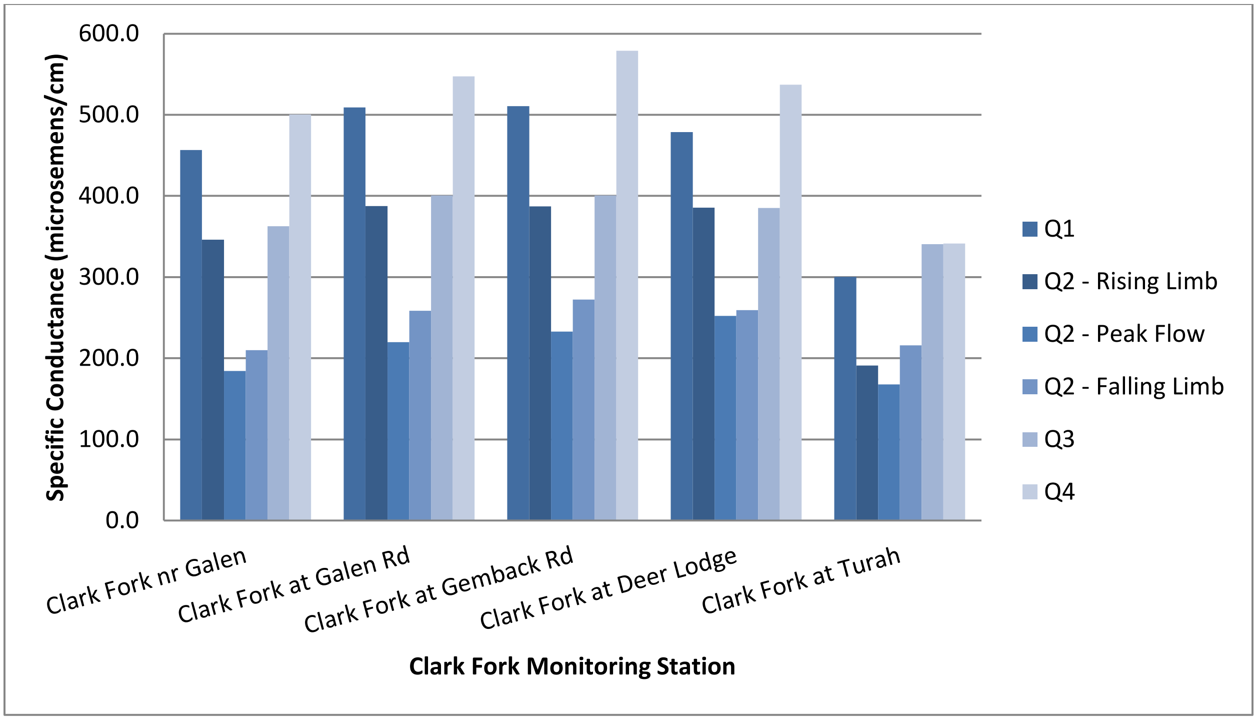

Figure 2-11. Conductivity at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

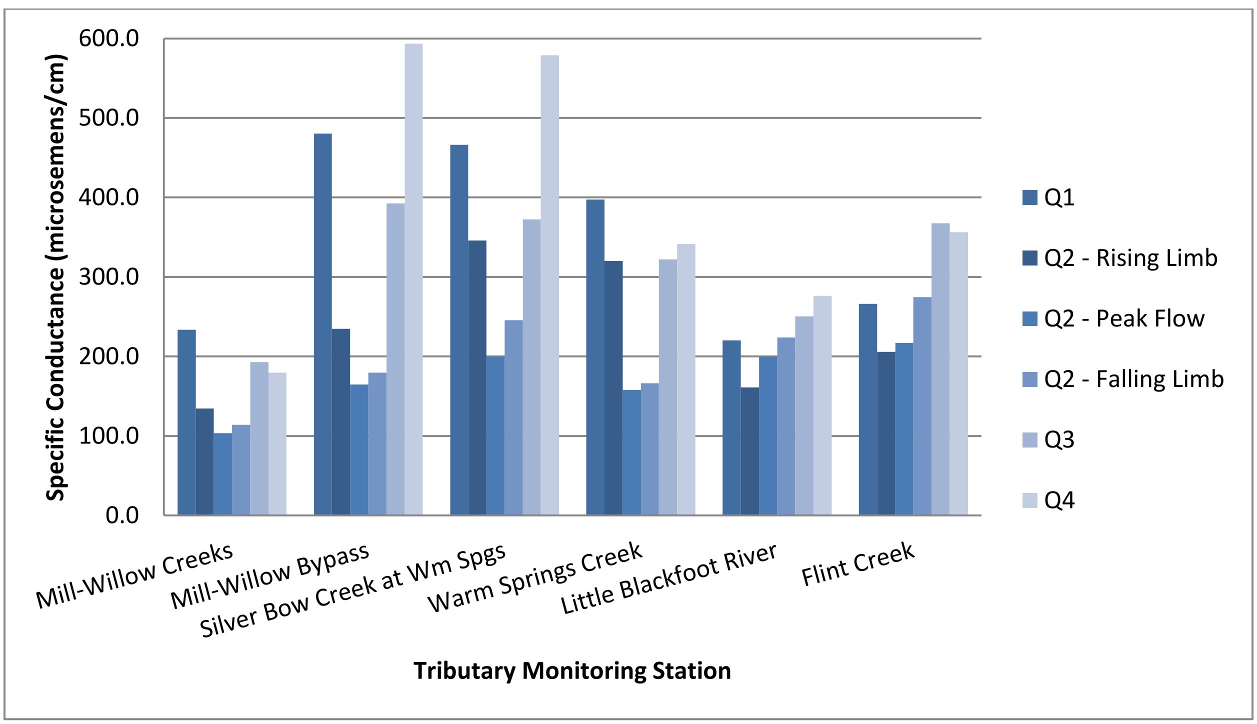

Figure 2-12. Conductivity at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.2.4 Dissolved Oxygen

Dissolved oxygen concentrations in the upper Clark Fork River in 2014 ranged from 8.29-15.23 mg/L. The lowest dissolved oxygen concentration was observed in the Little Blackfoot River near its mouth in Q2-Falling and the maximum concentration was observed in the Clark Fork River near Galen in Q2-Rising [Figure 2-13; Figure 2-14]. None of the 2014 dissolved oxygen measurements indicated water quality or water use limitations associated with inadequate oxygen concentrations. There were no clear spatial trends in dissolved oxygen concentration in 2014. The highest dissolved oxygen concentrations at nearly all monitoring stations were observed during Q2-Rising. The observed range of dissolved oxygen concentrations at Clark Fork River mainstem sites in 2014 (8.29-15.23) was slightly higher than in 2010 (8.69-15.03 mg/L), 2011 (8.60-14.85 mg/L), 2012 (8.49-14.05 mg/L), and 2013 (8.45-15.20 mg/L).

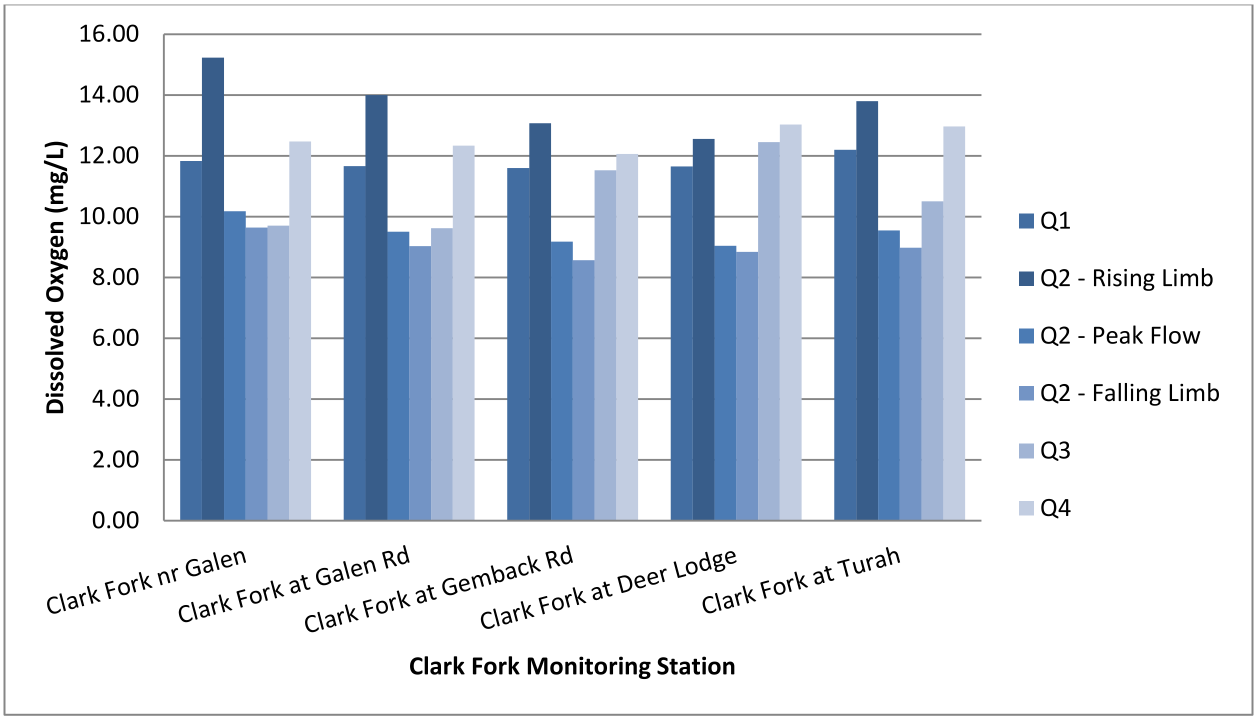

Figure 2-13. Dissolved oxygen concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

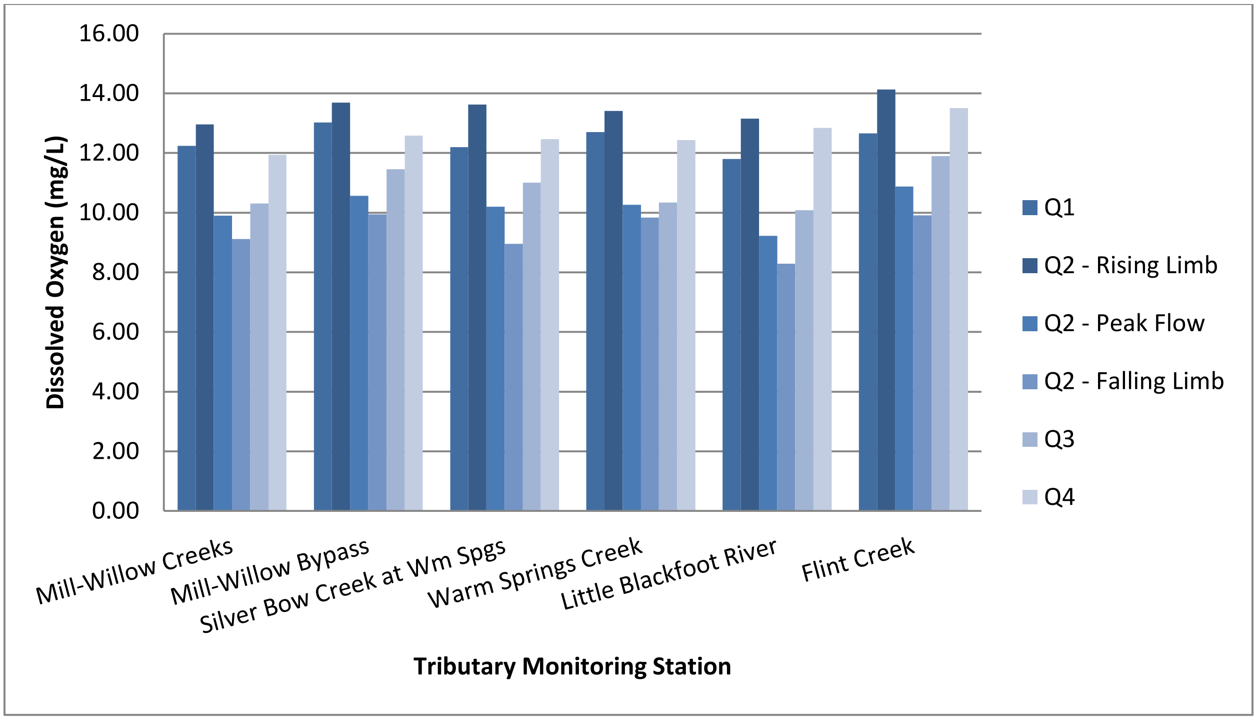

Figure 2-14. Dissolved oxygen concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.2.5 Turbidity

Turbidity at all mainstem Clark Fork River sites were highest during the Q1 2014 monitoring event and lowest in Q3. Turbidity usually increased in the Clark Fork River from near Galen to Deer Lodge, or Turah, depending on the monitoring event [Figure 2-15]. With the exception of the Q1 monitoring event, turbidity was generally low at mainstem monitoring sites during 2014 (range of 1.36-10.70 NTU) [Figure 2-15].

Turbidity at the tributary monitoring sites was more variable and less predictable than at the mainstem Clark Fork River sites. Highest turbidity was observed during the Q2-Peak or Q2-Falling monitoring events at three of the six tributary sites in 2014. Two other tributary sites showed highest turbidity in Q1, and the sixth site (Mill-Willow Creeks at the Frontage Road) had highest turbidity in Q4. The latter site also showed elevated suspended sediment and COC metals concentrations (see Sections 2.3.3 and 2.3.6). Turbidity at the tributary monitoring stations ranged from a low of 0.94 NTU in the Little Blackfoot River in Q3 to a high of 15.60 NTU in Mill-Willow Creek in Q4 [Figure 2-16].

Non-spring runoff period turbidity measurements were similar in each of 2010-2014, with several exceptions. In Q2 2011, turbidity during peak spring snowmelt runoff conditions was higher than during the same periods in 2010-2014. Q1 2014 turbidity was higher at the Clark Fork River at Deer Lodge and Turah sites than during Q1 in each of years 2010-2013. Lastly, turbidity in Mill-Willow Creek at the Frontage Road was higher in Q4 2014 than during any prior quarterly monitoring event in the 2012-2014 periods.

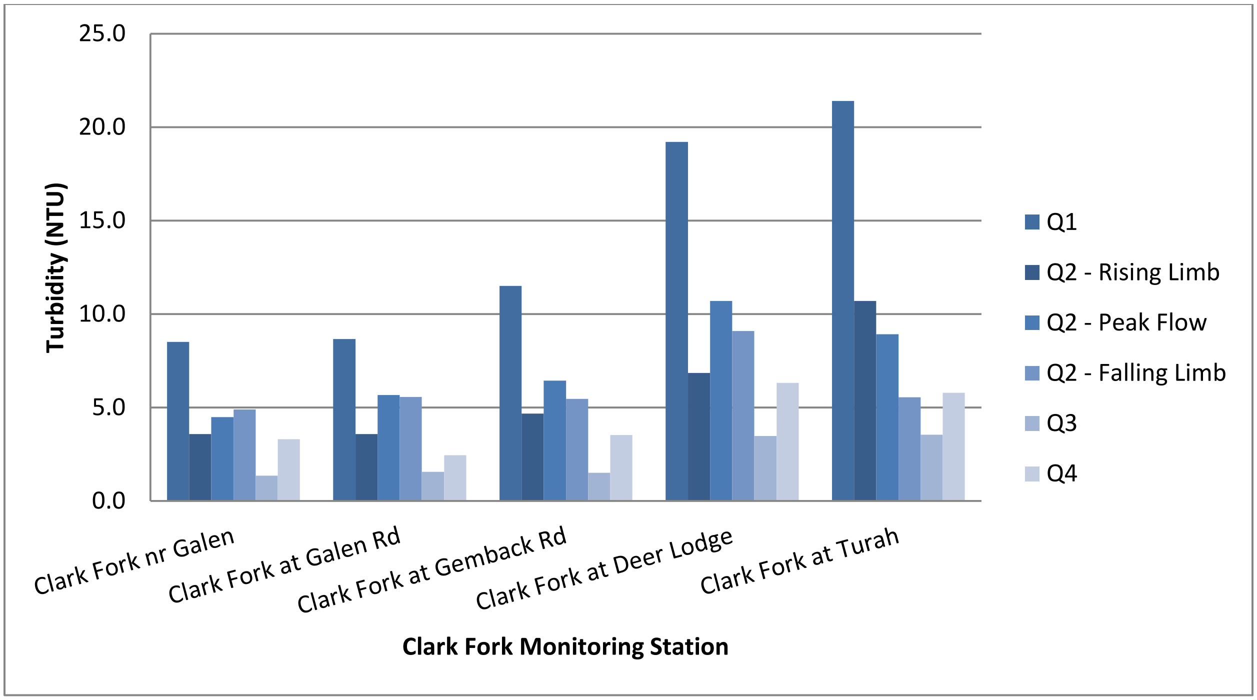

Figure 2-15. Turbidity at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

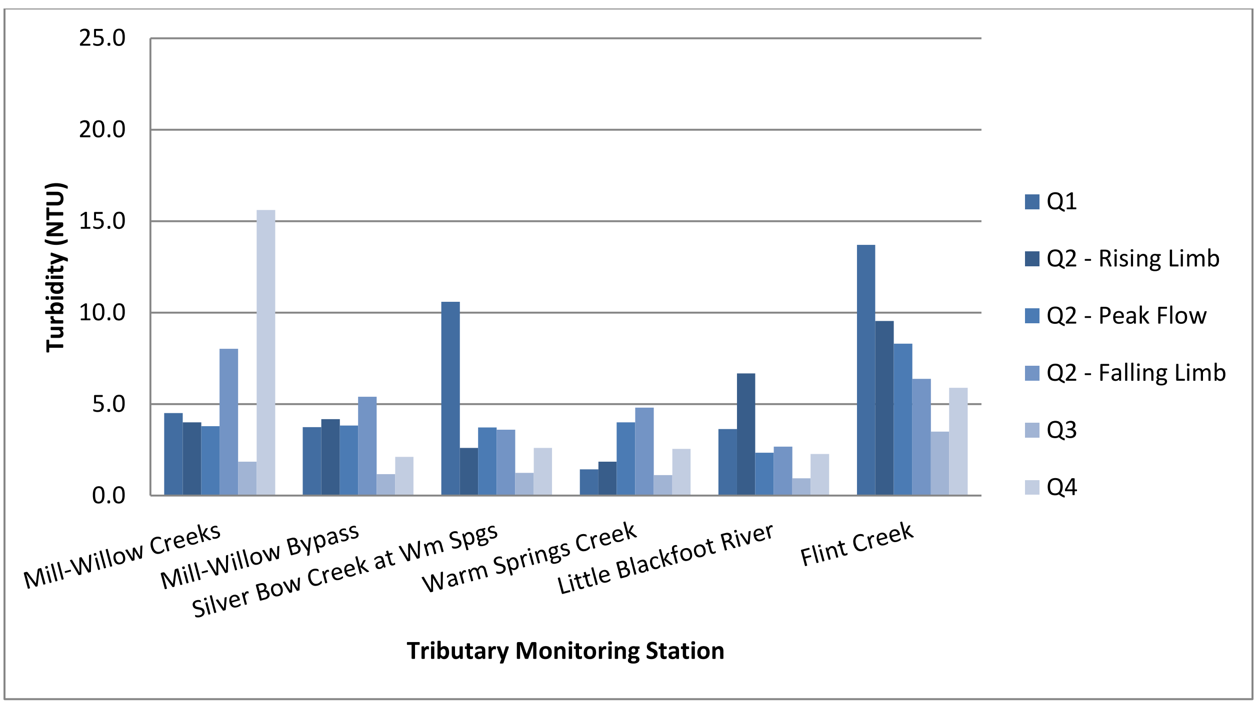

Figure 2-16. Turbidity at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.3 Total Suspended Sediment

Total suspended sediment (TSS) concentrations at Clark Fork River mainstem monitoring stations in 2014 were elevated in Q1, particularly at Gemback Road, Deer Lodge and Turah. Like turbidity, this was associated with an early snowmelt runoff event in March. Second highest total suspended sediment concentrations were observed during the Q2 spring runoff monitoring events, particularly during Q2-Peak. The spatial pattern for total suspended sediment concentrations in the Clark Fork River was for increasing concentrations from near Galen to Deer Lodge, followed by similar concentrations at Turah. Largest inter-site increases in total suspended sediment concentration were noted from Gemback Road to Deer Lodge during the Q1 monitoring event. The overall range of total suspended sediment concentrations at mainstem sites was from 1-45 mg/L. Highest concentrations were noted at Deer Lodge and Turah in Q1 2014, with concentrations of 45 and 39 mg/L, respectively [Figure 2-17].

Total suspended sediment concentrations measured at the tributary monitoring stations during 2014 were generally less variable than at the mainstem stations [Figure 2-17; Figure 2-18]. On average, Flint Creek near its mouth exhibited the highest total suspended sediment concentrations of the six tributaries monitored in 2014. Mill-Willow Creek at Frontage Road had a very high total suspended sediment concentration during the Q4 monitoring event. The source is unknown, but field notes indicate high levels of turbidity extending well upstream from the sampling site at Frontage Road. COC metals concentrations were also greatly elevated at this site in Q4 (see Section 2.3.6). The overall range of total suspended sediment concentrations at the tributary sites was from less than the analytical reporting level of 1 mg/L in Mill-Willow Bypass and Warm Springs Creek during some quarters to a high of 37 mg/L in Mill-Willow Creek in Q4.

Total suspended sediment concentrations at CFROU mainstem monitoring stations during most monitoring events in 2014 were generally comparable to concentrations measured between 2010 and 2013. However, peak total suspended sediment concentrations measured during Q2 monitoring events in each of years 2010-2012 were substantially higher than any of the total suspended sediment concentrations measured during 2014.

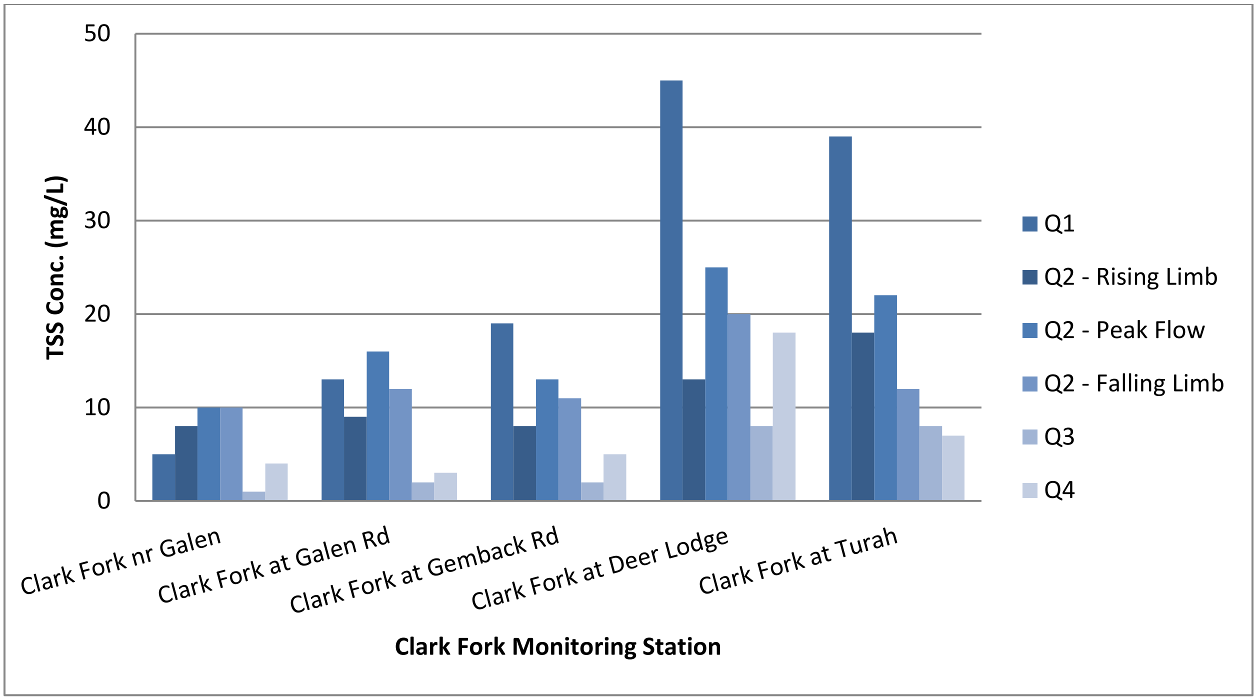

Figure 2-17. Total suspended sediment concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

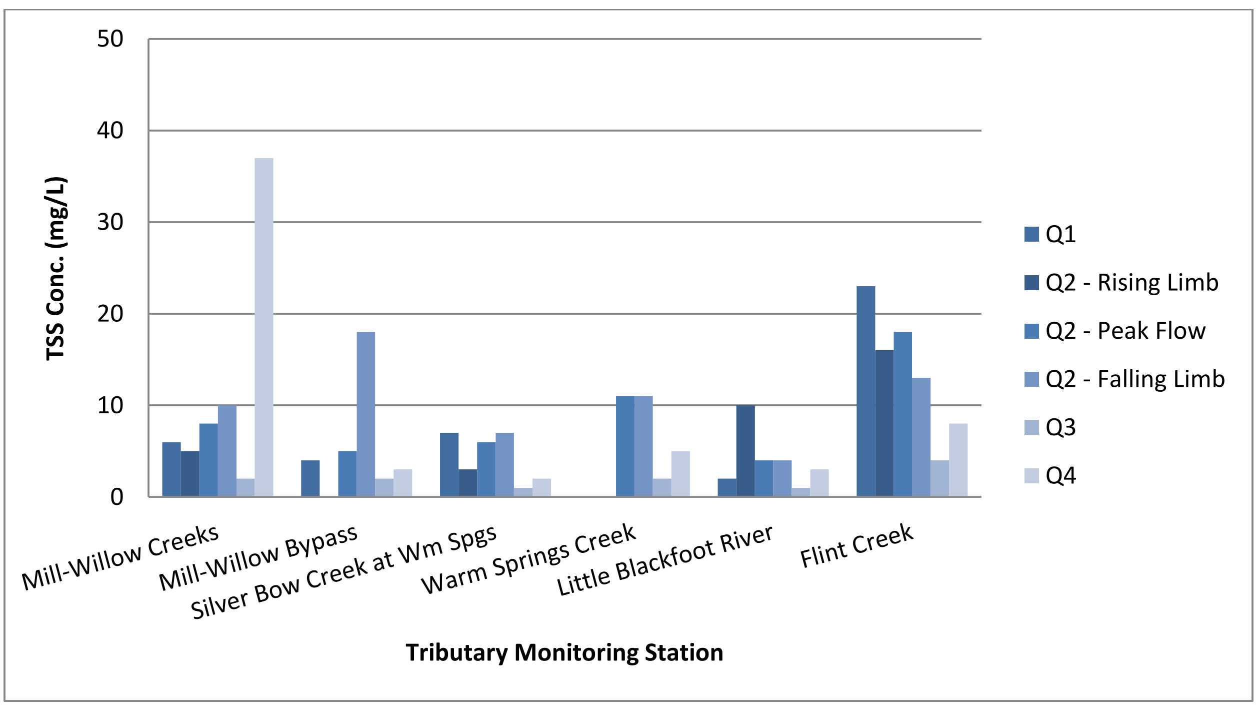

Figure 2-18. Total suspended sediment concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2014. No bars indicate values below the analytical reporting limit.

2.3.4 Common Ions

2.3.4.1 Hardness

Except during the Q2 monitoring events, water hardness at Clark Fork River mainstem stations in 2014 ranged from 148-272 mg/L as CaCO3 (i.e., “hard” to “very hard”) [Figure 2-19]. The Clark Fork River at Turah site and Mill-Willow Creek at Frontage Road during the Q2-Peak monitoring event exhibited the lowest hardness (75 and 46 mg/L, respectively) [Figure 2-19; Figure 2-20]. Particularly high water hardness was observed in the Mill-Willow Bypass in Q4 (287 mg/L) and Clark Fork River mainstem monitoring stations at Galen Road (259 mg/L), at Gemback Road (272 mg/L), and at Deer Lodge (252 mg/L). Water hardness during 2014 quarterly monitoring events was generally within the range of values observed in each of years 2010-2013.

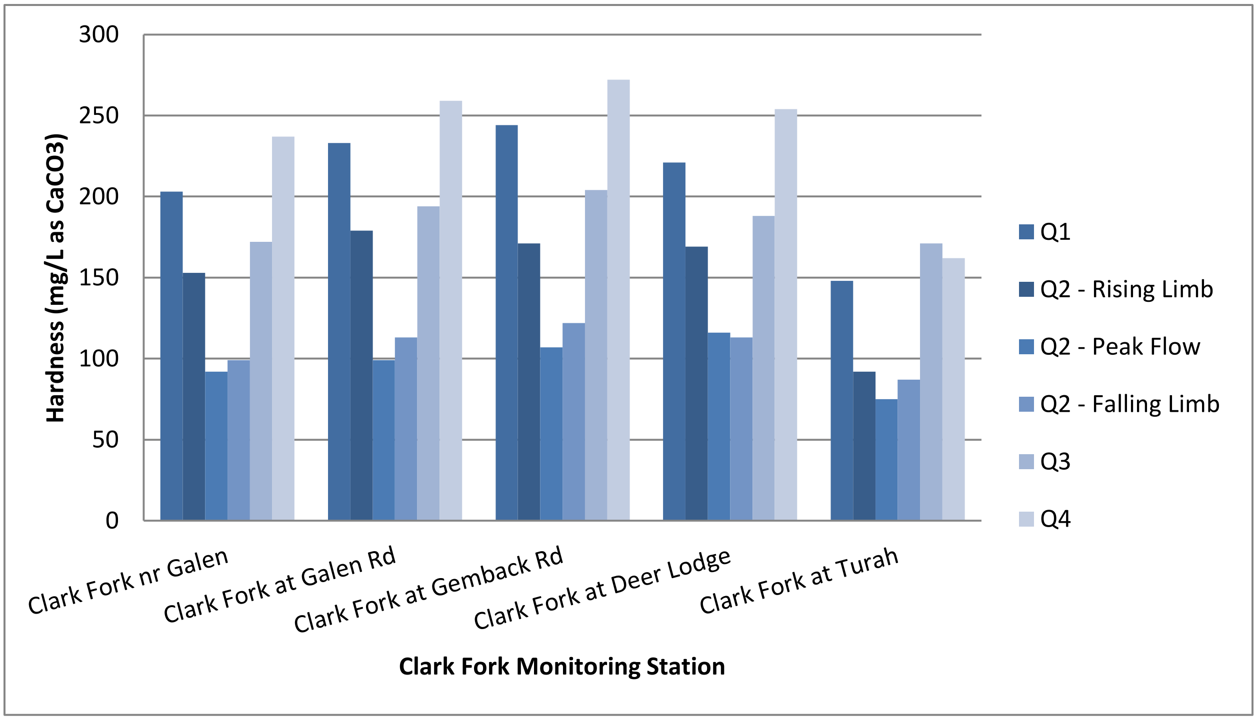

Figure 2-19. Water hardness at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

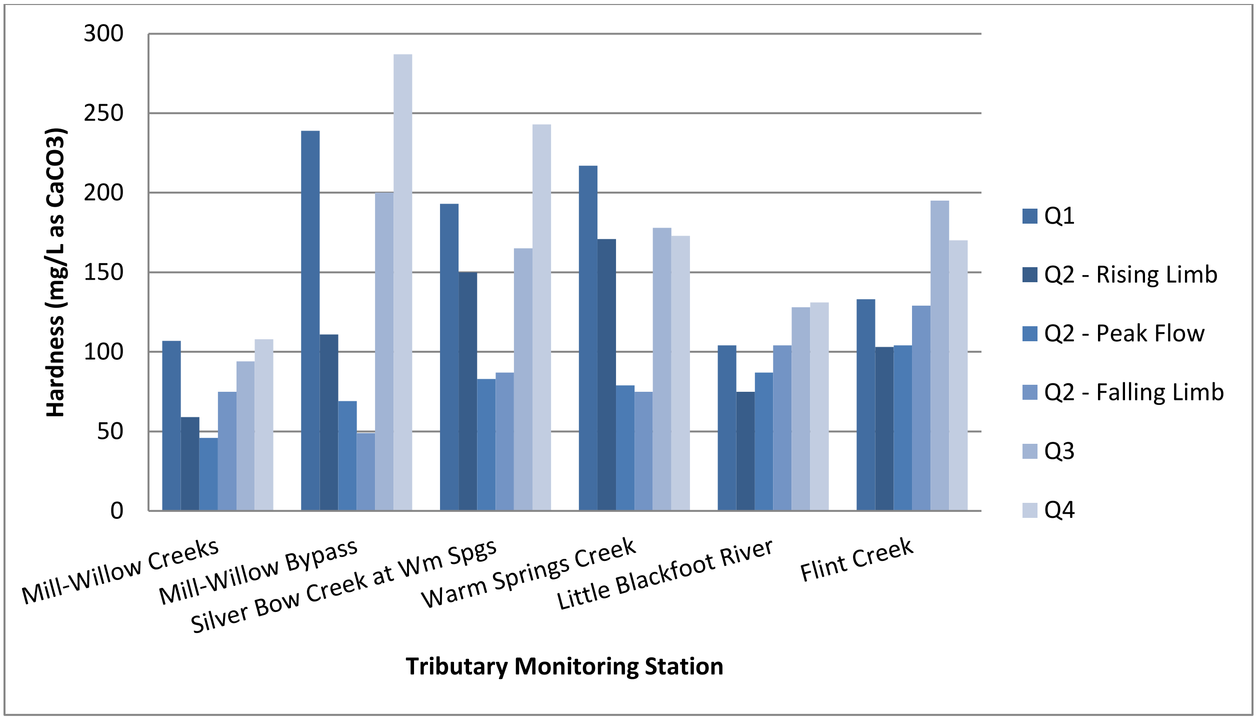

Figure 2-20. Water hardness at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.4.2 Alkalinity and Bicarbonate

Total and bicarbonate alkalinity in the mainstem Clark Fork River in 2014 showed a modest increasing trend from near Galen to Deer Lodge, followed by lower concentrations at Turah [Figure 2-21; Figure 2-23]. Among the tributary monitoring stations, the highest alkalinity occurred in Flint Creek, the Little Blackfoot River and Warm Springs Creek, while lowest alkalinity occurred in Mill-Willow Creek at Frontage Road [Figure 2-22; Figure 2-24]. Alkalinity was relatively low during the three Q2 monitoring events. The highest alkalinity was most commonly observed in Q4. Total and bicarbonate alkalinity at CFROU mainstem and tributary monitoring stations during monitoring events in 2014 were within the range of values measured in 2010-2013.

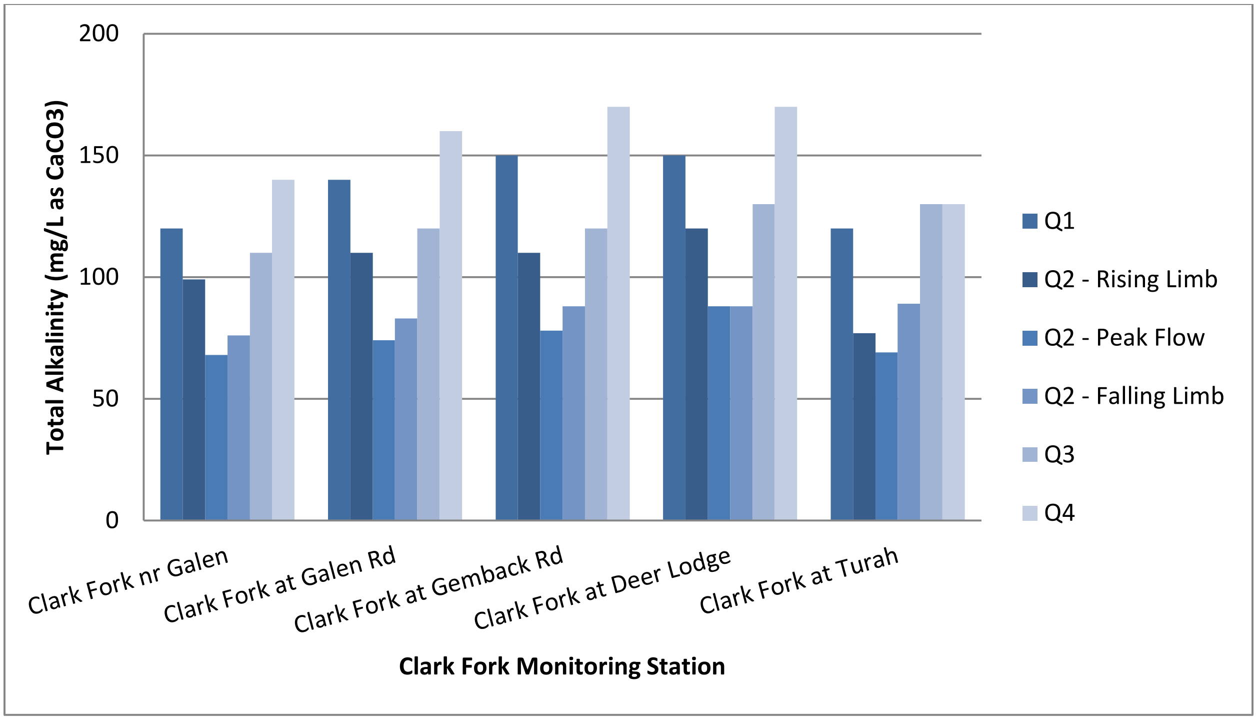

Figure 2-21. Alkalinity at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

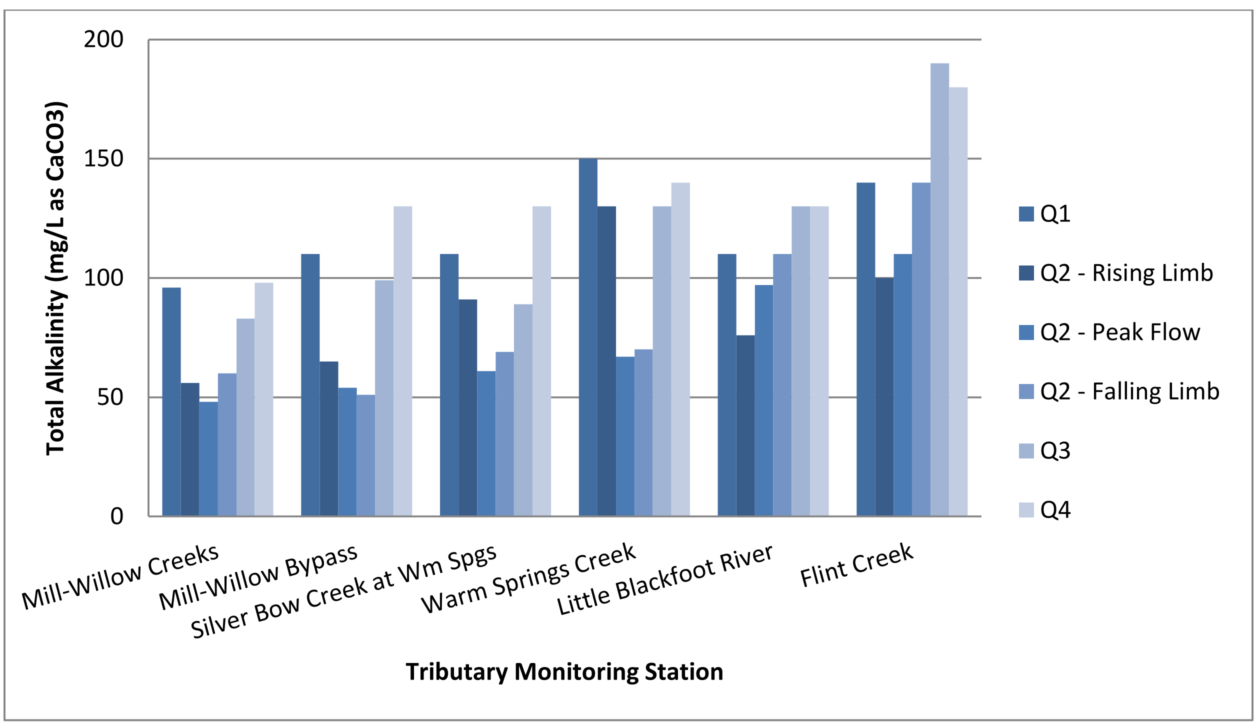

Figure 2-22. Alkalinity at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

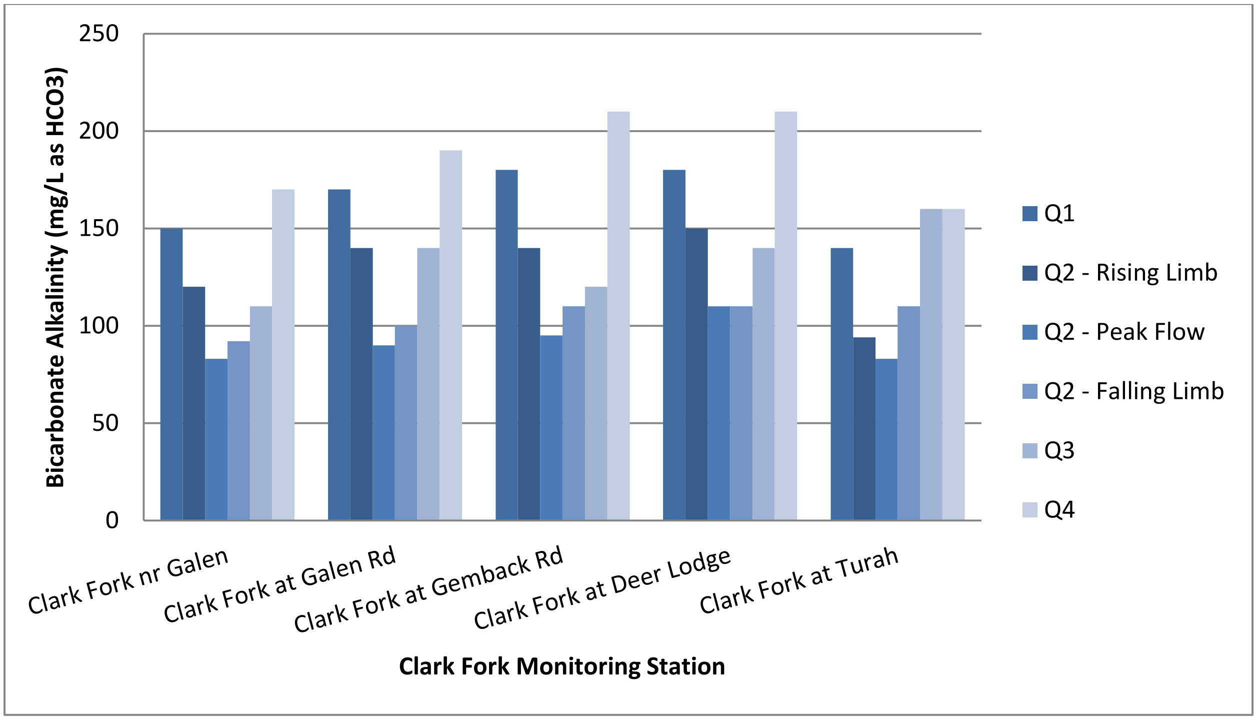

Figure 2-23. Bicarbonate alkalinity at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

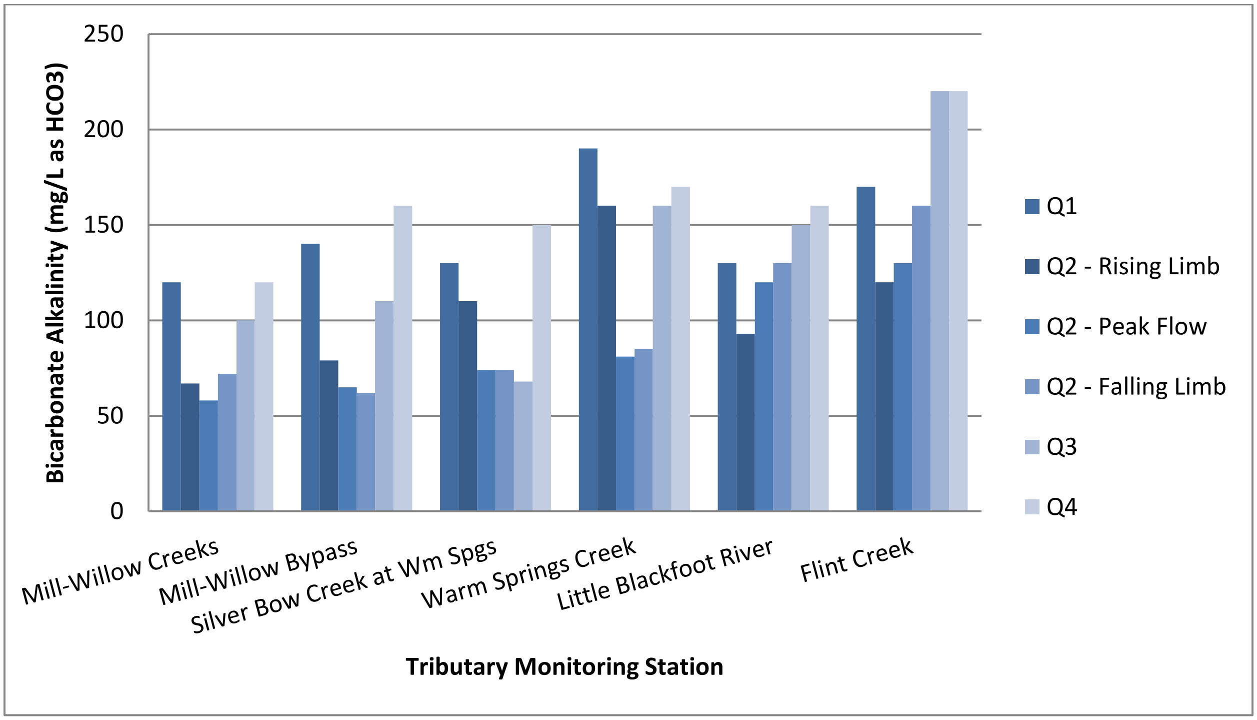

Figure 2-24. Bicarbonate alkalinity at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.4.3 Sulfate

Sulfate concentrations in the mainstem Clark Fork River were generally comparable from the near Galen to Gemback Road monitoring sites, somewhat lower at the Deer Lodge site, and lower at Turah [Figure 2-25]. The tributary monitoring stations had the highest sulfate concentrations in the Mill-Willow Bypass and in Silver Bow Creek at Warm Springs, and the lowest concentrations in the Little Blackfoot River and Flint Creek [Figure 2-26]. Similar to alkalinity, sulfate concentrations were relatively low during the Q2 monitoring events and relatively high in Q1 and Q4. Sulfate concentrations measured at CFROU monitoring stations during 2014 were within the range of values measured in 2010-2013.

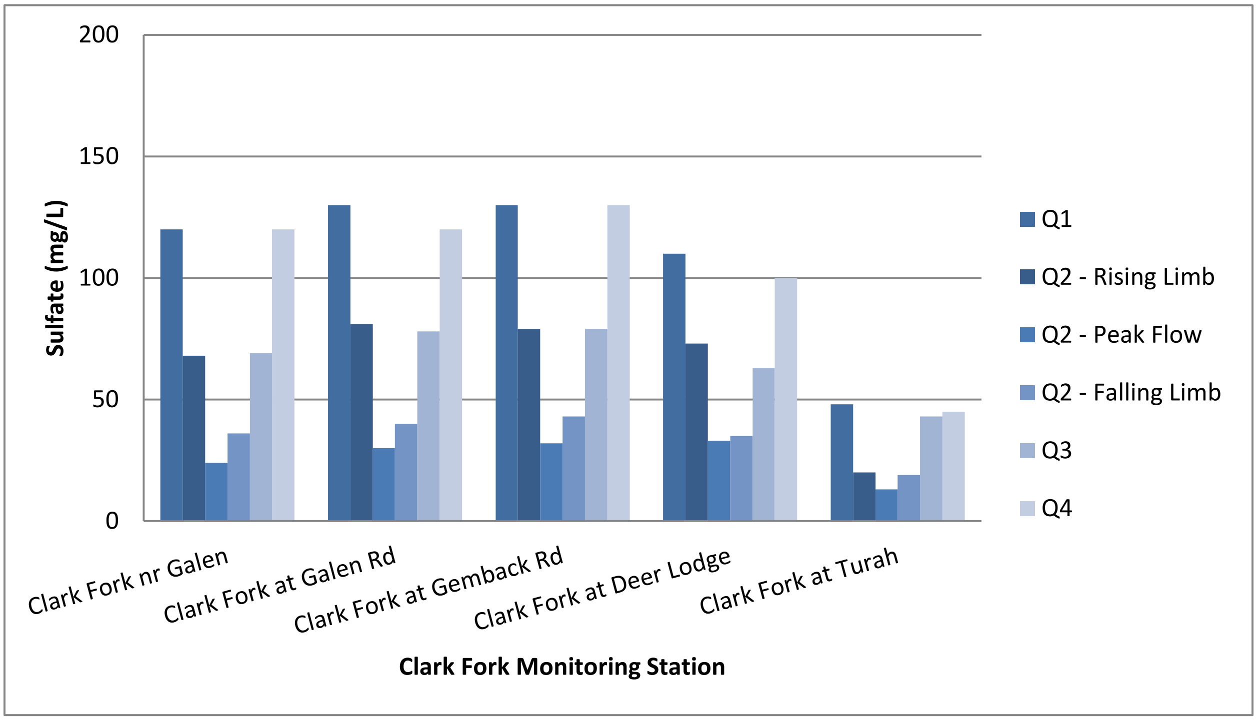

Figure 2-25. Sulfate concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2014.

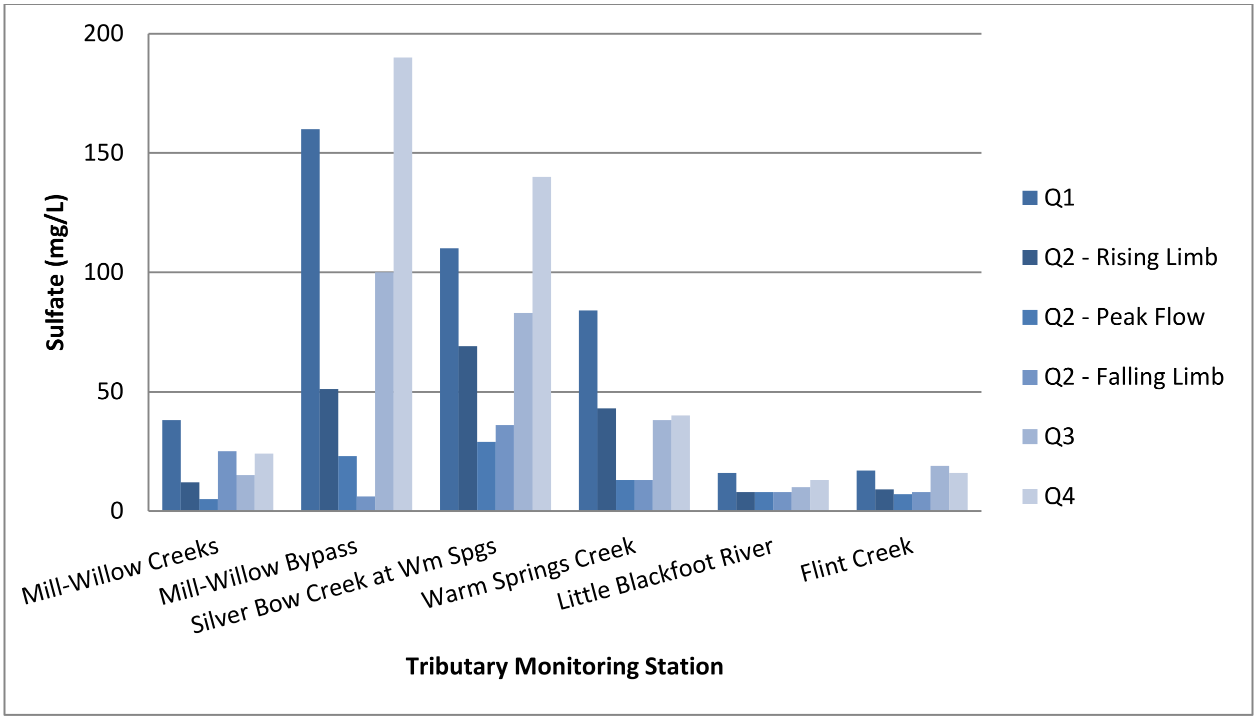

Figure 2-26. Sulfate concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.5 Nutrients

2.3.5.1 Total Nitrogen

Compared to the summertime Clark Fork River water quality standards, total nitrogen concentrations were periodically elevated in the Clark Fork River at Deer Lodge in 2014 [Table 2-5; Figure 2-27]. The numeric water quality standards for nutrients in the Clark Fork River (ARM 17.30.631) apply only to the CFROU mainstem monitoring sites during the 2014 Q2-Falling and Q3 monitoring events, which occurred during the applicable June 21 to September 21 period. Compared to newly adopted summertime base numeric nutrient standards for the Middle Rockies Ecoregion, which apply to the July 1 to September 30 time period, total nitrogen concentrations were acceptable in 2014 at all six CFROU tributary monitoring stations [Table 2-5, Figure 2-28]. Based on these criteria, exceedances of the relevant total nitrogen standards were observed only at the Clark Fork River at Deer Lodge monitoring station in 2014 [Table 2-5].

Total nitrogen concentrations were highest at most stations in Q1. The maximum total nitrogen concentrations were observed in the Clark Fork River at Deer Lodge in Q1 (0.94 mg/L) and in Silver Bow Creek at Warm Springs (1.08 mg/L), also in Q1. The lowest total nitrogen concentrations were observed in Mill-Willow Creek at Frontage Road, Mill-Willow Bypass, and Warm Springs Creek (all less than the analytical reporting limit) in Q3, and in the mainstem Clark Fork River at Turah in Q3 [Table 2-5]. Total nitrogen concentrations in the mainstem Clark Fork River were similar from near Galen to Gemback Road, slightly higher at Deer

Lodge, and consistently lower at Turah. Total nitrogen concentrations during 2014 monitoring events were within the range of concentrations measured at CFROU monitoring sites in 2011-2013.

Table 2-5. Total nitrogen concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.92	0.48	0.20	0.15	0.22	0.64
CFR-07D	Clark Fork River at Galen Road	0.86	0.46	0.19	0.15	0.17	0.70
CFR-11F	Clark Fork River at Gemback Road	0.88	0.39	0.23	0.19	0.25	0.66
CFR-27H	Clark Fork River at Deer Lodge	0.94	0.46	0.32	0.30	0.32	0.82
CFR-116A	Clark Fork River at Turah	0.70	0.29	0.20	0.08	0.10	0.46
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	1.08	0.67	0.18	0.32	0.27	0.67
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.16	0.24	0.15	0.21	ND	0.42
MWB-SBC	Mill-Willow Bypass near mouth	0.19	0.31	0.13	0.16	ND	0.31
WSC-SBC	Warm Springs Creek near mouth	0.06	0.22	0.14	0.05	ND	0.16
LBR-CFR	Little Blackfoot River near Garrison	0.32	0.30	0.21	0.19	0.08	0.20
FC-CFR	Flint Creek near mouth	0.84	0.39	0.35	0.34	0.28	0.50

(shaded) Exceeds Clark Fork River total nitrogen standard applicable June 21 to September 21 (0.30 mg/L; ARM 17.30.631), or Middle Rockies Ecoregion total nitrogen standard applicable July 1 to September 30 (0.30 mg/L) [MDEQ, 2014b].

ND Not detected at analytical reporting limit.

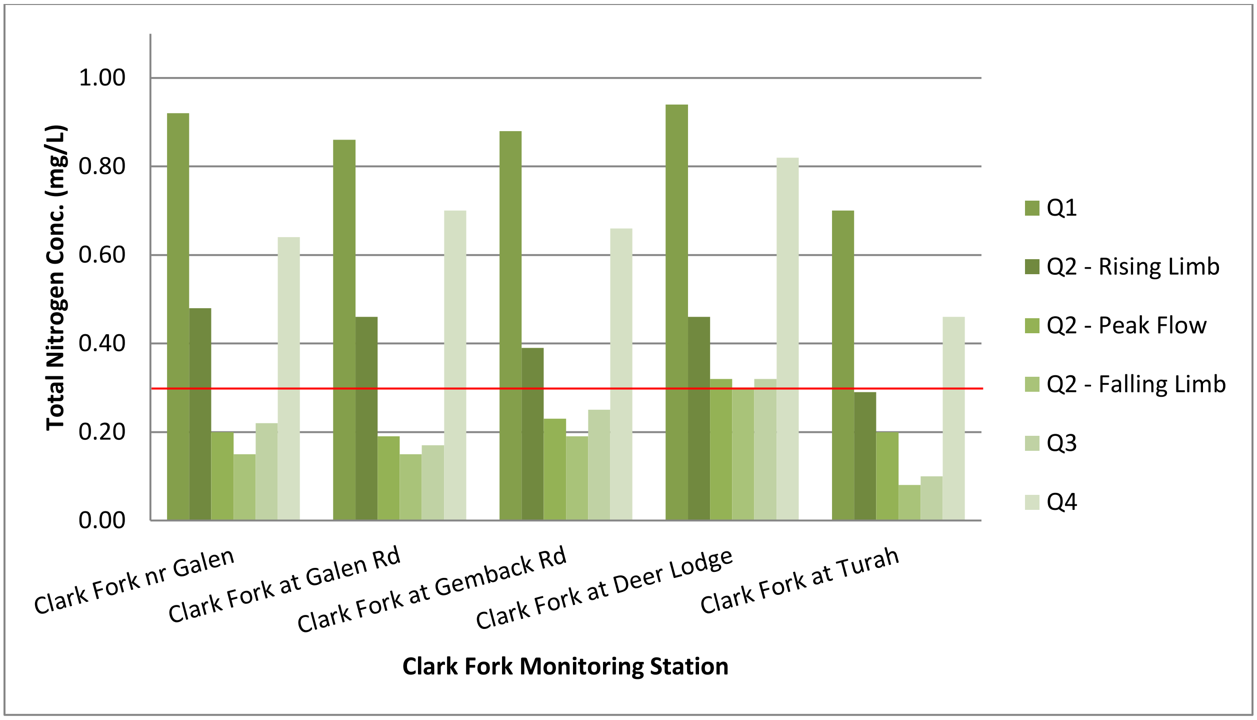

Figure 2-27. Total nitrogen concentrations (mg/L) at Clark Fork River mainstem monitoring stations, 2014. Red line represents total nitrogen standard [MDEQ, 2014b].

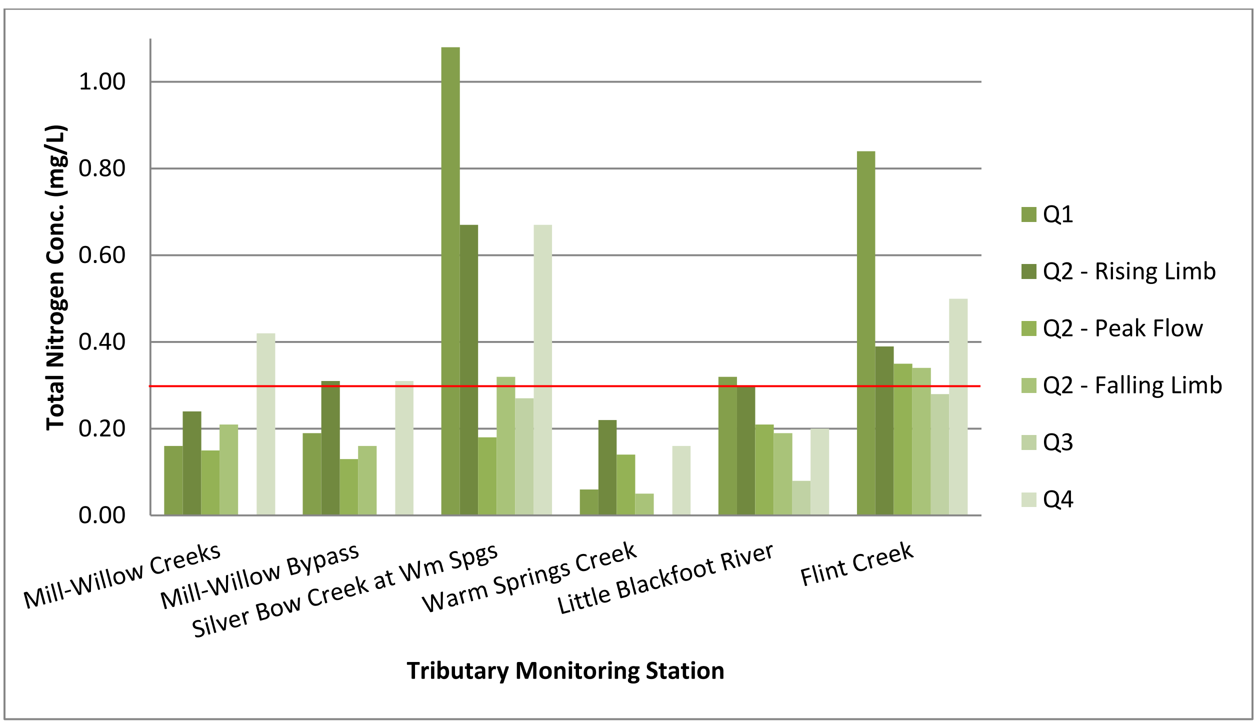

Figure 2-28. Total nitrogen concentrations (mg/L) at Clark Fork River tributary monitoring stations, 2014. Red line represents total nitrogen standard [MDEQ, 2014b].

2.3.5.2 Nitrate Plus Nitrite Nitrogen

Concentrations of nitrate plus nitrite nitrogen were somewhat elevated in Q1 and Q4 during low streamflow conditions, and generally low during other quarterly monitoring events in 2014 [Figure 2-29; Figure 2-30]. The spatial trend for nitrate plus nitrite concentrations in the mainstem Clark Fork River showed increasing concentrations from near Galen to Deer Lodge during several monitoring events, followed by a decline at the downstream Turah monitoring site. Nitrate plus nitrite nitrogen concentrations were frequently below the minimum analytical reporting limit during many of the 2014 monitoring events, at both mainstem Clark Fork River as well as tributary monitoring stations (41 of 66 site observations were below the reporting limit) [Table 2-6]. Nitrate plus nitrite concentrations during 2014 monitoring events were within the range of concentrations measured at CFROU monitoring sites in 2011-2013.

Table 2-6. Nitrate plus nitrite nitrogen concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.37	0.07	ND	ND	ND	0.20
CFR-07D	Clark Fork River at Galen Road	0.38	0.08	ND	ND	ND	0.31
CFR-11F	Clark Fork River at Gemback Road	0.38	0.08	ND	ND	ND	0.32
CFR-27H	Clark Fork River at Deer Lodge	0.41	0.06	ND	ND	0.03	0.44
CFR-116A	Clark Fork River at Turah	0.18	ND	ND	ND	ND	0.17
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.44	0.13	ND	ND	ND	0.26
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.07	ND	ND	ND	ND	0.12
MWB-SBC	Mill-Willow Bypass near mouth	ND	ND	ND	ND	ND	0.11
WSC-SBC	Warm Springs Creek near mouth	ND	ND	ND	ND	ND	0.13
LBR-CFR	Little Blackfoot River near Garrison	0.06	ND	ND	ND	ND	ND
FC-CFR	Flint Creek near mouth	0.19	ND	ND	ND	ND	0.21

ND Not detected at analytical reporting limit.

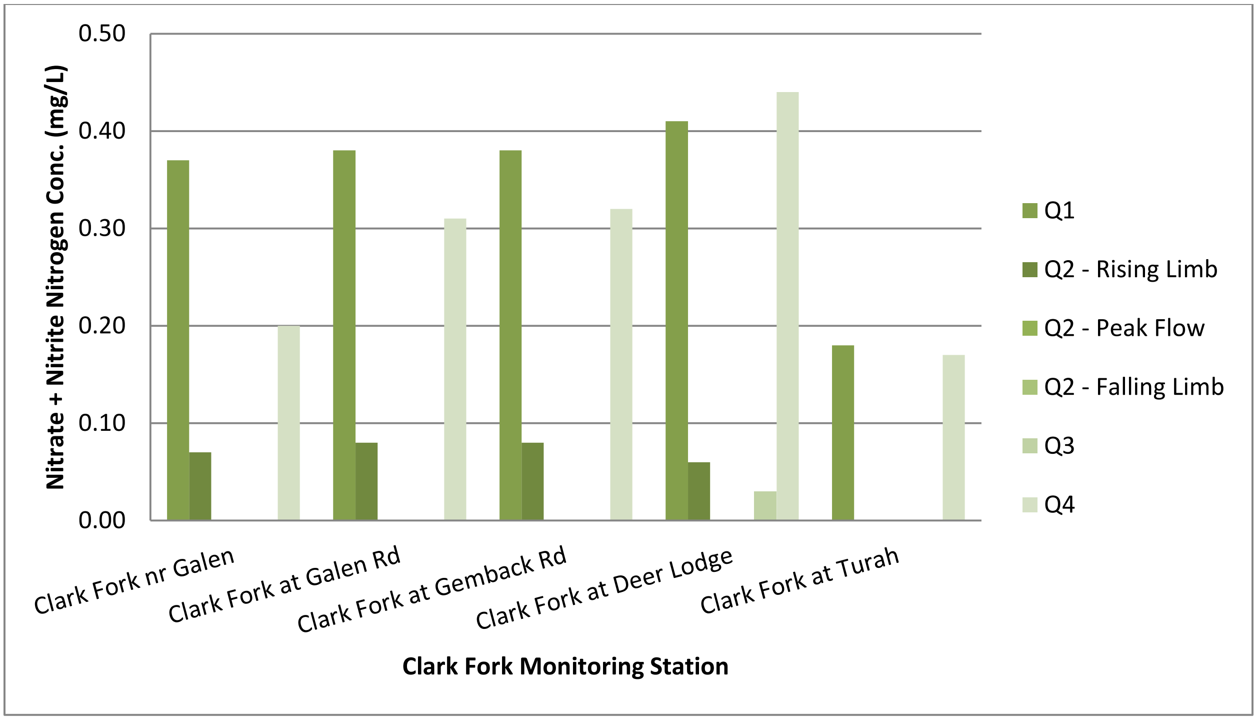

Figure 2-29. Nitrate plus nitrite nitrogen concentrations (mg/L) at Clark Fork River mainstem monitoring stations, 2014.

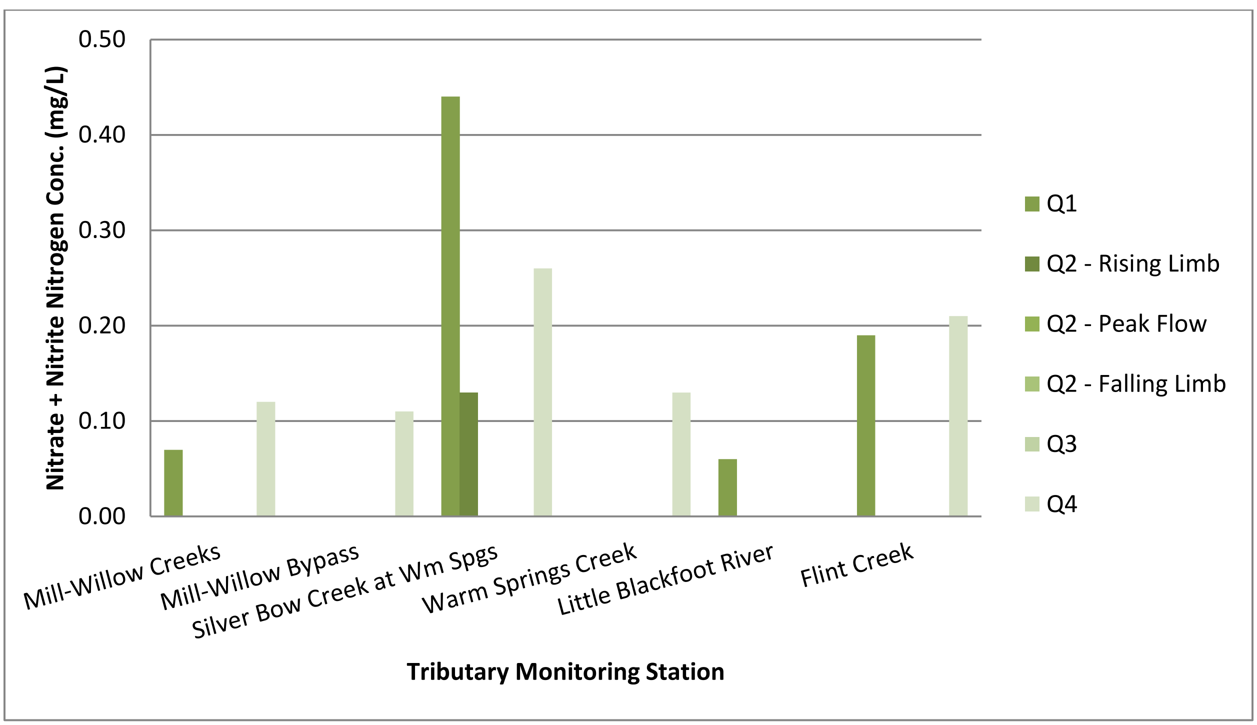

Figure 2-30. Nitrate plus nitrite nitrogen concentrations (mg/L) at Clark Fork River tributary monitoring stations, 2014.

2.3.5.3 Total Ammonia

All but four of 66 samples collected from the CFROU in 2014 had ammonia concentrations below the analytical reporting limit. In Q1 2014, ammonia was detectable in Silver Bow Creek at Warm Springs and at three Clark Fork River mainstem sites downstream from Silver Bow Creek [Table 2-7]. The total ammonia concentration (1.08 mg/L) in Silver Bow Creek at Warm Springs on March 19, 2014 was 189% higher than the water temperature- and pH-dependent chronic toxicity ALS and was 86% of the acute ALS.

Spring turnover in the Warm Springs Ponds on Silver Bow Creek was believed to be the cause of the elevated ammonia concentrations during the Q1 monitoring event. Prior to 2014, ammonia was not detected at any of the CFROU monitoring stations during any quarterly monitoring event since 2013.

Table 2-7. Total ammonia concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.11	ND	ND	ND	ND	ND
CFR-07D	Clark Fork River at Galen Road	ND	ND	ND	ND	ND	ND
CFR-11F	Clark Fork River at Gemback Road	0.06	ND	ND	ND	ND	ND
CFR-27H	Clark Fork River at Deer Lodge	0.06	ND	ND	ND	ND	ND
CFR-116A	Clark Fork River at Turah	ND	ND	ND	ND	ND	ND
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	1.08	ND	ND	ND	ND	ND
MCWC-MWB	Mill-Willow Creek at Frontage Road	ND	ND	ND	ND	ND	ND
MWB-SBC	Mill-Willow Bypass near mouth	ND	ND	ND	ND	ND	ND
WSC-SBC	Warm Springs Creek near mouth	ND	ND	ND	ND	ND	ND
LBR-CFR	Little Blackfoot River near Garrison	ND	ND	ND	ND	ND	ND
FC-CFR	Flint Creek near mouth	ND	ND	ND	ND	ND	ND

(highlighted) Exceeds the chronic aquatic life standard [MDEQ, 2012b].

ND Not detected at analytical reporting limit.

2.3.5.4 Total Phosphorus

Total phosphorus concentrations in 2014 exceeded the Clark Fork River total phosphorus water quality standard (0.020 mg/L) at all five mainstem sites during at least one summertime monitoring event [Table 2-8; Figure 2-31]. Total phosphorus concentrations exceeded the Middle Rockies Ecoregion total phosphorus water quality standard (0.030 mg/L) at two tributary sites: Silver Bow Creek and Flint Creek [Table 2-8; Figure 2-32]. Concentrations of total phosphorus were highest at most sites during the Q1 monitoring event, when streamflows were still elevated from the unusual March snowmelt runoff event. All five mainstem Clark Fork River monitoring sites exceeded the relevant total phosphorus standard during Q2-Falling monitoring event, whereas four of five mainstem sites exhibited exceedances during the Q3 monitoring event. Silver Bow Creek and Flint Creek exceeded the relevant total phosphorus standard during Q3 monitoring event.

Total phosphorus concentrations were highest in Flint Creek, the Clark Fork River at Turah, and in Silver Bow Creek at Warm Springs during Q1. Total phosphorus concentrations tended to be similar throughout much of the Clark Fork River mainstem sites. The lowest total phosphorus concentrations were observed in Warm Springs Creek [Figure 2-32]. Total phosphorus concentrations in 2014 were within the range of concentrations measured at CFROU monitoring sites in 2011-2013. However, total phosphorus concentrations at mainstem Clark Fork River sites during Q2 2011 and Q2 2012 were higher than those observed during the Q2 2013 and Q2 2014 monitoring events.

Table 2-8. Total phosphorus concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.080	0.029	0.027	0.027	0.044	0.032
CFR-07D	Clark Fork River at Galen Road	0.067	0.027	0.030	0.027	0.035	0.023
CFR-11F	Clark Fork River at Gemback Road	0.064	0.025	0.028	0.025	0.037	0.024
CFR-27H	Clark Fork River at Deer Lodge	0.091	0.029	0.045	0.031	0.028	0.031
CFR-116A	Clark Fork River at Turah	0.128	0.036	0.037	0.026	0.017	0.037
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.113	0.031	0.037	0.045	0.067	0.039
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.031	0.032	0.026	0.028	0.018	0.059
MWB-SBC	Mill-Willow Bypass near mouth	0.027	0.030	0.025	0.033	0.014	0.021
WSC-SBC	Warm Springs Creek near mouth	0.008	0.009	0.013	0.009	0.008	0.015
LBR-CFR	Little Blackfoot River near Garrison	0.074	0.033	0.033	0.028	0.019	0.034
FC-CFR	Flint Creek near mouth	0.144	0.045	0.046	0.048	0.046	0.046

(Shaded cells) Exceeds Clark Fork River total phosphorus standard applicable June 21 to September 21 (0.020 mg/L; ARM 17.30.631), or Middle Rockies Ecoregion total phosphorus standard applicable July 1 to September 30 (0.030 mg/L) [MDEQ, 2014b].

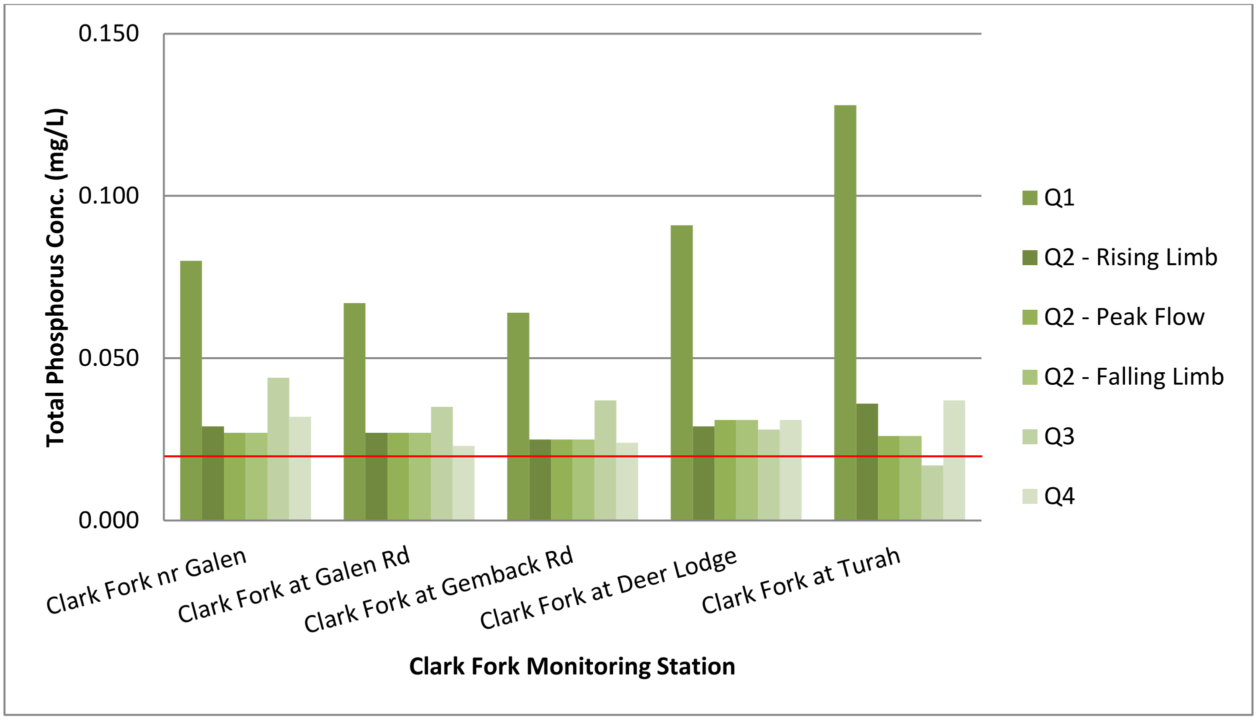

Figure 2-31. Total phosphorus concentrations (mg/L) at Clark Fork River mainstem monitoring stations, 2014. Red line represents total nitrogen standard [MDEQ, 2014b].

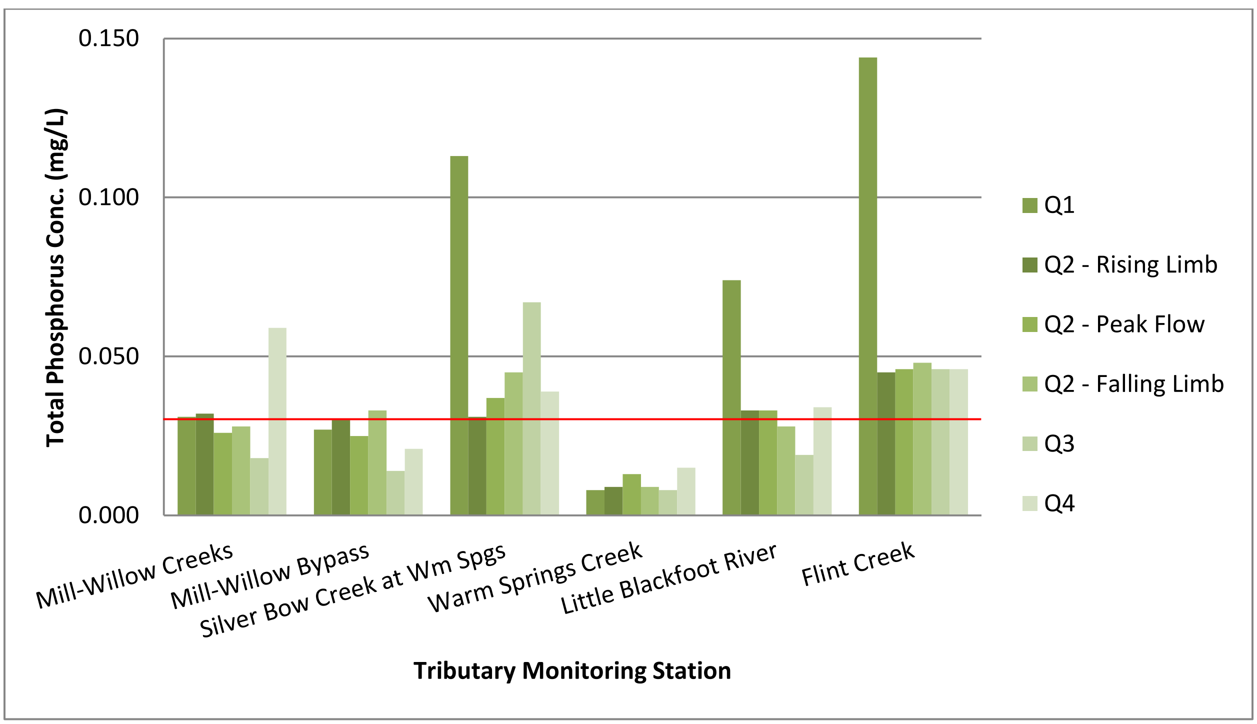

Figure 2-32. Total phosphorus concentrations (mg/L) at Clark Fork River tributary monitoring stations, 2014. Red line represents total nitrogen standard [MDEQ, 2014b].

2.3.6 Contaminants of Concern

2.3.6.1 Arsenic

Average concentrations of total recoverable (TR) and dissolved arsenic at CFROU monitoring stations during 2014 were highest in Mill-Willow Creek at Frontage Road, Mill-Willow Bypass, Silver Bow Creek at Warm Springs, and the Clark Fork River station at Deer Lodge. Arsenic concentrations were lowest in the Little Blackfoot River, Warm Springs Creek, and in the Clark Fork River at Turah [Figure 2-33; Figure 2-34]. Arsenic concentrations were comparable in the reach of the Clark Fork River from near Galen to Gemback Road, slightly higher at Deer Lodge, and lower at the Clark Fork River at Turah station below Rock Creek. The single highest arsenic concentrations were observed in Mill-Willow Creek, Mill-Willow Bypass and Silver Bow Creek at Warm Springs. Arsenic concentrations showed minimal seasonal variation at most of the CFROU monitoring stations during most of the six monitoring events. However, lowest concentrations were observed at most of the monitoring sites in Q4. With the exception of the second quarter 2011 monitoring event when both streamflows and arsenic concentrations at some sites were unusually high, arsenic concentrations at CFROU mainstem monitoring stations during the 2014 calendar year were comparable to those measured in 2010-2013.

A high percentage of arsenic detected at CFROU monitoring stations in 2014 was present in the dissolved form during all of the six monitoring events [Figure 2-33]. Arsenic concentrations commonly exceeded the dissolved and total recoverable performance goals [USEPA, 2004] at seven of the 11 CFROU monitoring stations during the 2014 monitoring year [Table 2-9; Table 2-10]. None of the measured arsenic values during 2014 exceeded the acute or chronic aquatic life standard (ALS) [MDEQ, 2012b]. The frequencies of arsenic performance goal excursions at CFROU monitoring sites in 2014 was slightly higher than during monitoring in 2010-2013. In 2014, 61% of the dissolved and 38% of the total recoverable samples in the CFROU exceeded the performance goals [USEPA, 2004].

The arsenic performance goal [USEPA, 2004] and chronic ALS [MDEQ, 2012b] compliance ratios for the four selected stations have remained relatively stable over the four year period [Figure 2-35 through Figure 2-38]. The performance goal compliance ratios for Silver Bow Creek at Warm Springs and the Clark Fork River near Galen and at Deer Lodge were commonly near or above 1.0 during monitoring events in the examined period indicating frequent exceedances of that goal. In contrast, the Clark Fork River at Turah rarely exceeded the 1.0 threshold value during the same time period. The chronic ALS compliance ratio for arsenic was consistently below 1.0 at all four of the selected stations. Examining the two human health compliance ratios for arsenic during the six 2014 monitoring events, ratios were similar at the upper four Clark Fork River mainstem stations from near Galen to Deer Lodge and were always near or greater than 1.0, then much lower at the Turah station [Figure 2-39; Figure 2-40]. Among the tributary monitoring stations, the two arsenic human health compliance ratios during 2014 were near or greater than 1.0 in Mill-Willow Creek at Frontage Road, Mill-Willow Bypass, and Silver Bow Creek at Warm Springs, and below 1.0 in Warm Springs Creek, the Little Blackfoot River, and Flint Creek [Figure 2-41; Figure 2-42].

Table 2-9. Dissolved arsenic concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.013	0.015	0.014	0.018	0.021	0.010
CFR-07D	Clark Fork River at Galen Road	0.015	0.014	0.015	0.017	0.020	0.011
CFR-11F	Clark Fork River at Gemback Road	0.015	0.015	0.016	0.018	0.021	0.011
CFR-27H	Clark Fork River at Deer Lodge	0.014	0.015	0.018	0.016	0.018	0.012
CFR-116A	Clark Fork River at Turah	0.007	0.005	0.005	0.006	0.007	0.006
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.014	0.017	0.022	0.026	0.028	0.009
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.019	0.025	0.019	0.024	0.019	0.011
MWB-SBC	Mill-Willow Bypass near mouth	0.018	0.025	0.020	0.025	0.019	0.014
WSC-SBC	Warm Springs Creek near mouth	0.008	0.006	0.005	0.006	0.007	0.005
LBR-CFR	Little Blackfoot River near Garrison	0.004	0.004	0.006	0.006	0.005	0.004
FC-CFR	Flint Creek near mouth	0.008	0.006	0.008	0.009	0.008	0.006

(shaded)	Exceeds specified arsenic surface water performance goal for dissolved concentration (0.010 mg/L) [USEPA, 2004].

Table 2-10. Total recoverable arsenic concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.016	0.016	0.015	0.020	0.021	0.012
CFR-07D	Clark Fork River at Galen Road	0.018	0.017	0.017	0.020	0.021	0.012
CFR-11F	Clark Fork River at Gemback Road	0.020	0.017	0.018	0.020	0.021	0.012
CFR-27H	Clark Fork River at Deer Lodge	0.023	0.018	0.023	0.021	0.020	0.014
CFR-116A	Clark Fork River at Turah	0.012	0.006	0.006	0.007	0.008	0.007
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.016	0.018	0.023	0.027	0.029	0.011
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.022	0.027	0.021	0.026	0.020	0.019
MWB-SBC	Mill-Willow Bypass near mouth	0.020	0.027	0.021	0.028	0.021	0.016
WSC-SBC	Warm Springs Creek near mouth	0.008	0.007	0.006	0.007	0.008	0.006
LBR-CFR	Little Blackfoot River near Garrison	0.005	0.005	0.006	0.006	0.005	0.004
FC-CFR	Flint Creek near mouth	0.013	0.009	0.012	0.012	0.008	0.007

(Shaded) Exceeds specified arsenic surface water performance goal for total recoverable concentration (0.018 mg/L) [USEPA, 2004].

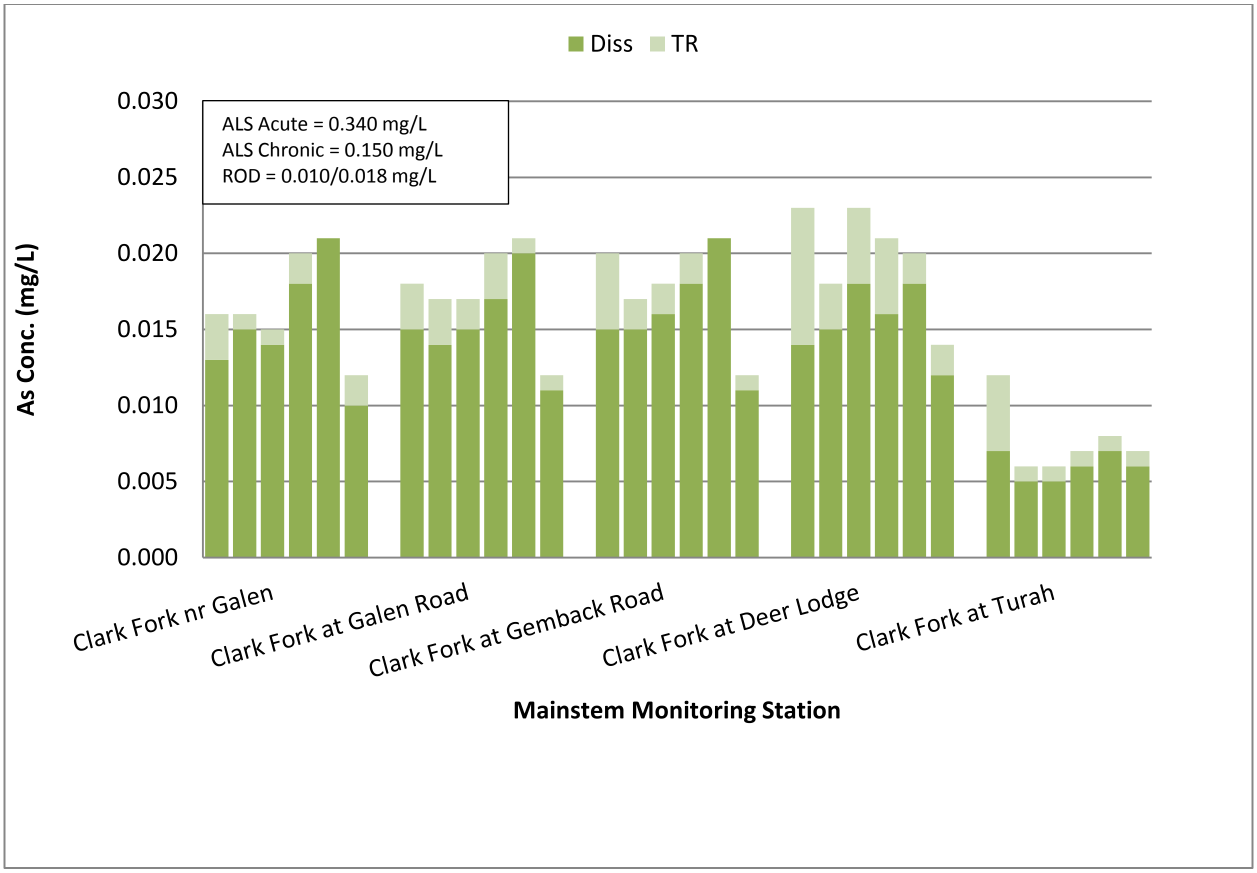

Figure 2-33. Total recoverable and dissolved arsenic (As) concentrations at mainstem sampling sites in the Clark Fork River Operable Unit (CFROU), 2014. Applicable water quality standards are the acute and chronic aquatic life standards (ALS) [MDEQ, 2012b] and the arsenic performance goals from the CFROU Record of Decision (ROD) [USEPA, 2004]. The ROD performance goals are 0.010 mg/L for dissolved and 0.018 mg/L for total recoverable arsenic [USEPA, 2004].

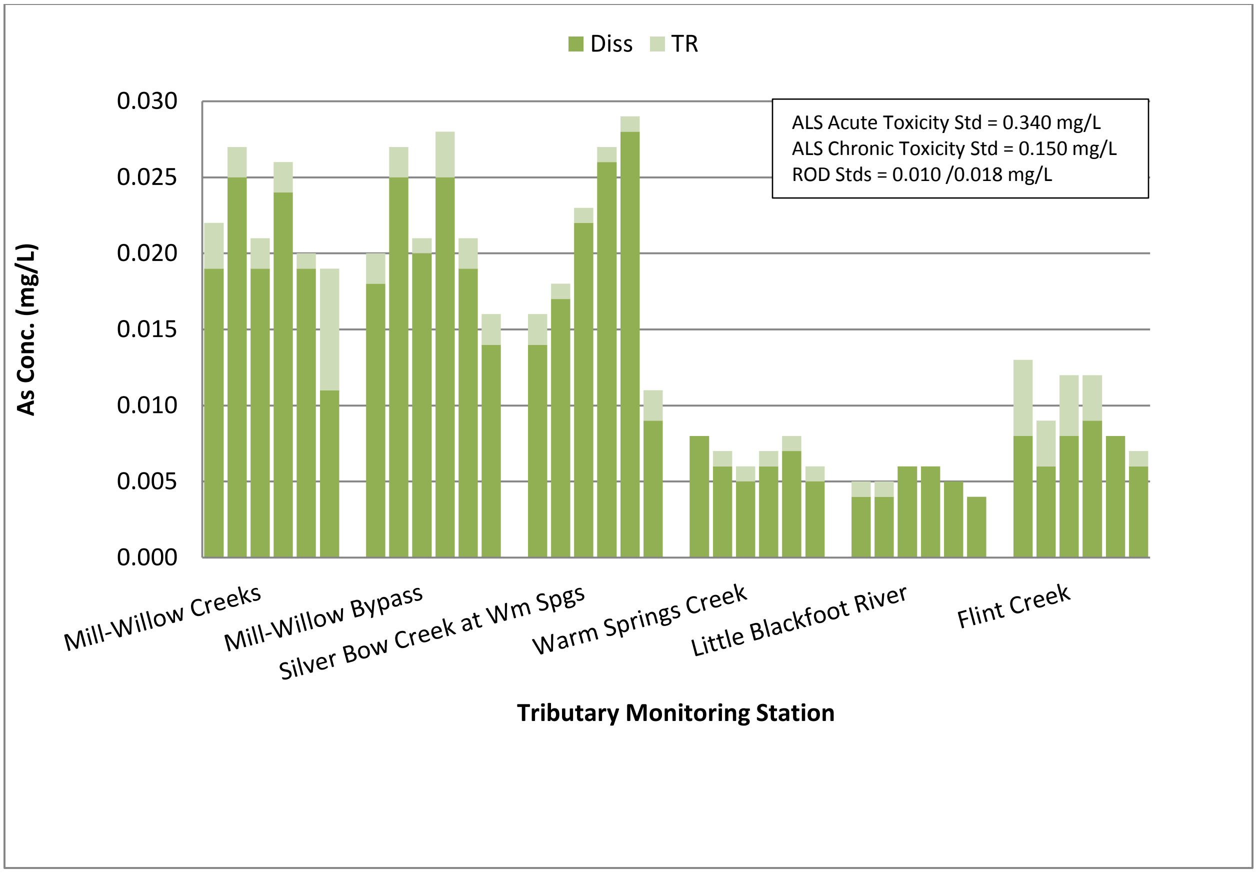

Figure 2-34. Total recoverable (TR) and dissolved (Diss) arsenic concentrations at Clark Fork River tributary sites, 2014. Applicable water quality standards are the acute and chronic aquatic life standards (ALS) [MDEQ, 2012b] and the arsenic performance goals from the CFROU Record of Decision (ROD) [USEPA, 2004]. The ROD performance goals are 0.010 mg/L for dissolved and 0.018 mg/L for total recoverable arsenic [USEPA, 2004].

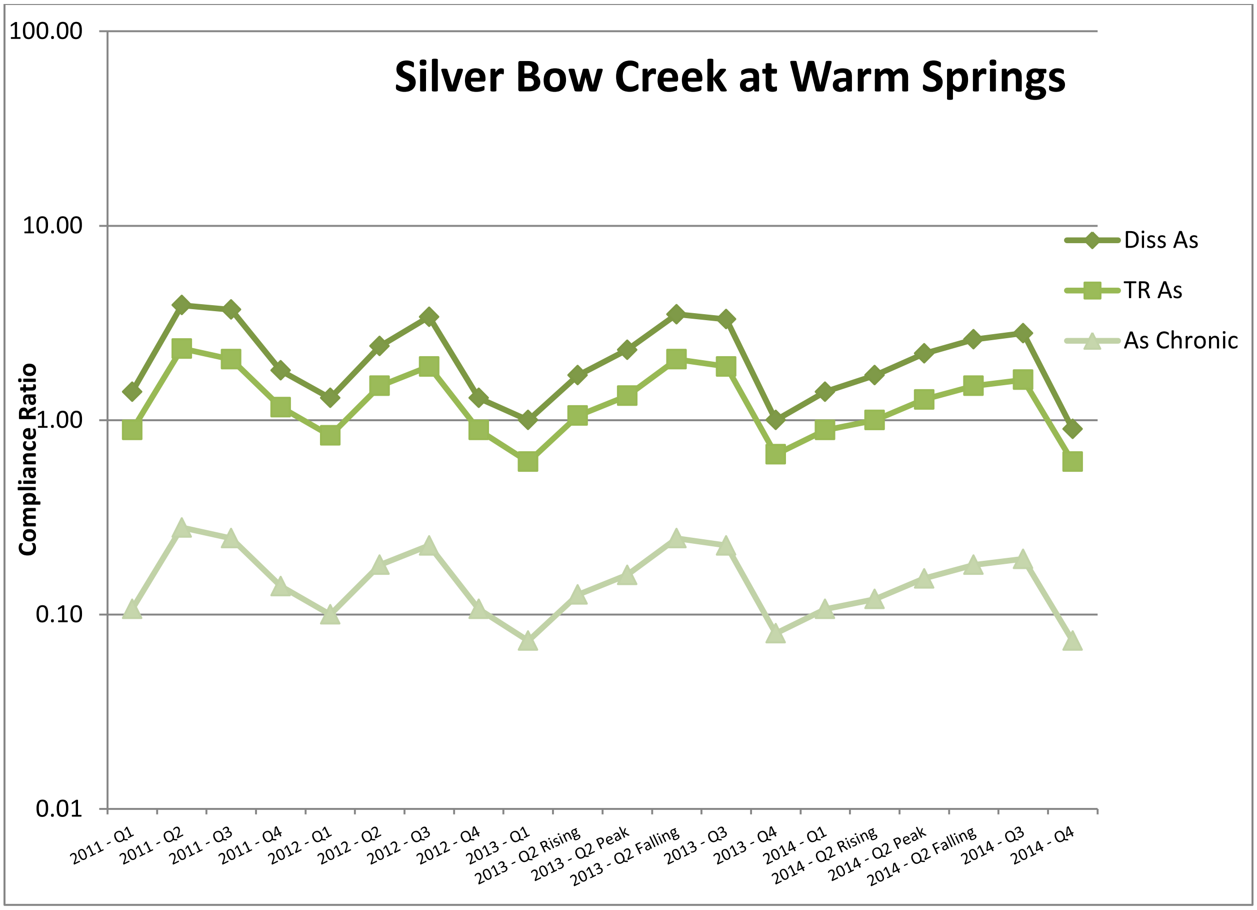

Figure 2-35. Total recoverable arsenic (As) compliance ratios for the Silver Bow Creek at Warm Springs site, 2011-2014. Compliance ratios are based on the chronic aquatic life standard (As Chronic) [MDEQ, 2012b] and the Clark Fork River Operable Unit Record of Decision performance goals for dissolved (Diss As) and total recoverable (TR As) arsenic concentrations [USEPA, 2004].

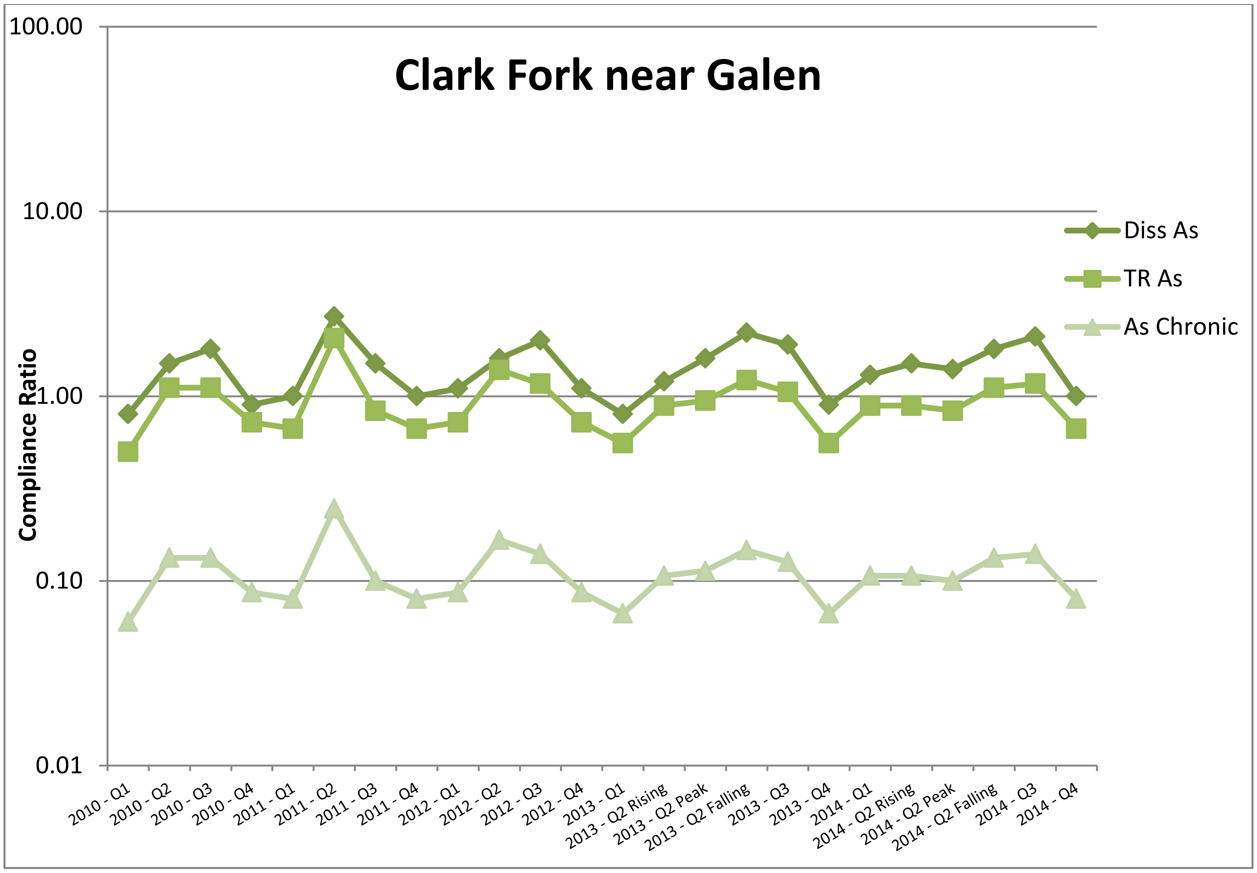

Figure 2-36. Total recoverable arsenic (As) compliance ratios for the Clark Fork River near Galen site, 2010-2014. Compliance ratios are based on the chronic aquatic life standard (As Chronic) [MDEQ, 2012b] and the Clark Fork River Operable Unit Record of Decision performance goals for the dissolved (Diss As) and total recoverable (TR As) arsenic concentrations [USEPA, 2004].

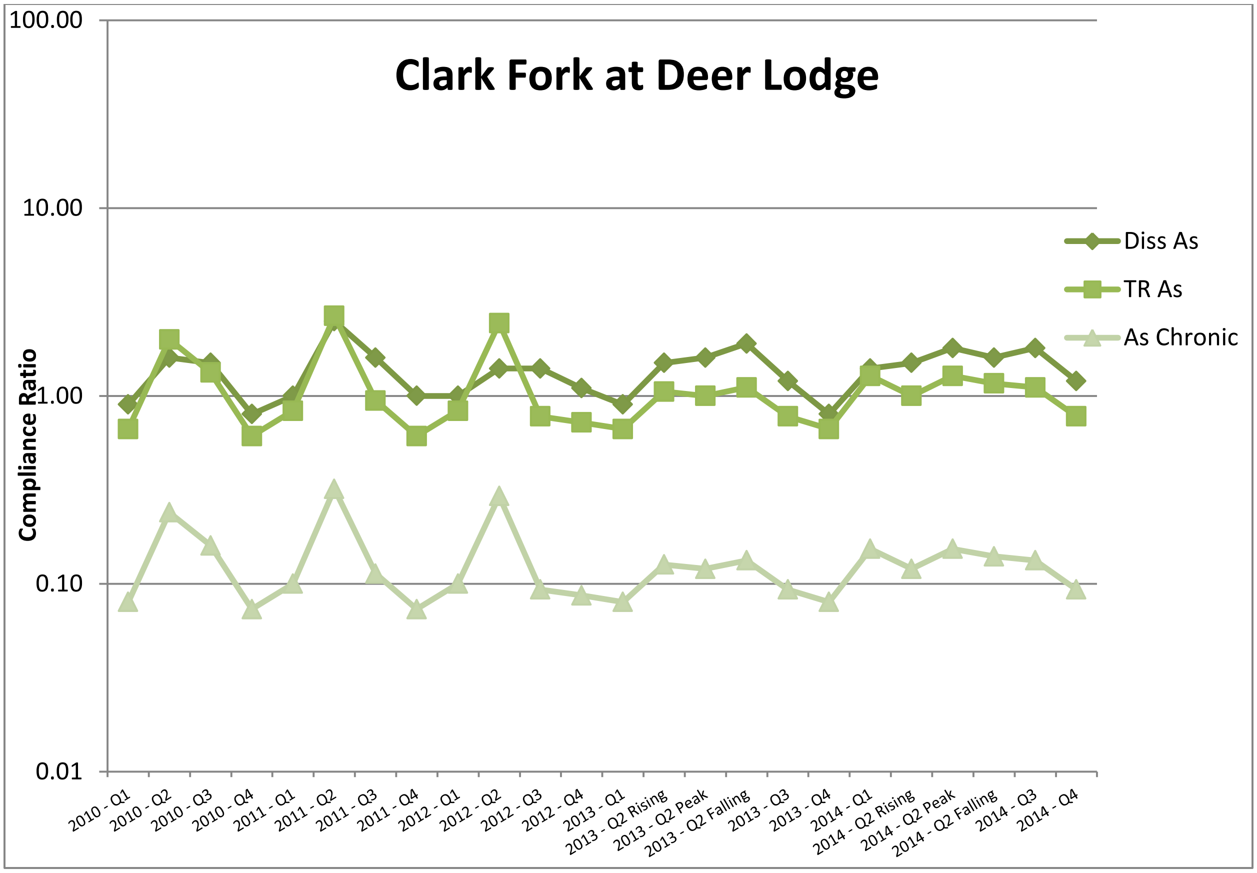

Figure 2-37. Total recoverable arsenic (As) compliance ratios for the Clark Fork River at Deer Lodge site, 2010-2014. Compliance ratios are based on the chronic aquatic life standard (As Chronic) [MDEQ, 2012b] and the Clark Fork River Operable Unit Record of Decision performance goals for the dissolved (Diss As) and total recoverable (TR As) arsenic concentrations [USEPA, 2004].

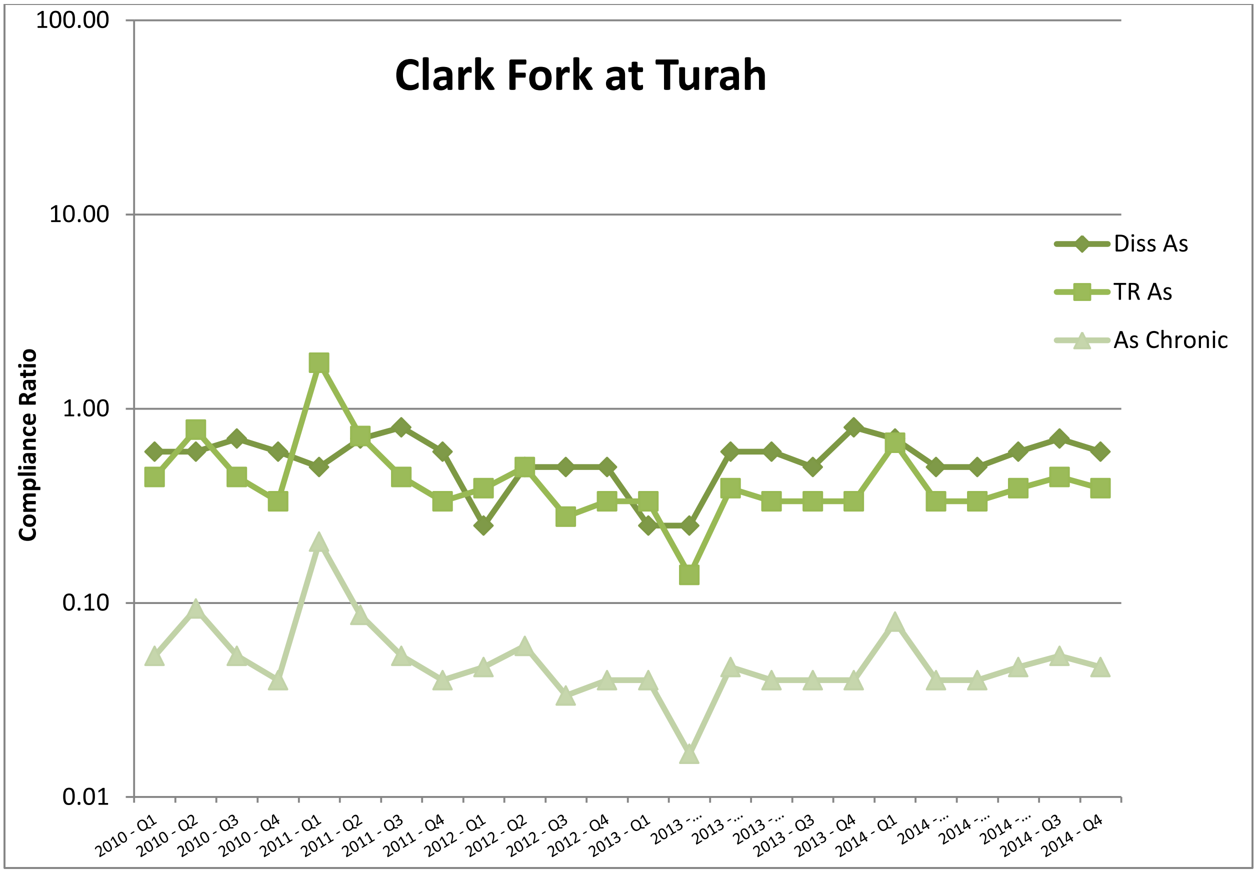

Figure 2-38. Total recoverable arsenic (As) compliance ratios for the Clark Fork River at Turah site, 2010-2014. Compliance ratios are based on the chronic aquatic life standard (As Chronic) [MDEQ, 2012b] and the Clark Fork River Operable Unit Record of Decision performance goals for the dissolved (Diss As) and total recoverable (TR As) arsenic concentrations [USEPA, 2004].

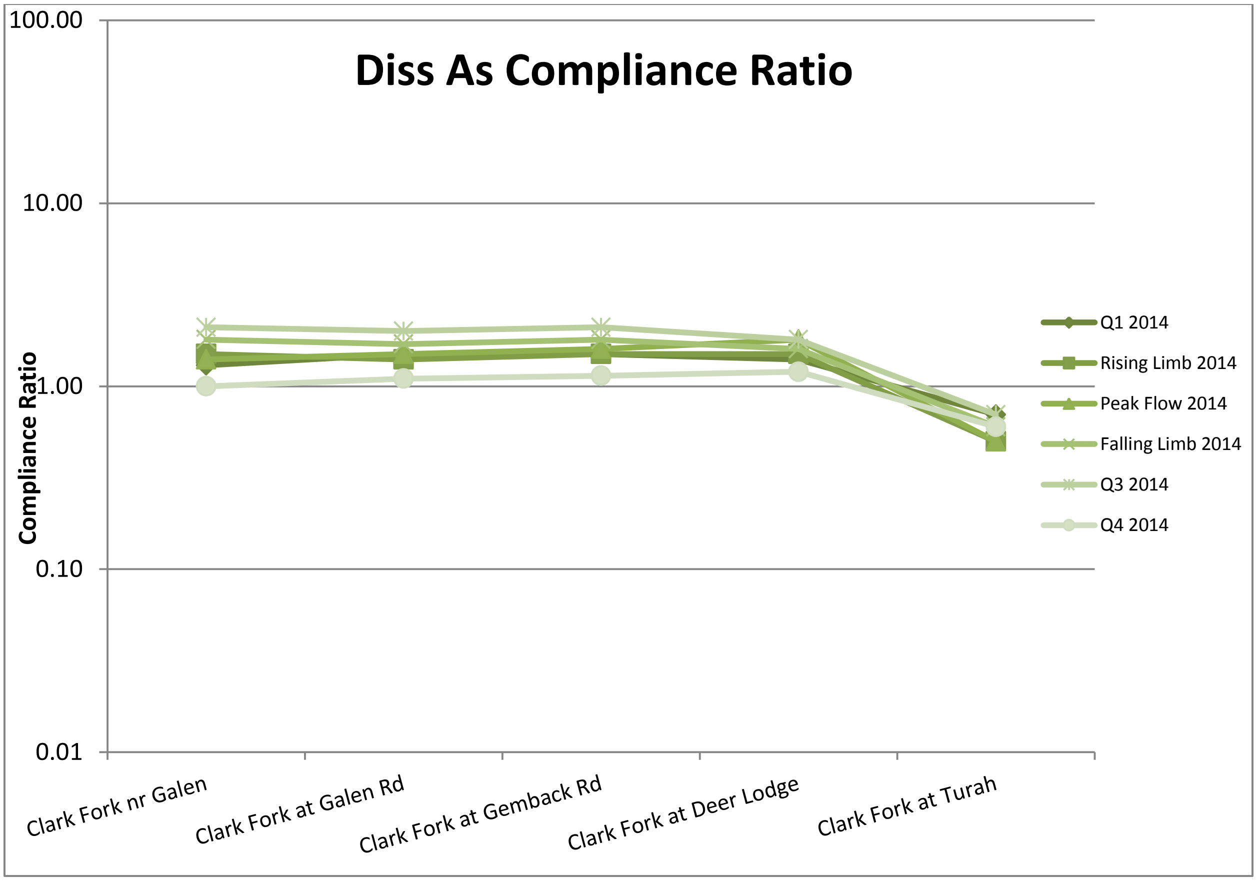

Figure 2-39. Dissolved arsenic compliance ratios for the Clark Fork River mainstem sites, 2014. Compliance ratio is based on Clark Fork River Operable Unit Record of Decision performance goal for dissolved arsenic (Diss As) concentration [USEPA, 2004].

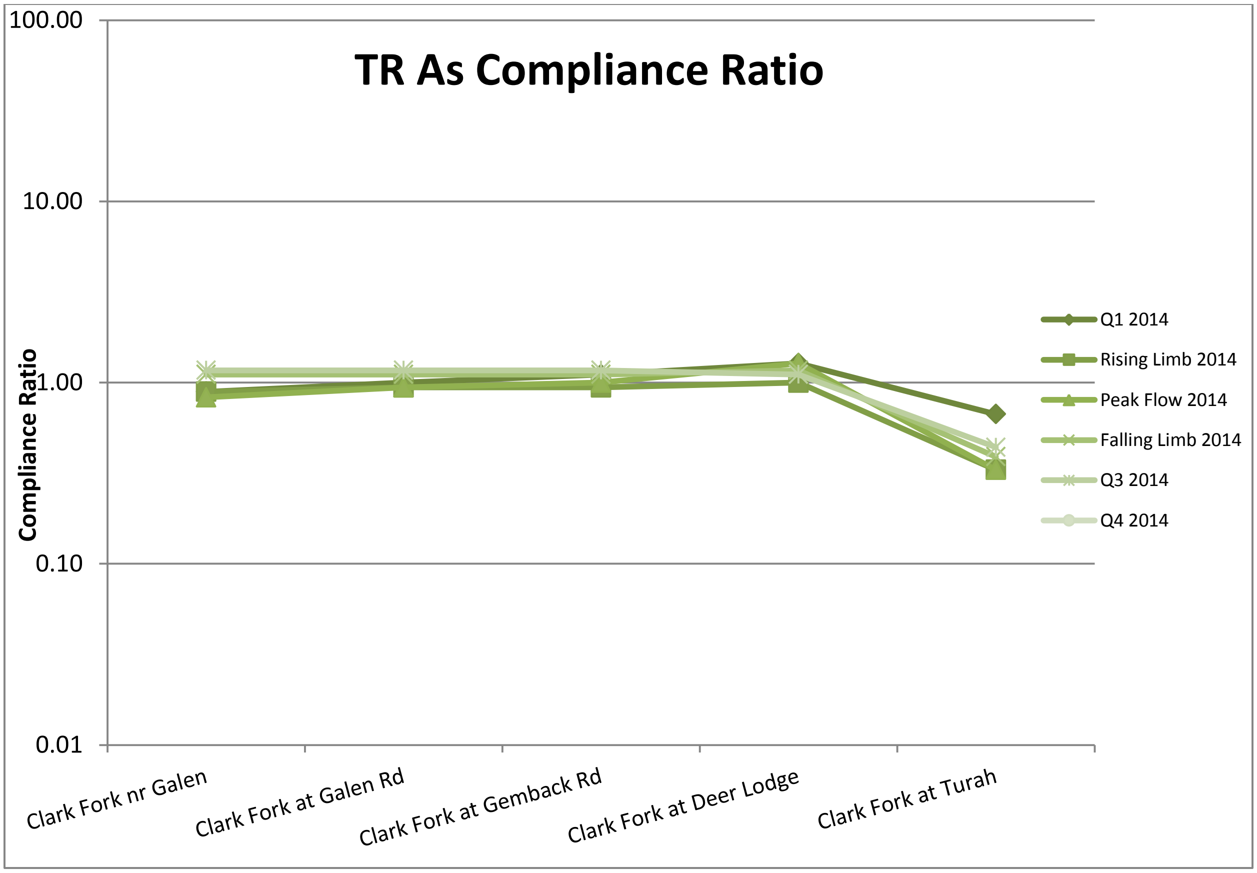

Figure 2-40. Total recoverable arsenic compliance ratios for the Clark Fork River mainstem sites, 2014. Compliance ratio is based on Clark Fork River Operable Unit Record of Decision performance goal for total recoverable arsenic (TR As) concentration [USEPA, 2004].

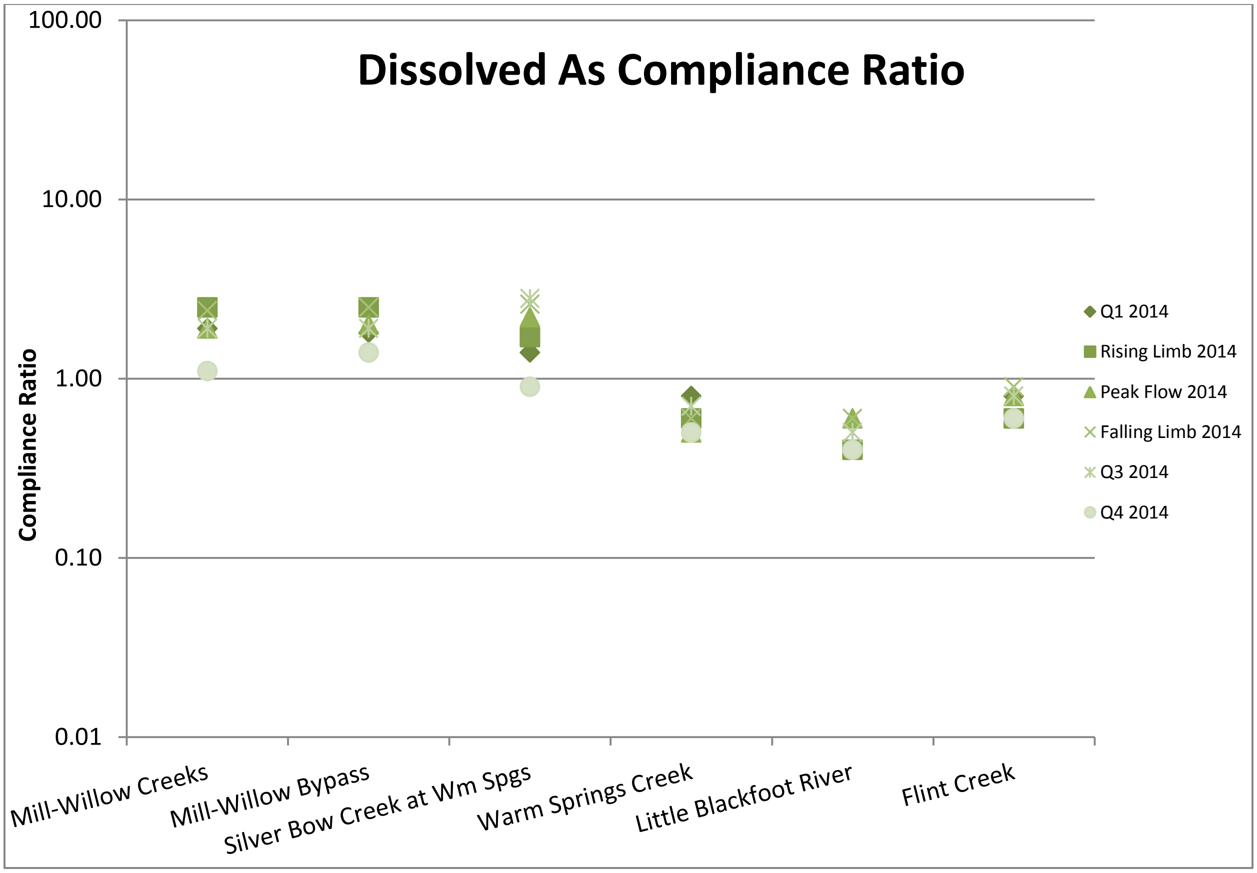

Figure 2-41. Dissolved arsenic compliance ratios for the Clark Fork River tributary sites, 2014. Compliance ratio is based on Clark Fork River Operable Unit Record of Decision performance goal for dissolved arsenic (Diss As) concentration [USEPA, 2004].

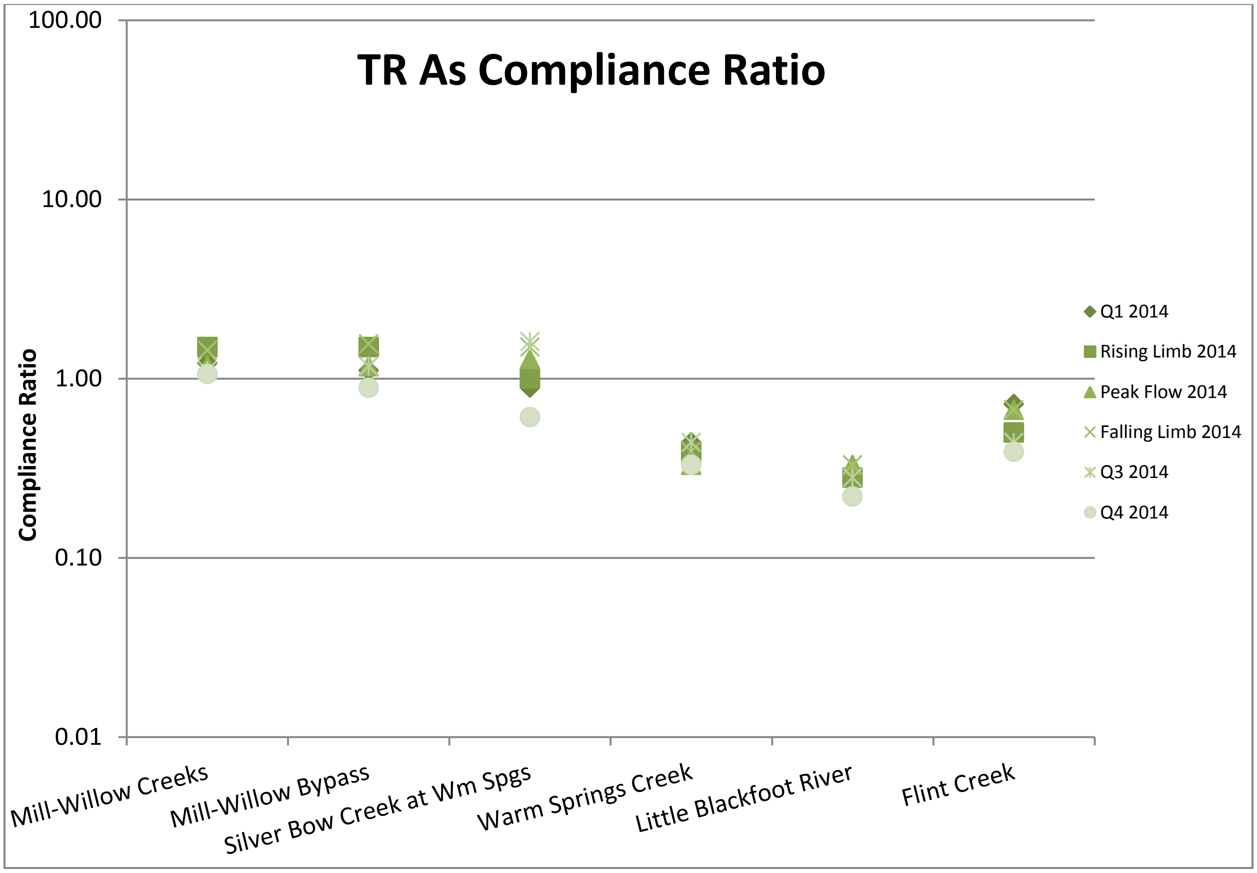

Figure 2-42. Total recoverable arsenic compliance ratios for the Clark Fork River tributary sites, 2014. Compliance ratio is based on Clark Fork River Operable Unit Record of Decision performance goal for total recoverable arsenic (TR As) concentration [USEPA, 2004].

2.3.6.2 Cadmium

Concentrations of total recoverable cadmium during 2014 were generally comparable and low at mainstem Clark Fork River monitoring stations extending from near Galen to Gemback Road and at Turah, with slightly higher concentrations at Deer Lodge [Table 2-11; Figure 2-43]. Cadmium concentrations were generally somewhat lower at all six of the tributary monitoring stations [Table 2-11; Figure 2-44]. Concentrations of dissolved cadmium were usually close to the minimum analytical reporting limit during 2014 monitoring events and most measureable cadmium was present in a sediment-associated state (i.e., total recoverable).

The highest concentrations of total recoverable cadmium were almost always measured during the Q1 monitoring event. The maximum concentrations in 2014 were recorded at the Clark Fork River at Deer Lodge site in Q1 (0.00038 mg/L), and in Mill-Willow Creek at Frontage Road in Q4 (0.00034 mg/L). Unexplained high turbidity conditions were encountered in Mill-Willow Creek during the Q4 2014 monitoring event and several COC metals as well as total suspended sediment were elevated. The lowest concentrations of total recoverable cadmium were observed during the Q3 monitoring event at all sites except Warm Springs Creek, which had the lowest seasonal concentration in Q4 [Table 2-11].

The minimum analytical reporting level for cadmium was lowered in 2014 from 0.00008 mg/L to 0.00003 mg/L. This improved detection capability makes direct comparison of the 2014 cadmium concentrations to earlier monitoring years difficult. This is especially true because many of the 2010-2013 measurements were below the current reporting level. Total recoverable cadmium concentrations in 2014 only rarely exceeded the chronic ALS, and never exceeded the acute ALS or the HHSWS at any of the CFROU monitoring stations [Table 2-11]. The Q4 2014 cadmium measurement at the Mill-Willow Creek at Frontage Road site represented the only exceedance of the chronic ALS. No exceedances of the established ALS or HHSWS performance goals were observed in 60 site measurements in 2013. In contrast, a higher frequency of exceedances was observed in each of the prior three years: 2010 (5 of 24 exceedances), 2011 (6 of 28 exceedances), and 2012 (4 of 60 exceedances).

The cadmium chronic ALS compliance ratios for the three selected Clark Fork River stations, but not for the Silver Bow Creek site, appear to have declined to some degree since 2010 [Figure 2-45 through Figure 2-48]. Chronic ALS compliance ratios have not exceeded 1.0 at any of the selected stations since Q1 2012. The acute ALS compliance ratios for total recoverable cadmium were also below 1.0 at all mainstem and tributary monitoring sites examined. The highest chronic ALS compliance ratios for total recoverable cadmium were observed during the Q1 monitoring event. The Clark Fork River at Deer Lodge most frequently showed the highest cadmium ALS compliance ratios during 2014, and the Clark Fork River sites from near Galen to Gemback Road showed the lowest ratios [Figure 2-49]. Among the tributaries, Mill-Willow Creek at Frontage Road showed the highest cadmium compliance ratios and the Little Blackfoot River showed the lowest ratios [Figure 2-50].

Table 2-11. Total recoverable cadmium concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.00018	0.00011	0.00008	0.00008	0.00004	0.00009
CFR-07D	Clark Fork River at Galen Road	0.00019	0.00012	0.00011	0.00012	0.00005	0.00007
CFR-11F	Clark Fork River at Gemback Road	0.00020	0.00015	0.00013	0.00012	0.00005	0.00007
CFR-27H	Clark Fork River at Deer Lodge	0.00038	0.00018	0.00021	0.00019	0.00009	0.00013
CFR-116A	Clark Fork River at Turah	0.00024	0.00012	0.00009	0.00006	0.00006	0.00006
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.00019	0.00009	0.00008	0.00010	ND	0.00013
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.00013	0.00009	0.00010	0.00011	0.00004	0.00034
MWB-SBC	Mill-Willow Bypass near mouth	0.00009	0.00007	0.00008	0.00016	0.00004	0.00005
WSC-SBC	Warm Springs Creek near mouth	0.00008	0.00007	0.00007	0.00010	0.00004	ND
LBR-CFR	Little Blackfoot River near Garrison	ND	0.00004	ND	ND	ND	ND
FC-CFR	Flint Creek near mouth	0.00008	0.00006	0.00006	0.00006	ND	ND

(shaded) Exceeds chronic aquatic life standard [MDEQ, 2012b].

ND Not detected at analytical reporting limit.

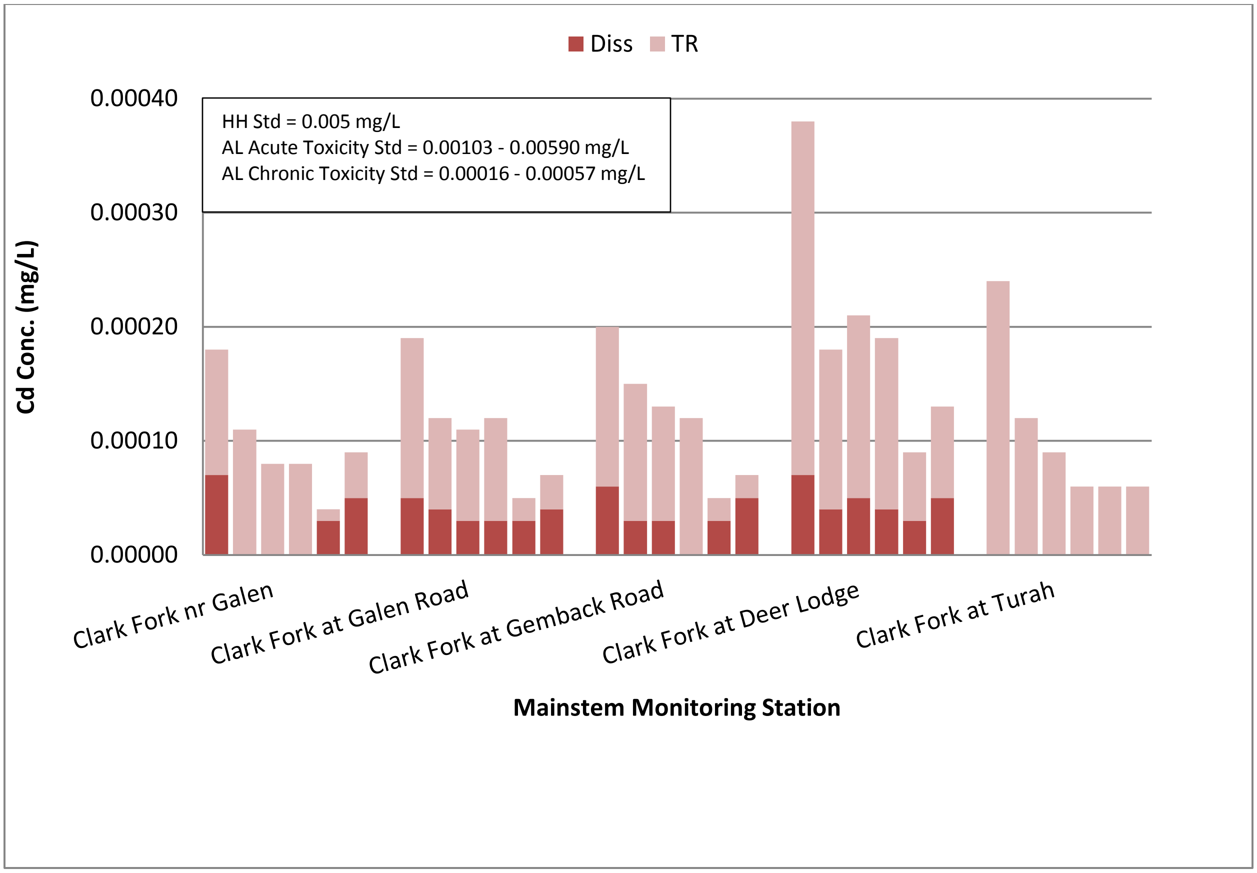

Figure 2-43. Total recoverable (TR) and dissolved (Diss) cadmium concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2014. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

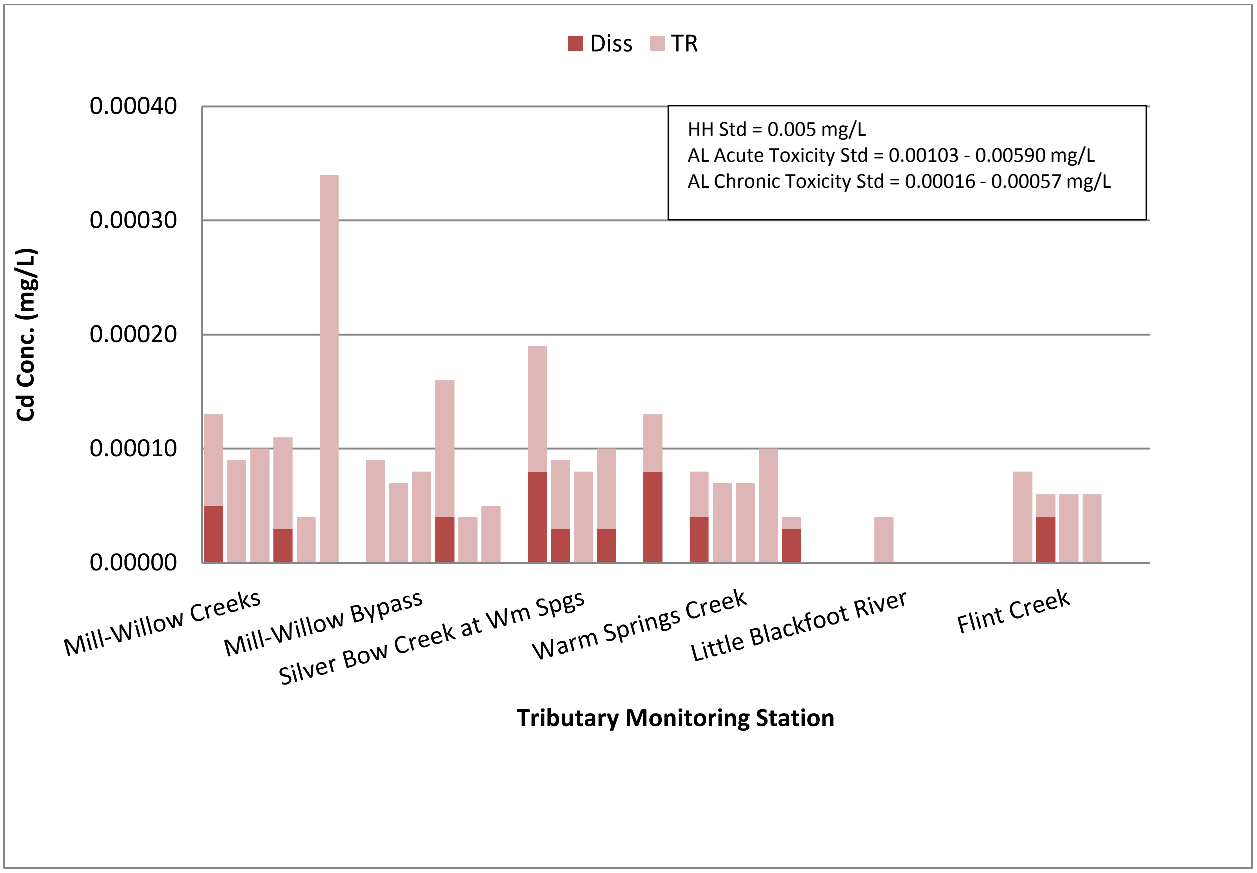

Figure 2-44. Total recoverable (TR) and dissolved (Diss) cadmium concentrations at Clark Fork River tributary sampling sites, 2014. No bars indicate concentrations below the analytical reporting limit. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

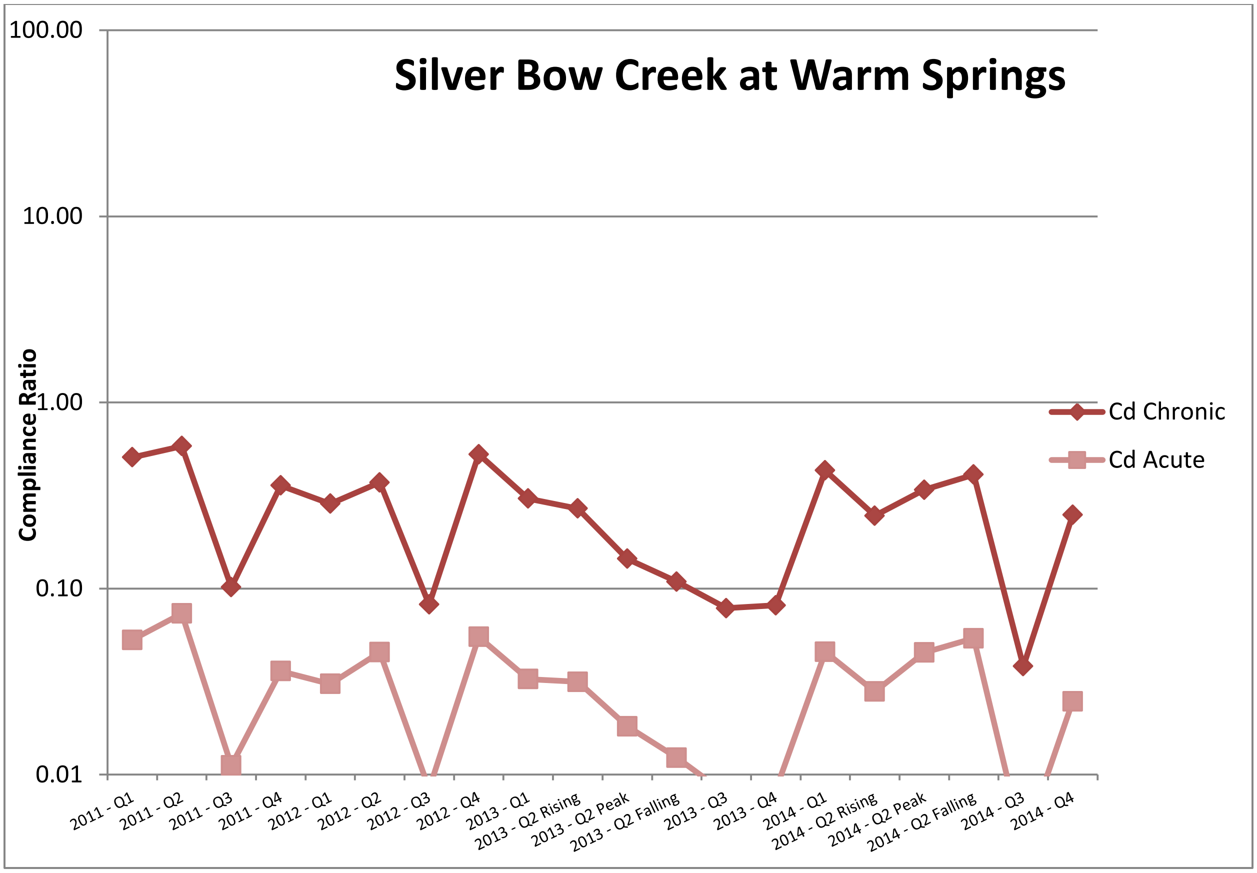

Figure 2-45. Total recoverable cadmium (Cd) compliance ratios for Silver Bow Creek at Warm Springs site, 2011-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

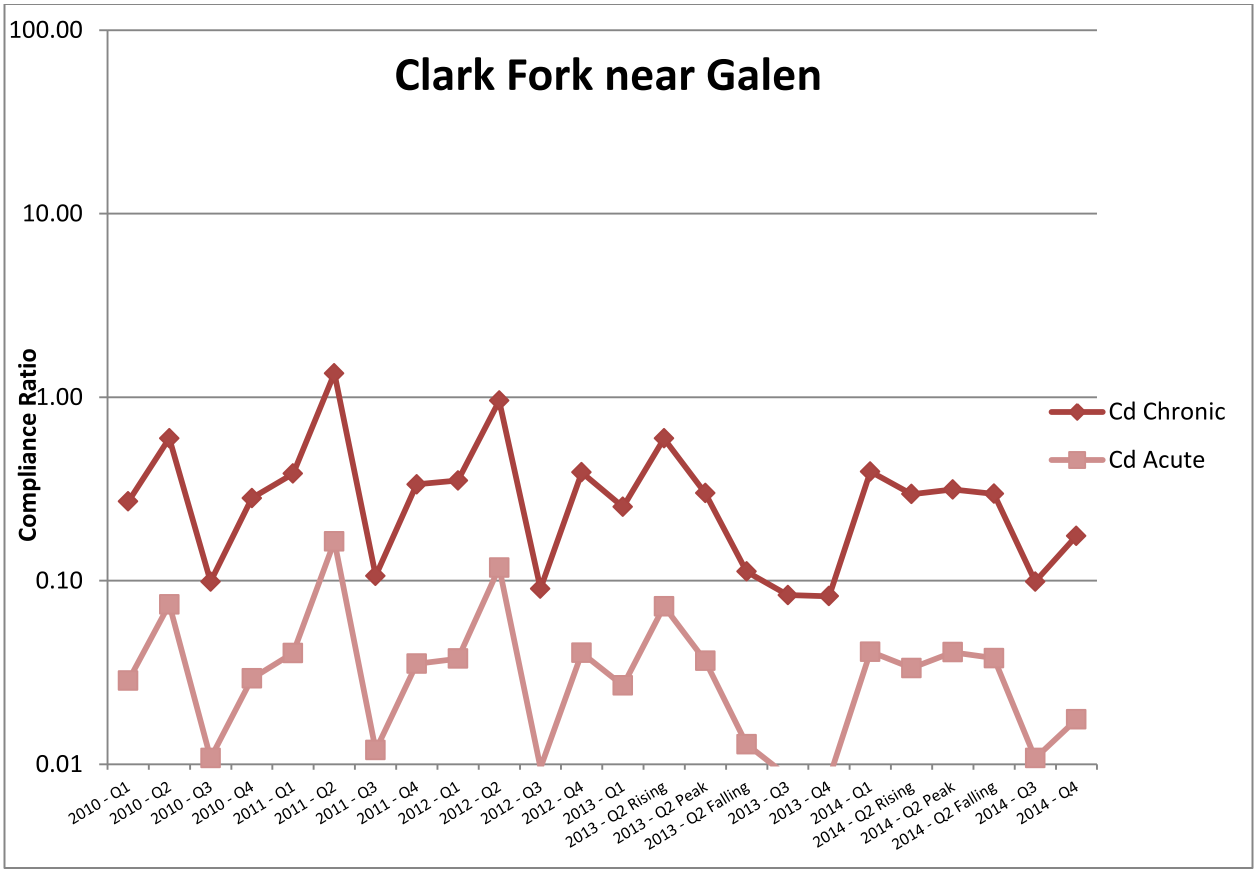

Figure 2-46. Total recoverable cadmium (Cd) compliance ratios for Clark Fork River near Galen site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

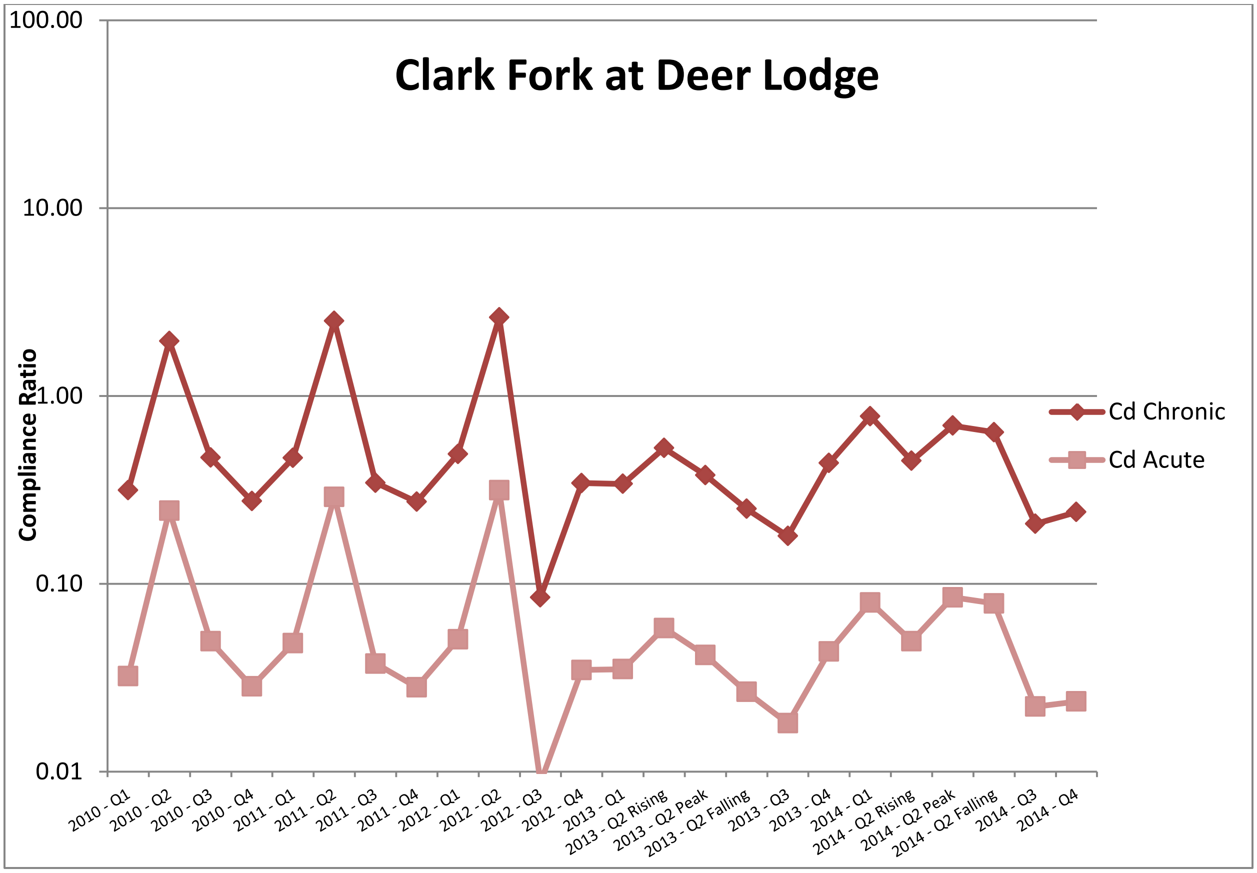

Figure 2-47. Total recoverable cadmium (Cd) compliance ratios for Clark Fork River at Deer Lodge site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

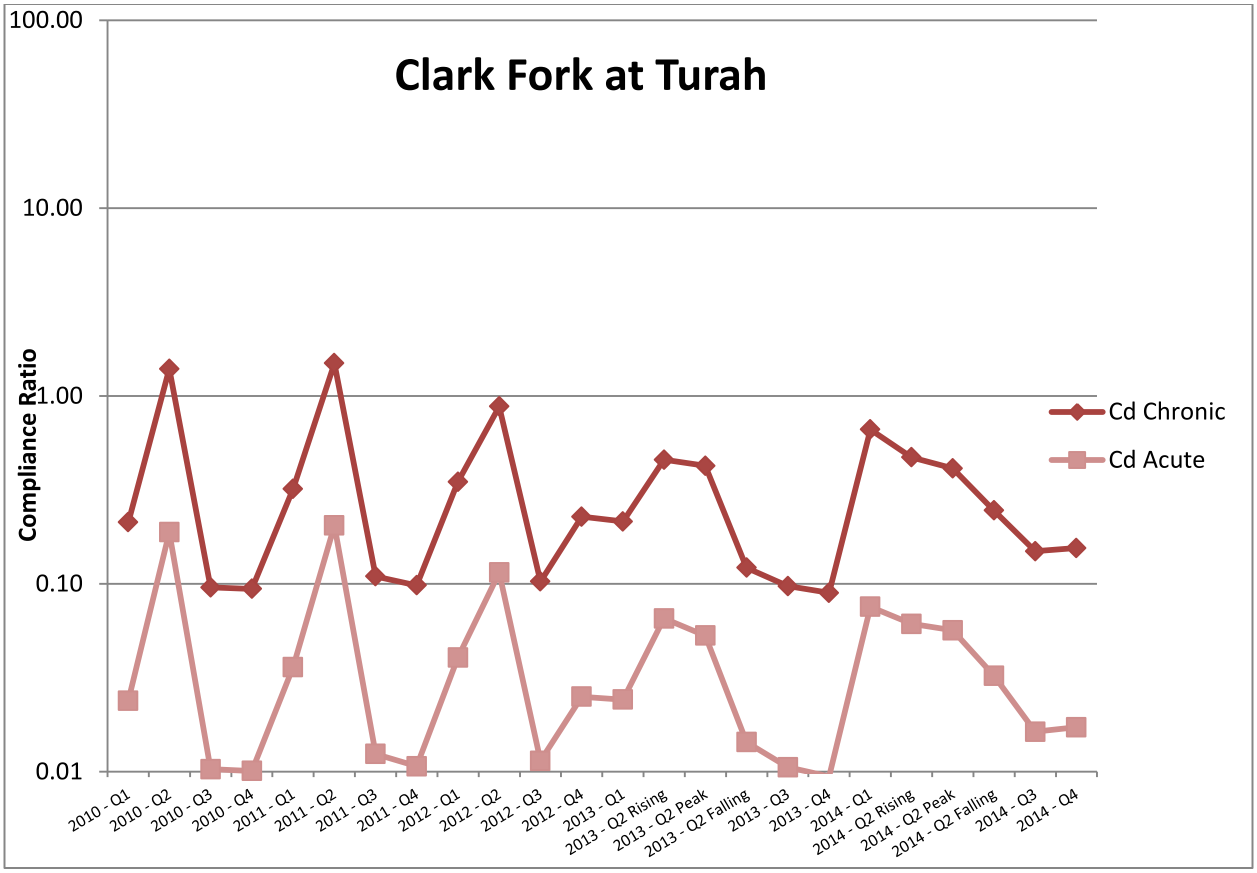

Figure 2-48. Total recoverable cadmium (Cd) compliance ratios for Clark Fork River at Turah site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

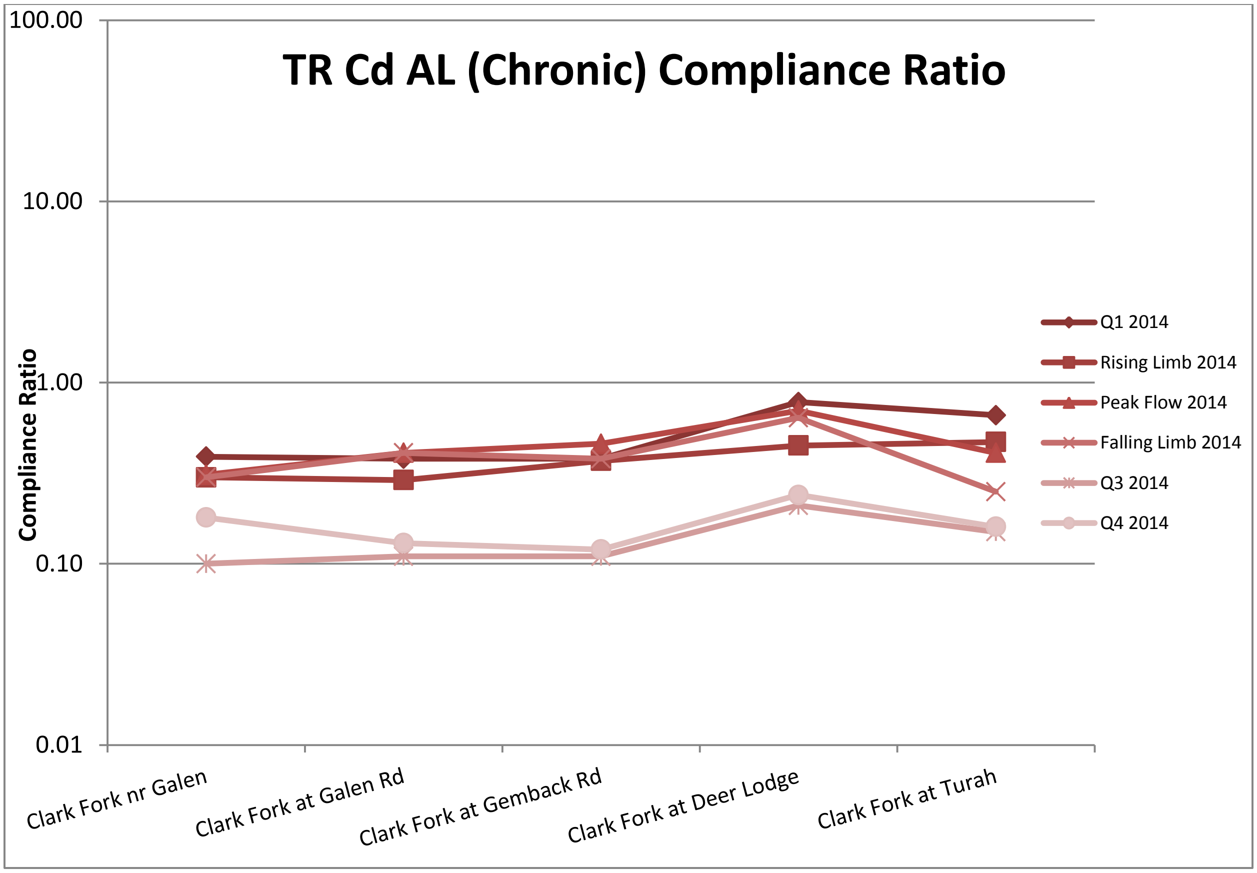

Figure 2-49. Total recoverable (TR) cadmium (Cd) compliance ratio in the Clark Fork River (CFR) mainstem sites, 2014. Compliance ratio is based on the chronic aquatic life standard (ALS) [MDEQ, 2012b].

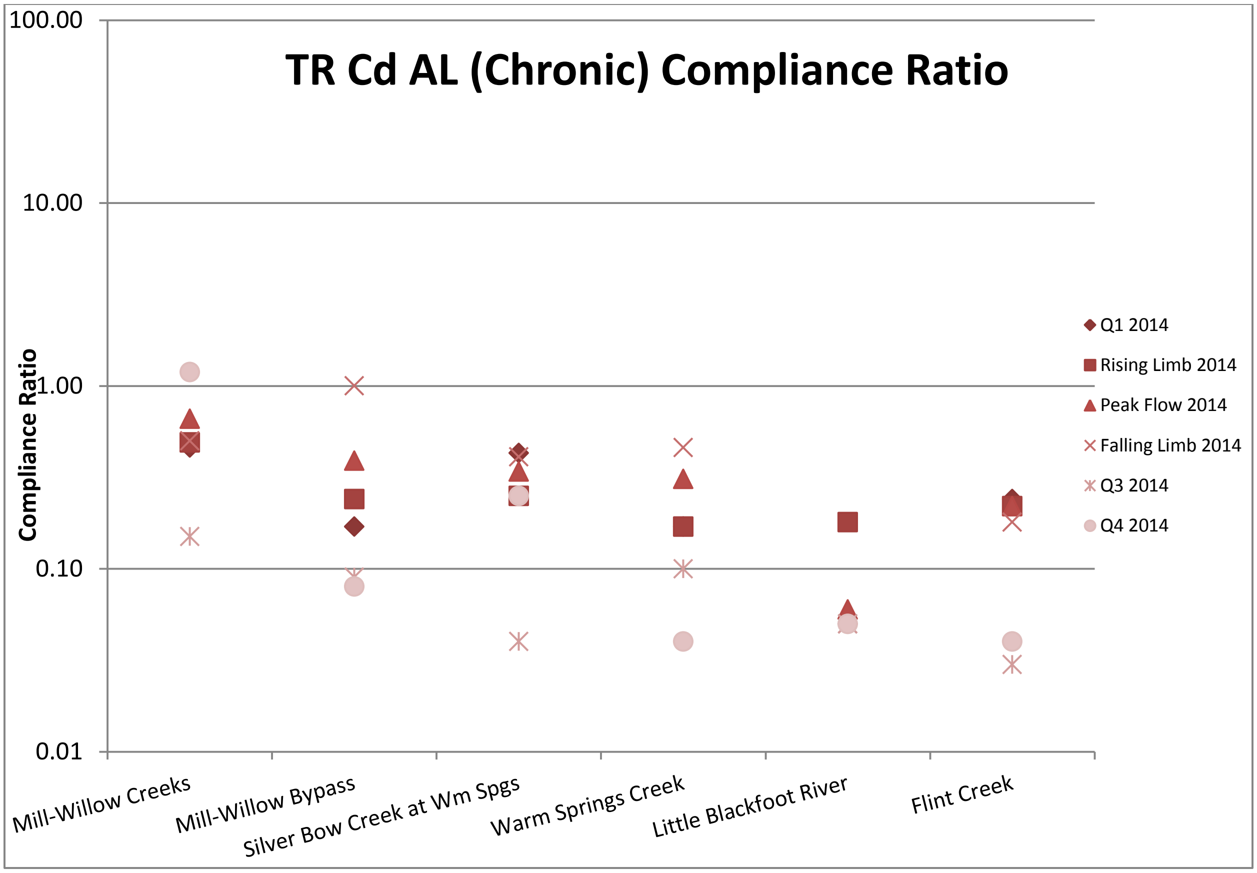

Figure 2-50. Total recoverable (TR) cadmium (Cd) compliance ratio in Clark Fork River (CFR) tributary sites, 2014. Compliance ratio is based on the chronic aquatic life standard (ALS) [MDEQ, 2012b].

2.3.6.3 Copper

Concentrations of total recoverable and dissolved copper during 2014 were elevated in Q1 and Q2 at all mainstem Clark Fork River sites and at several of the tributary monitoring sites. The highest concentrations of total recoverable copper were observed at the Clark Fork River at Deer Lodge station [Table 2-12]. Total recoverable copper concentrations increased from the near Galen site to Deer Lodge, and then declined downstream to the Turah site [Figure 2-51]. The lowest mainstem copper concentrations were observed at the near Galen site. Within the tributary sites, lowest concentrations were measured in the Little Blackfoot River, followed by Flint Creek [Table 2-12]. The other tributaries had higher copper concentrations; most notably Mill-Willow Creek at Frontage Road in Q4 in association with high turbidity (see Section 2.3.2.5) [Figure 2-52]. The highest copper concentrations at all of the CFROU mainstem monitoring sites were observed during the Q1 monitoring event, while lowest concentrations were observed in Q3. The tributary monitoring sites did not exhibit any consistent pattern of seasonality in 2014.

Dissolved copper concentrations were relatively consistent during each 2014 monitoring event compared to total recoverable copper concentrations.

Total recoverable copper concentrations frequently exceeded the chronic ALS (30 of 66 samples) during 2014 [Table 2-12]. The acute ALS was exceeded in 18 of 66 samples. Each of the five mainstem Clark Fork River monitoring stations had at least three exceedances of the chronic ALS during six monitoring events. Samples from the Clark Fork River at Deer Lodge site exceeded the chronic ALS during all six monitoring events, and exceeded the acute ALS during four of the six events. Samples from Warm Springs Creek near mouth showed two exceedances of the total recoverable copper acute ALS, and Silver Bow Creek at Warm Springs had two exceedances of the total recoverable copper chronic ALS. Mill-Willow Bypass had one exceedance of the chronic ALS. Only the samples from the Little Blackfoot River and Flint Creek were consistently below the chronic ALS for total recoverable copper. The overall frequency of exceedances of the copper ALS at CFROU monitoring stations in 2014 (30 of 66 samples) was somewhat higher than in 2012 (17 of 60 samples) and 2013 (19 of 60 samples), but lower than in 2011 (16 of 28 samples) and 2010 (15 of 24 samples).

Of the Clark Fork River mainstem stations that have been monitored each year since 2010 (near Galen, at Deer Lodge, and at Turah), the frequency of exceedances of the chronic and acute ALS for copper was similar in 2014 to each of the previous years. All of the ALS excursions in 2014 occurred during the Q1 and Q2 monitoring events during periods of elevated streamflows. Silver Bow Creek at Warm Springs, which has been monitored since 2011, showed similar total recoverable copper compliance ratios in each of years 2011-2014.

The magnitude of the chronic and acute ALS compliance ratios for total recoverable copper at the three Clark Fork River mainstem stations that have been monitored each year since 2010 (near Galen, at Deer Lodge, and at Turah) appear to have declined over the five year period [Figure 2-53 through Figure 2-56] Despite the apparent improvements, ALS compliance ratios for copper commonly continue to exceed 1.0 at the Deer Lodge station. The seasonal and spatial trends in ALS compliance ratios for total recoverable copper during 2014 were similar to the pattern noted for cadmium. The Clark Fork River at Deer Lodge had the highest copper ALS compliance ratios during 2014 [Figure 2-55]. The Clark Fork River near Galen had the lowest copper ALS compliance ratios of the mainstem monitoring sites during 2014 [Figure 2-57]. Among the tributary sites, Mill-Willow Creek at the Frontage Road, Warm Springs Creek near its mouth, and Silver Bow Creek at Warm Springs had the highest copper compliance ratios and the Little Blackfoot River had the lowest ratios [Figure 2-58]. The highest copper ALS compliance ratios at mainstem monitoring sites were observed during the Q1 or Q2-Peak monitoring event.

Table 2-12. Total recoverable copper concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.023	0.012	0.015	0.016	0.005	0.009
CFR-07D	Clark Fork River at Galen Road	0.028	0.020	0.024	0.027	0.007	0.008
CFR-11F	Clark Fork River at Gemback Road	0.036	0.022	0.027	0.026	0.008	0.009
CFR-27H	Clark Fork River at Deer Lodge	0.083	0.033	0.056	0.048	0.019	0.024
CFR-116A	Clark Fork River at Turah	0.038	0.017	0.013	0.012	0.007	0.009
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.022	0.009	0.007	0.009	0.004	0.008
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.008	0.008	0.007	0.008	0.004	0.034
MWB-SBC	Mill-Willow Bypass near mouth	0.006	0.007	0.006	0.011	0.003	0.003
WSC-SBC	Warm Springs Creek near mouth	0.008	0.008	0.012	0.017	0.006	0.008
LBR-CFR	Little Blackfoot River near Garrison	0.001	0.002	0.002	0.001	ND	ND
FC-CFR	Flint Creek near mouth	0.004	0.005	0.003	0.003	0.002	0.002

(yellow)	Exceeds chronic aquatic life standard [MDEQ, 2012b].
(orange)	Exceeds acute aquatic life standard [MDEQ, 2012b].
ND	Not detected at analytical reporting limit.

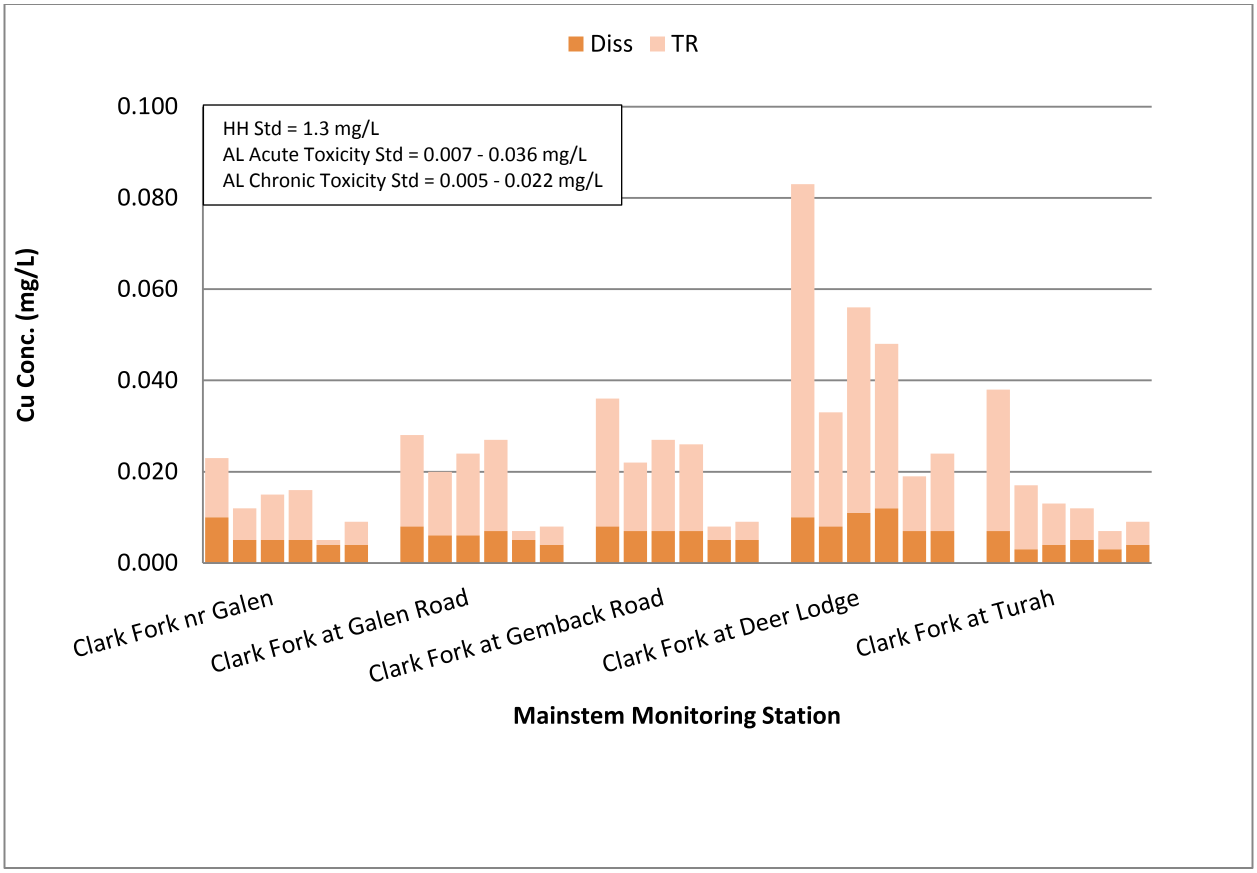

Figure 2-51. Total recoverable (TR) and dissolved (Diss) copper concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2014. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

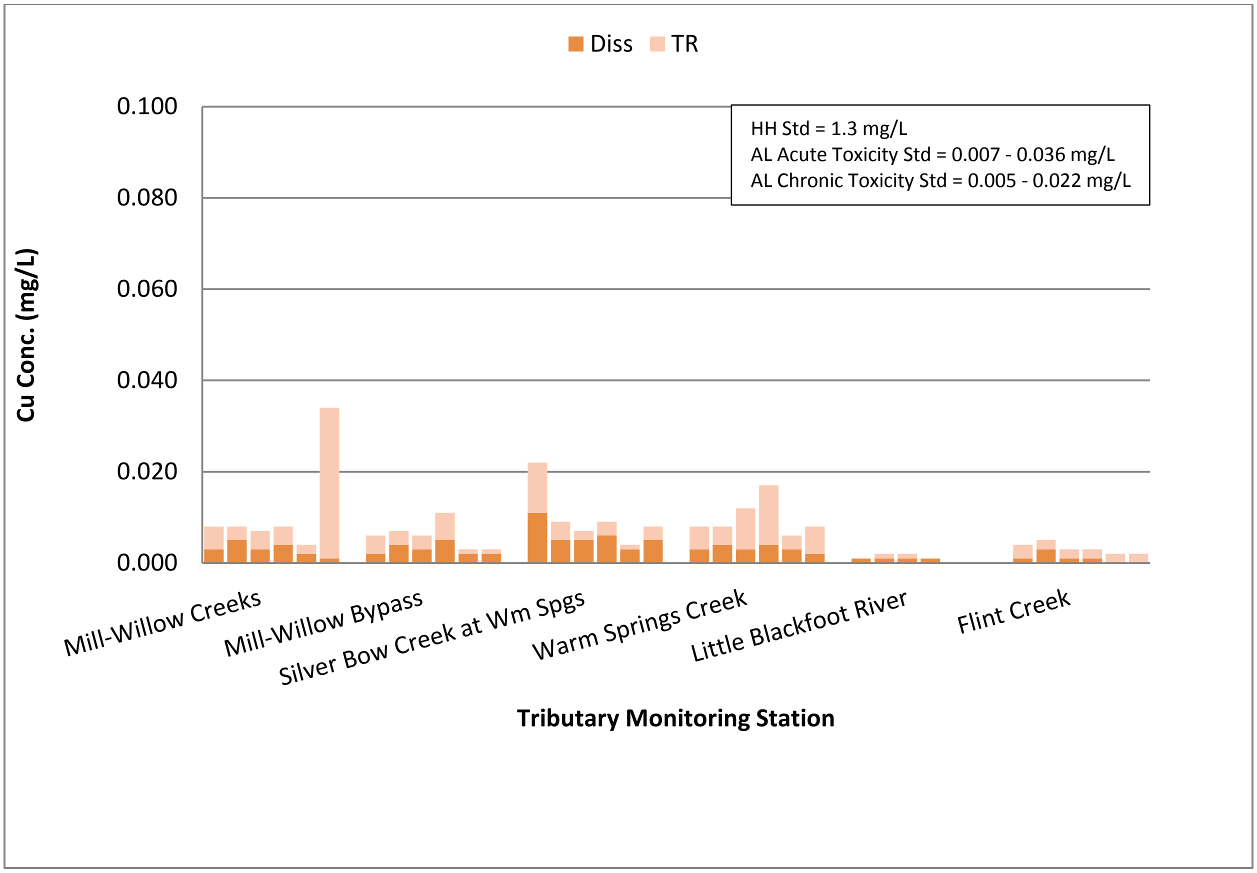

Figure 2-52. Total recoverable (TR) and dissolved (Diss) copper concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2014. No bars indicate concentrations below the analytical reporting limit. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

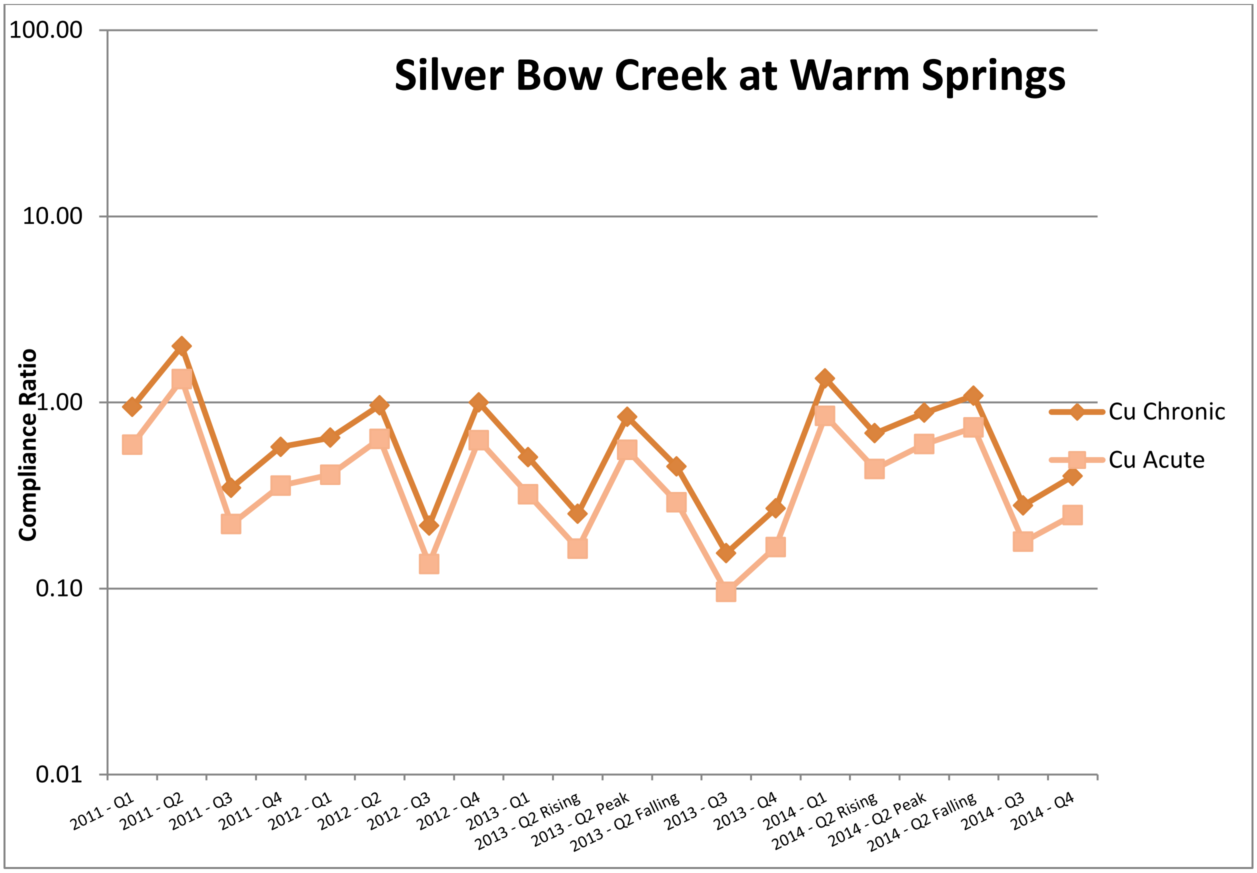

Figure 2-53. Total recoverable copper (Cu) compliance ratios for Silver Bow Creek at Warm Springs site, 2011-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

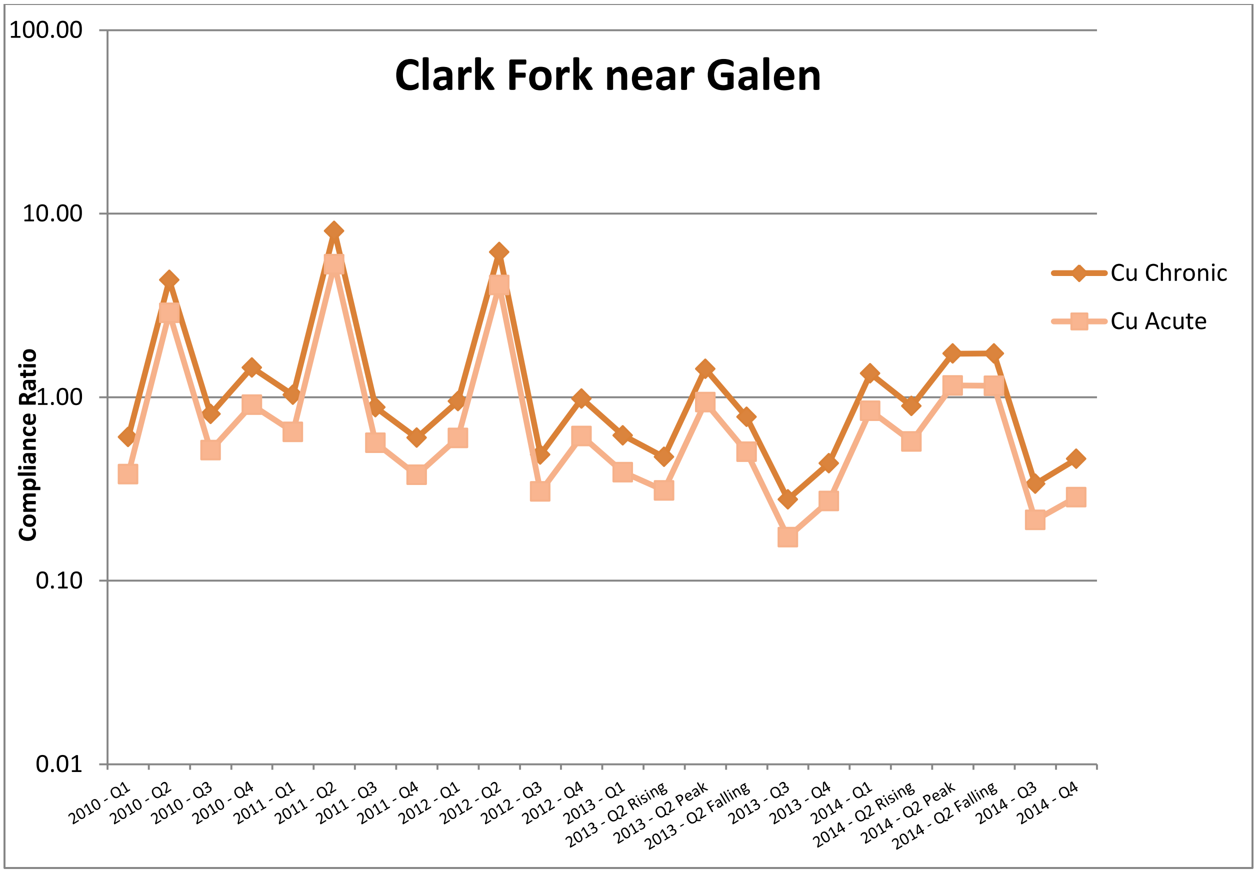

Figure 2-54. Total recoverable copper (Cu) compliance ratios for Clark Fork River near Galen site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

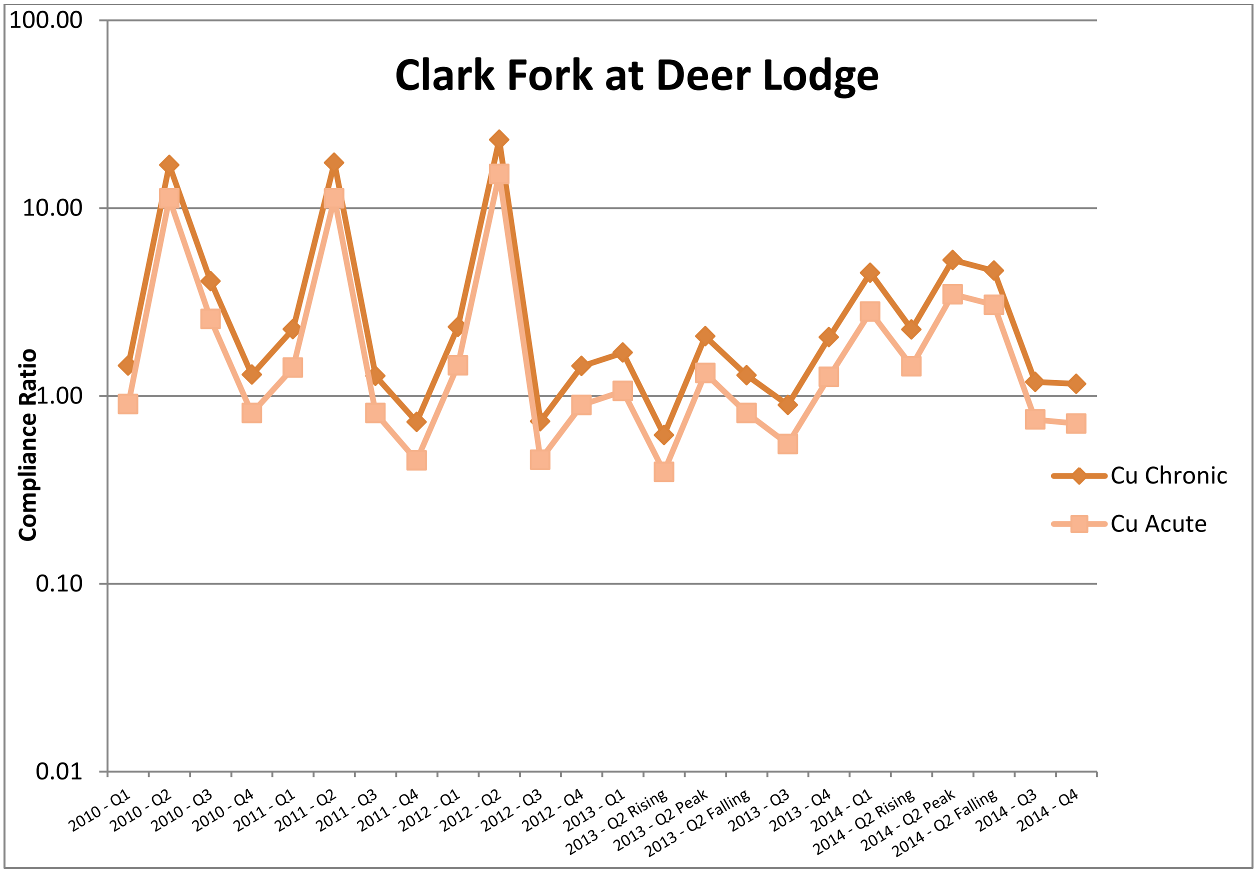

Figure 2-55. Total recoverable copper (Cu) compliance ratios for Clark Fork River at Deer Lodge site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

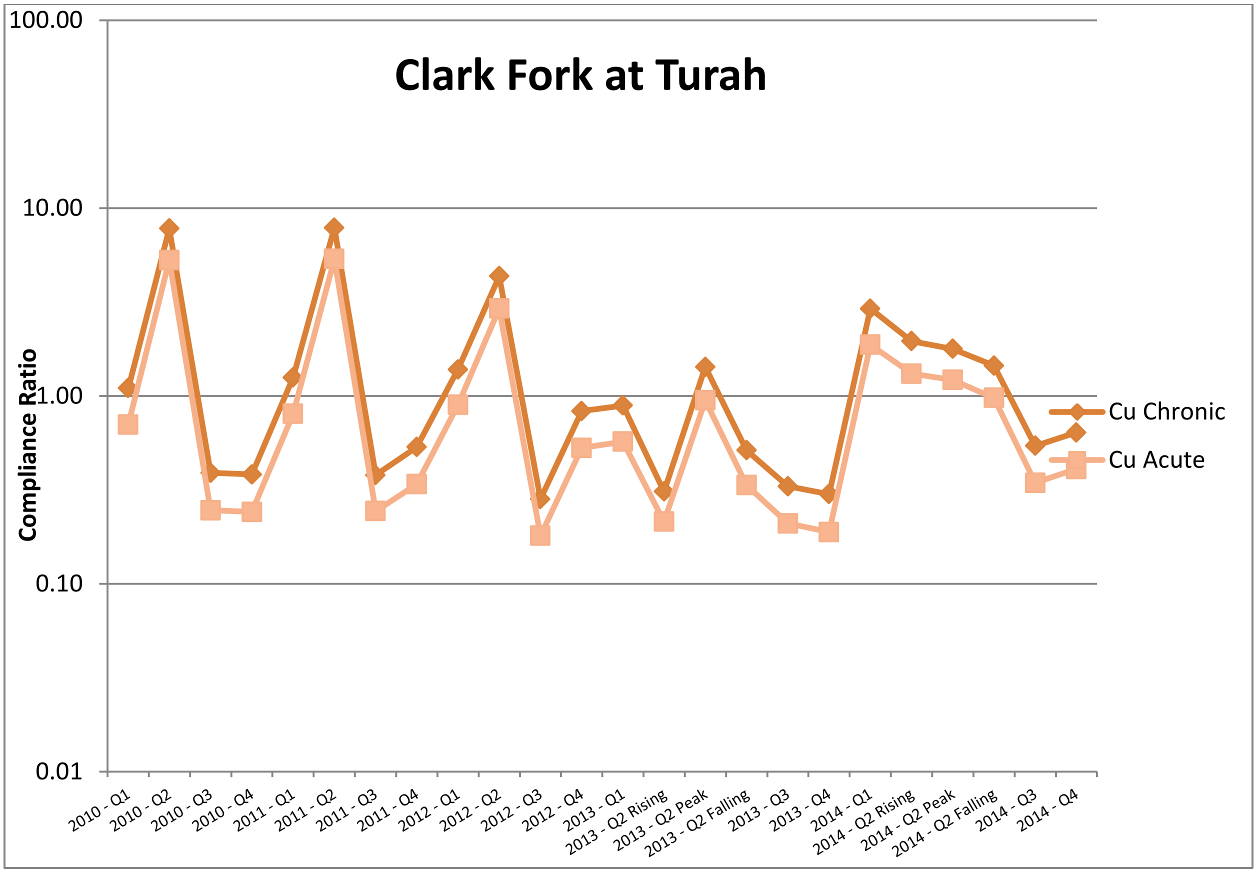

Figure 2-56. Total recoverable copper (Cu) compliance ratios for Clark Fork River at Turah site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

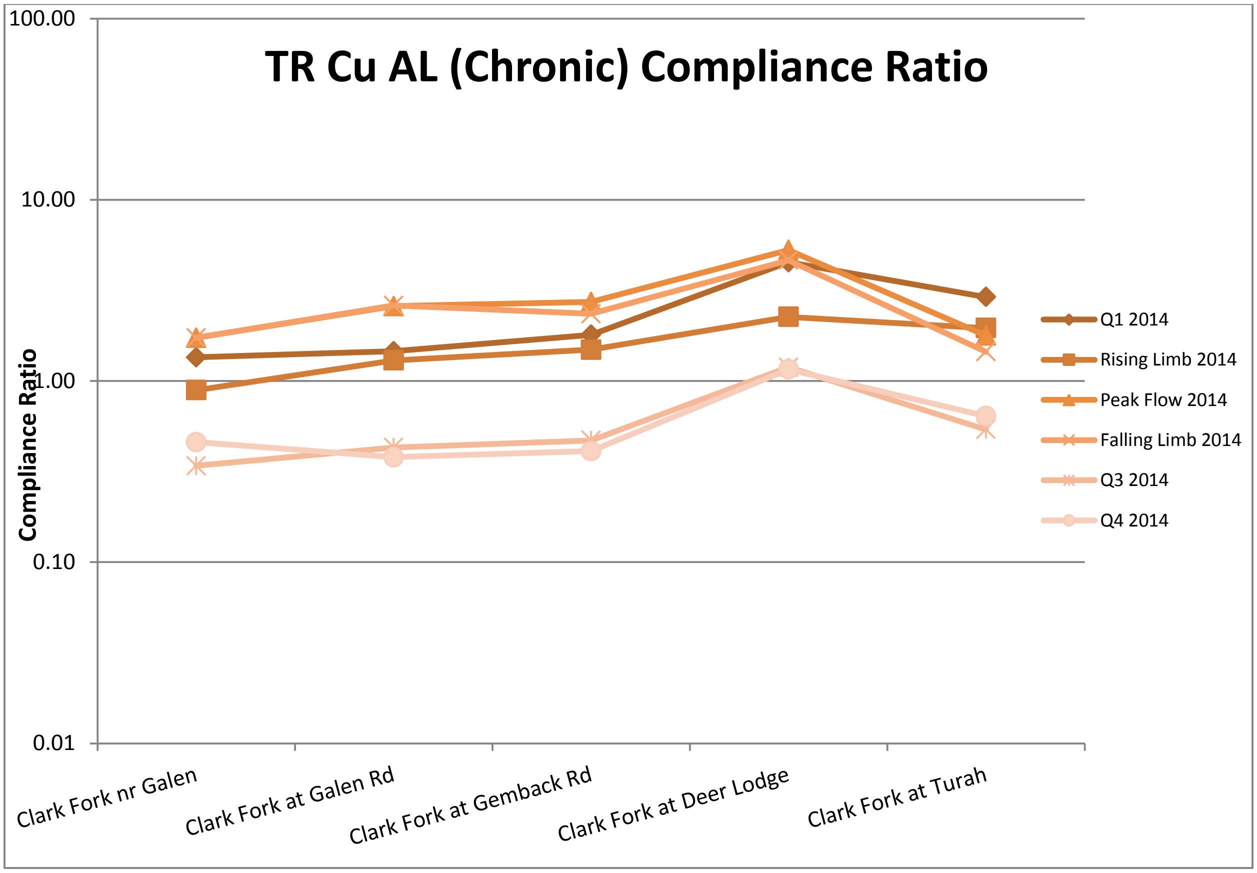

Figure 2-57. Total recoverable (TR) copper (Cu) compliance ratio in the Clark Fork River (CFR) mainstem sites, 2014. Compliance ratio is based on the chronic aquatic life standard (ALS) [MDEQ, 2012b].

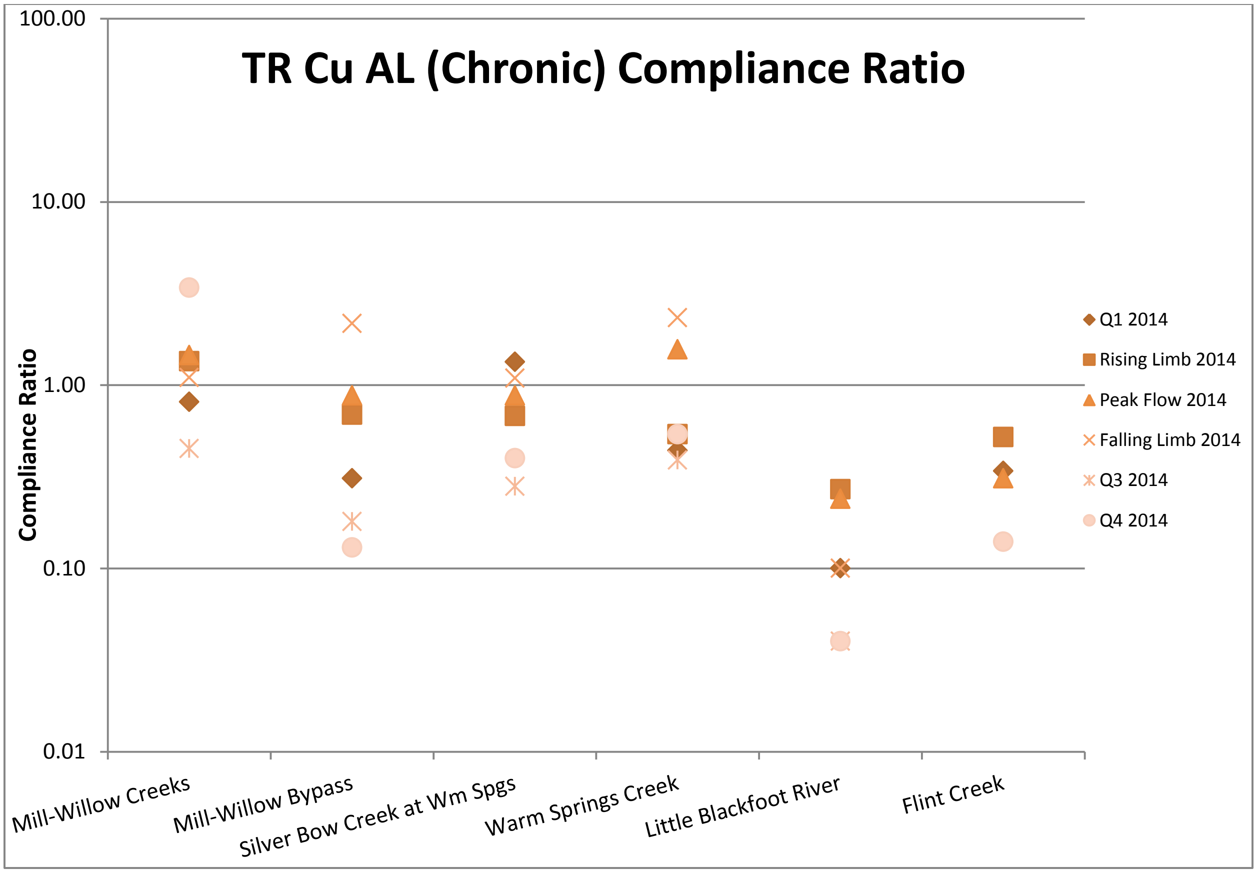

Figure 2-58. Total recoverable (TR) copper (Cu) compliance ratio in Clark Fork River (CFR) tributary sites, 2014. Compliance ratio is based on the chronic aquatic life standard (ALS) [MDEQ, 2012b].

2.3.6.4 Lead

Increasing concentrations of total recoverable lead were observed in the mainstem Clark Fork River from the near Galen site to the Deer Lodge site during 2014, followed by lower total recoverable lead concentrations downstream at Turah [Table 2-13; Figure 2-59]. Lowest mainstem total recoverable lead concentrations were found at the Clark Fork River near Galen site, and highest concentrations were observed at the Deer Lodge site. Among the tributary sites, concentrations of total recoverable lead were frequently high in Flint Creek, and were occasionally elevated in Mill-Willow Creek at Frontage Road, Mill-Willow Bypass, and Silver Bow Creek at Warm Springs in 2014 [Table 2-13; Figure 2-60]. The highest concentrations of lead were observed at most stations during the Q1 monitoring event. The overall highest total recoverable lead concentrations were measured in the Clark Fork River at Deer Lodge in Q1, and in Mill-Willow Creek at Frontage Road during the Q4 monitoring event when turbidity (Section 2.3.2.5) and total suspended sediment (Section 2.3.3) were also elevated at that site. Nearly all detectable lead was present in a sediment associated state; dissolved lead concentrations were commonly below the minimum analytical reporting limit during most (59 of 66) sampling events.

The maximum annual total recoverable lead concentration at CFROU monitoring stations in 2014 (0.0122 mg/L) was higher than the maximum concentration in 2013 (0.0060 mg/L), but lower than the maximum concentrations in 2010 (0.0295 mg/L), 2011 (0.0515 mg/L) and 2012 (0.0366 mg/L).

Total recoverable lead concentrations exceeded the chronic ALS at two Clark Fork River mainstem stations during 2014, including the Deer Lodge station (three exceedances; Q1, Q2-Peak, Q2-Falling) and the Turah station (one exceedance; Q1) [Table 2-13]. Flint Creek exhibited four exceedances of the chronic ALS in six measurements (Q1 and all Q2 events), while Mill-Willow Creek at Frontage Road had two exceedances (Q2-Peak and Q4) and the Mill-Willow Bypass had one exceedance (Q2-Falling). Samples collected at Clark Fork River mainstem stations near Galen, at Galen Road, and at Gemback Road, and tributary sites on Warm Springs Creek and the Little Blackfoot River, were consistently below the chronic ALS for total recoverable lead during 2014 monitoring events. The overall frequency of exceedances of the lead ALS at CFROU monitoring stations in 2014 (11 of 66 samples) was somewhat higher than in 2013 (3 of 60 samples), but lower than in each of 2012 (11 of 60 samples), 2011 (6 of 28 samples) and 2010 (7 of 24 samples).

The lead chronic and acute ALS compliance ratios for the Clark Fork River mainstem stations near Galen, at Deer Lodge, and at Turah appear to have declined somewhat over the five-year period since 2010 [Figure 2-61 through Figure 2-64]. The lead compliance ratio for Silver Bow Creek at Warm Springs was similar in each year from 2011 through 2014 [Figure 2-61].

The Clark Fork River near Galen frequently exceeded the lead chronic ALS compliance ratio from 2010-2013, but did not exceed the chronic ALS in 2014 [Figure 2-62]. The Clark Fork River at Galen Road and at Gemback Road also did not exceed the chronic ALS in 2014 [Figure 2-65]. Among the tributary sites, Mill-Willow Creek at Frontage Road, Mill-Willow Bypass, and Flint

Creek had the highest lead compliance ratios and the Little Blackfoot River had the lowest compliance ratios [Figure 2-66].

Table 2-13. Total recoverable lead concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.0051	0.0013	0.0015	0.0018	0.0003	0.0011
CFR-07D	Clark Fork River at Galen Road	0.0054	0.0021	0.0024	0.0027	0.0005	0.0008
CFR-11F	Clark Fork River at Gemback Road	0.0060	0.0025	0.0027	0.0027	0.0005	0.0007
CFR-27H	Clark Fork River at Deer Lodge	0.0122	0.0035	0.0061	0.0046	0.0018	0.0026
CFR-116A	Clark Fork River at Turah	0.0079	0.0028	0.0018	0.0016	0.0008	0.0010
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.0056	0.0012	0.0010	0.0012	0.0004	0.0012
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.0020	0.0012	0.0014	0.0016	0.0008	0.0112
MWB-SBC	Mill-Willow Bypass near mouth	0.0015	0.0011	0.0011	0.0027	0.0004	0.0007
WSC-SBC	Warm Springs Creek near mouth	0.0005	0.0005	0.0011	0.0015	0.0003	0.0005
LBR-CFR	Little Blackfoot River near Garrison	0.0003	0.0009	0.0004	0.0003	ND	ND
FC-CFR	Flint Creek near mouth	0.0087	0.0042	0.0051	0.0048	0.0009	0.0020

(highlighted) Exceeds chronic aquatic life standard [MDEQ, 2012b].

ND Not detected at analytical reporting limit.

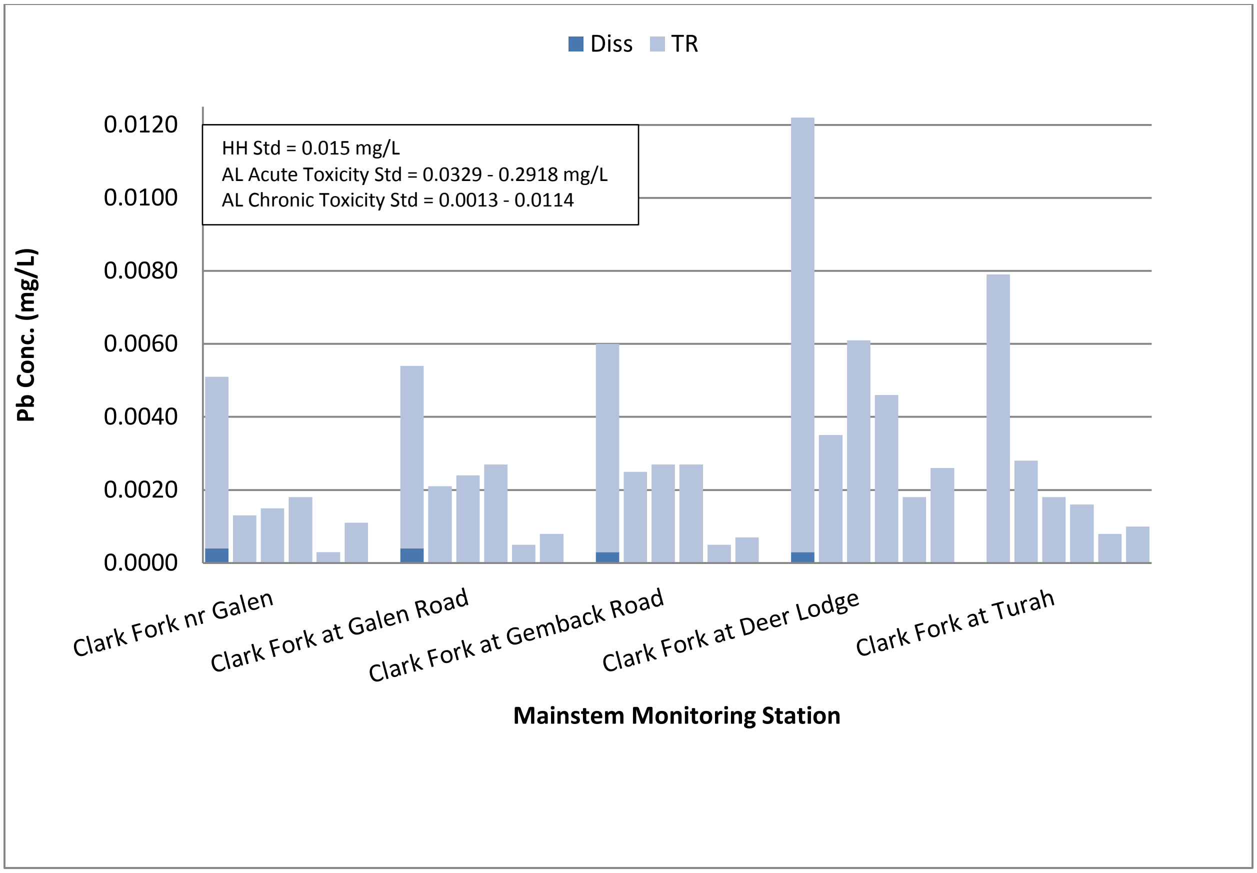

Figure 2-59. Total recoverable (total recoverable) and dissolved (Diss) lead concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2014. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

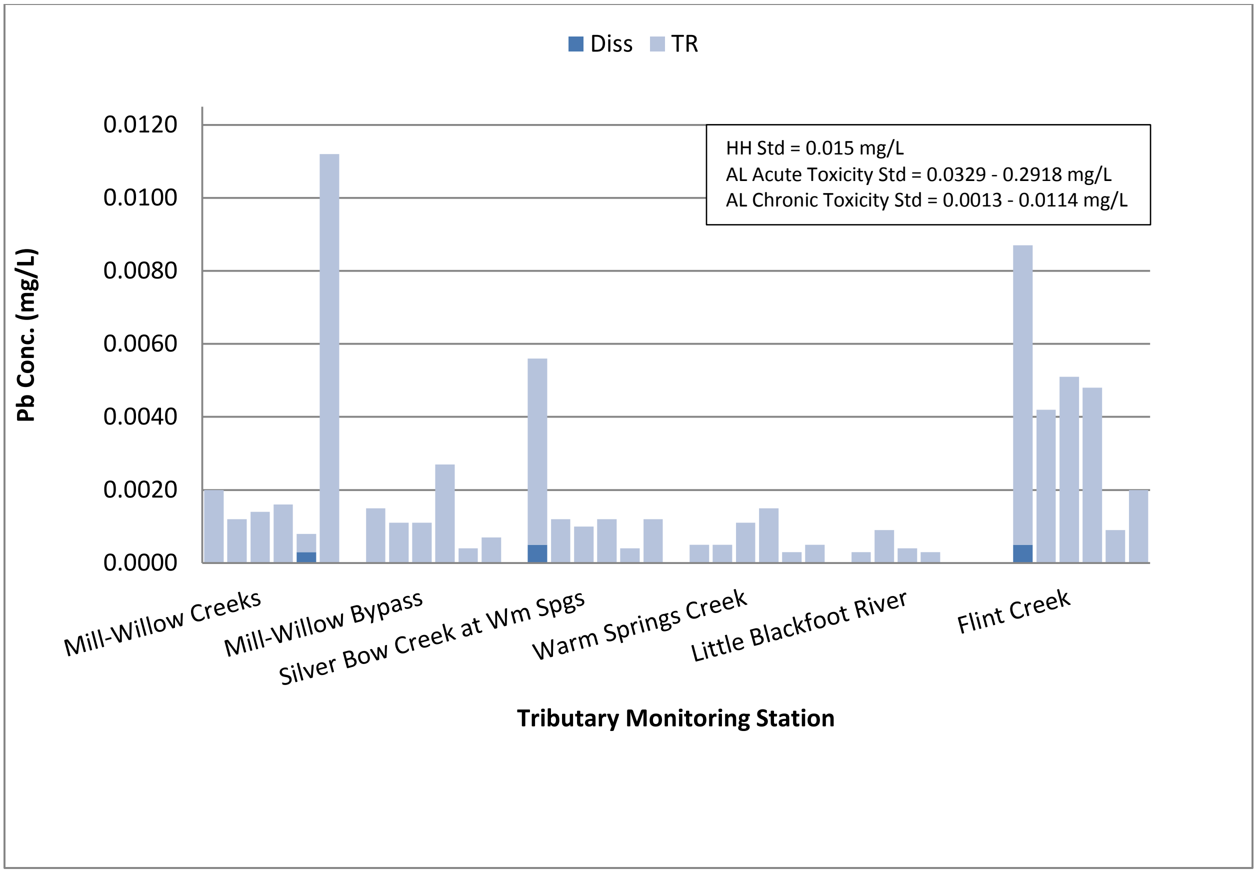

Figure 2-60. Total recoverable (TR) and dissolved (Diss) lead concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2014. No bars indicate concentrations below the analytical reporting limit. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

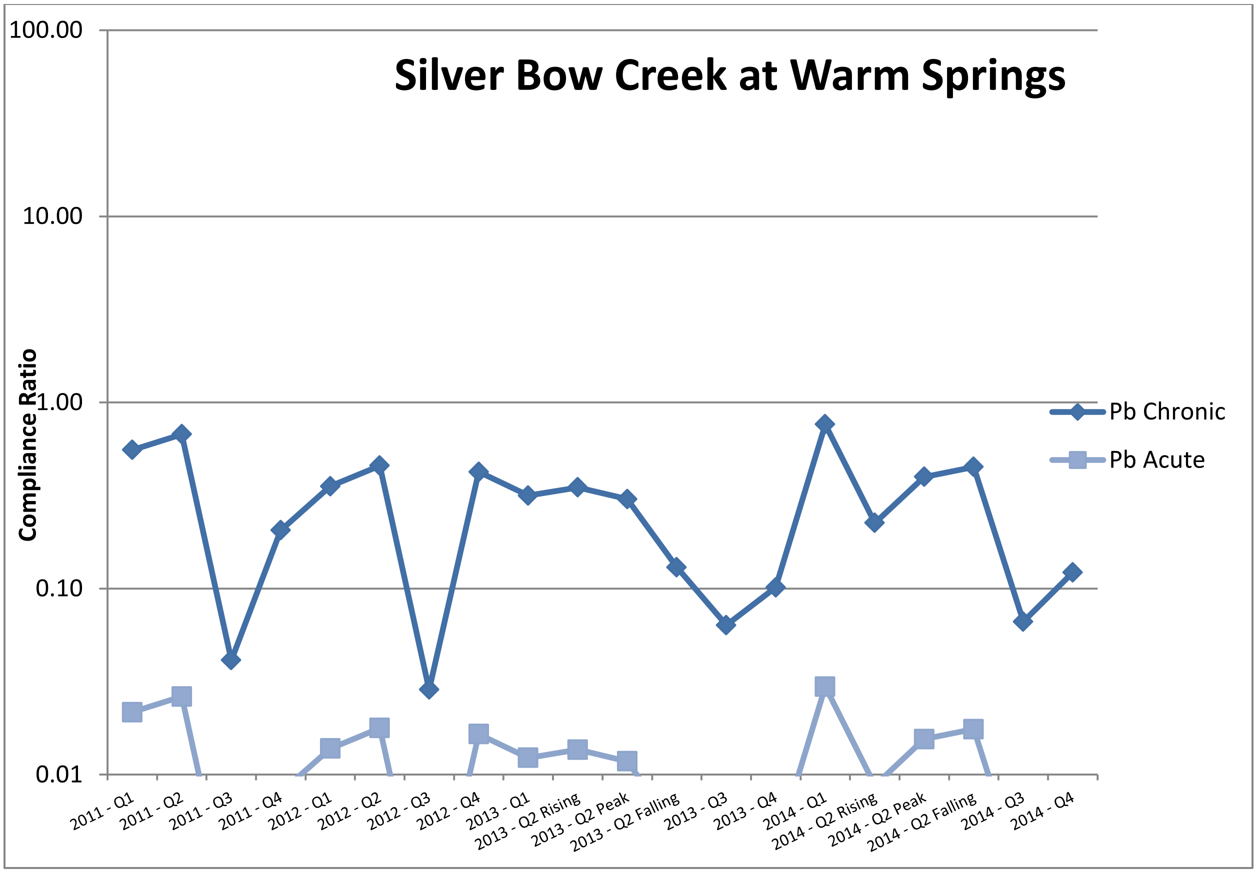

Figure 2-61. Total recoverable lead (Pb) compliance ratios for Silver Bow Creek at Warm Springs site, 2011-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

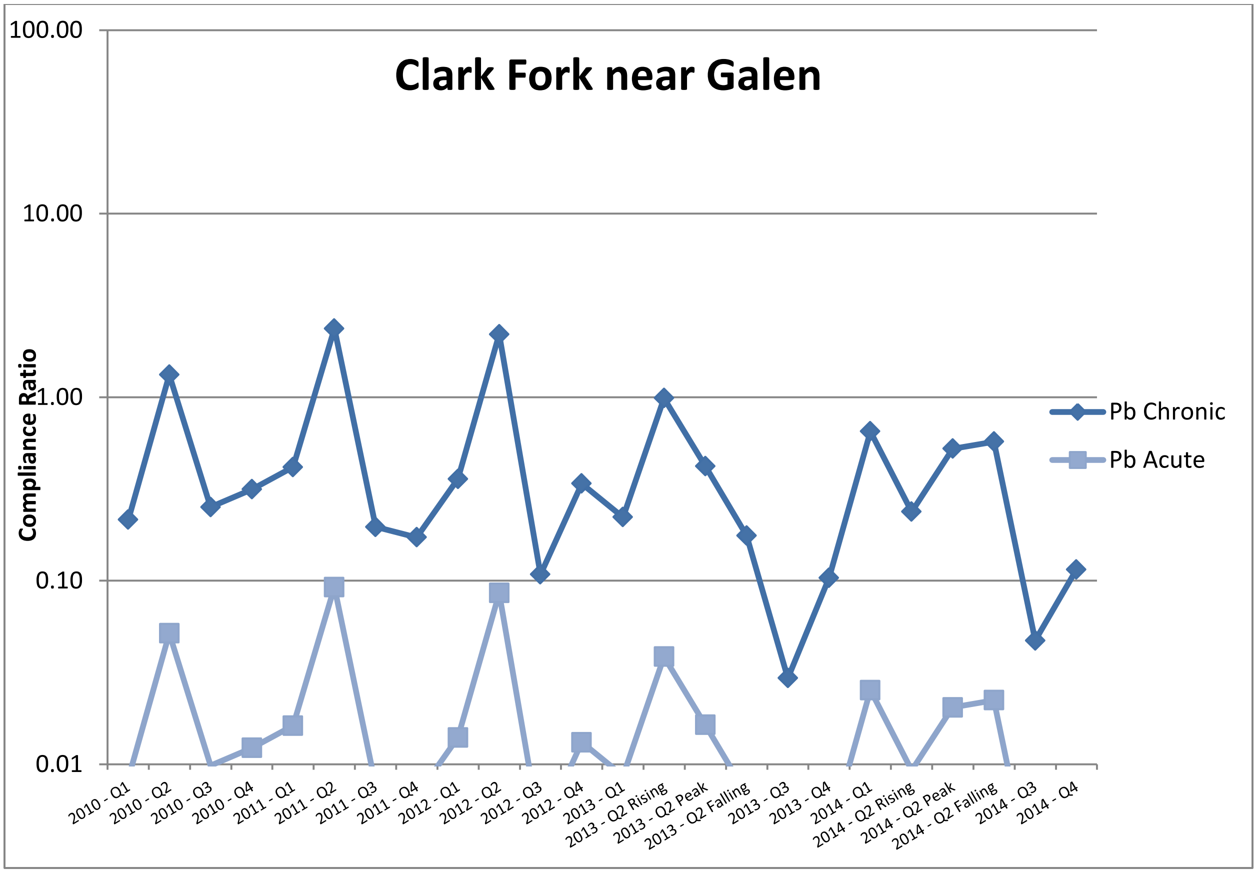

Figure 2-62. Total recoverable lead (Pb) compliance ratios for Clark Fork River near Galen site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

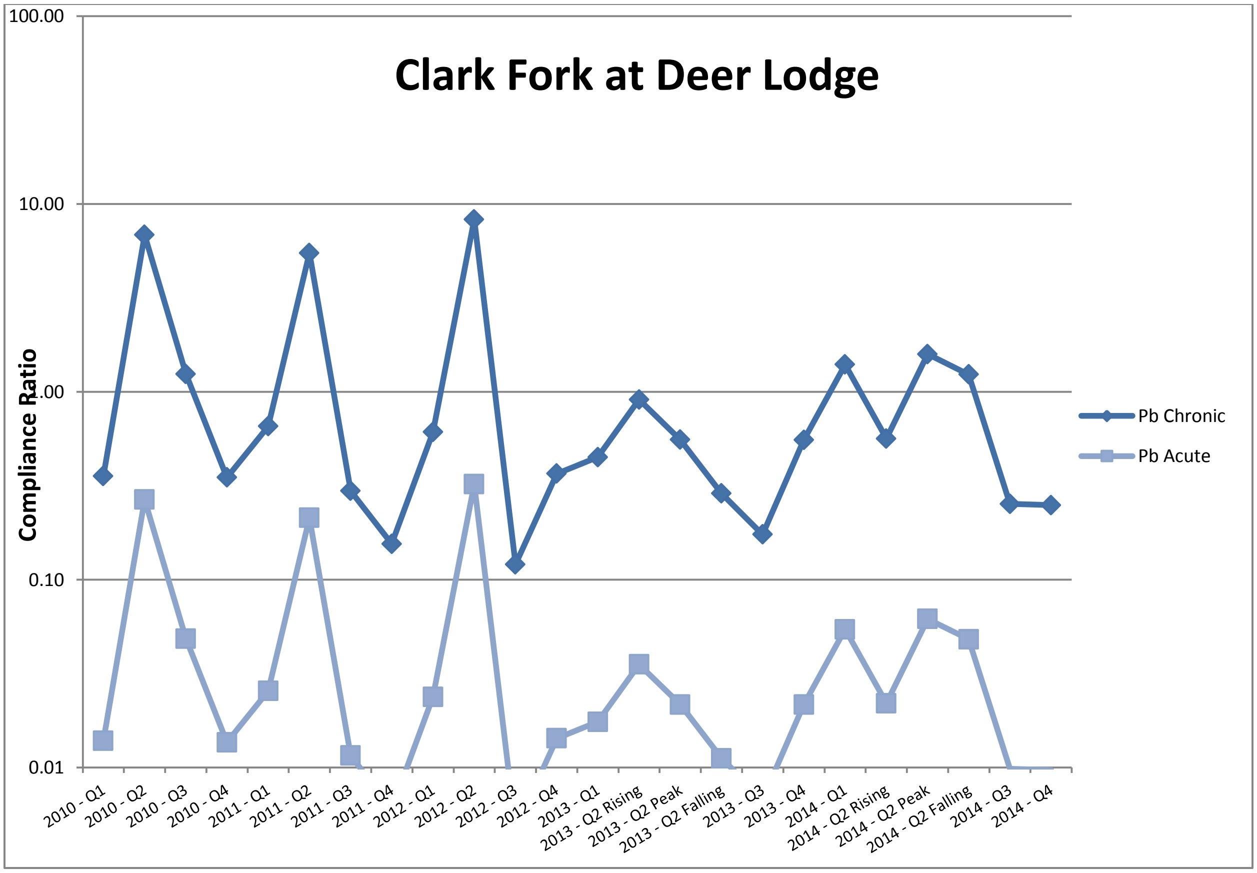

Figure 2-63. Total recoverable lead (Pb) compliance ratios for Clark Fork River at Deer Lodge site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

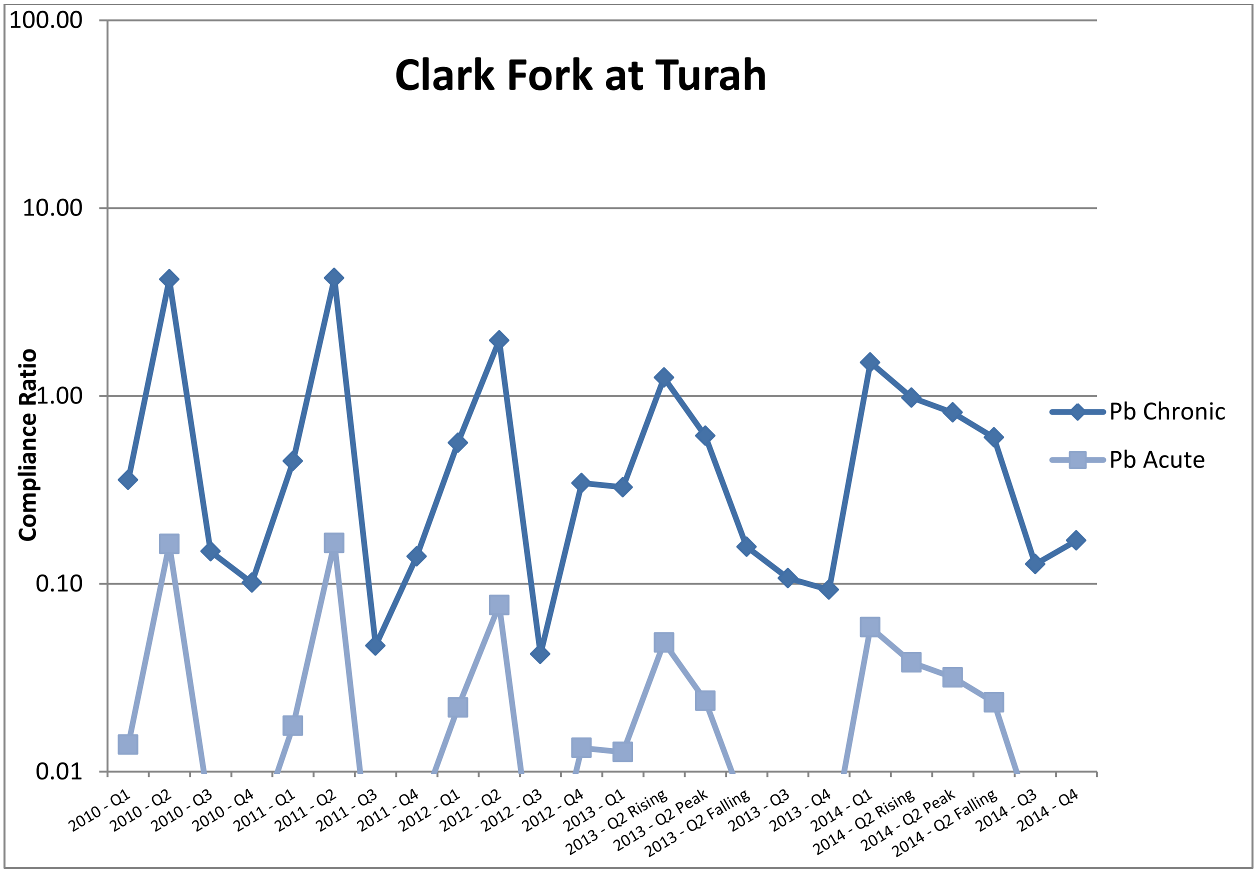

Figure 2-64. Total recoverable lead (Pb) compliance ratios for Clark Fork River at Turah site, 2010-2014. Compliance ratios are based on the chronic and acute aquatic life standards [MDEQ, 2012b].

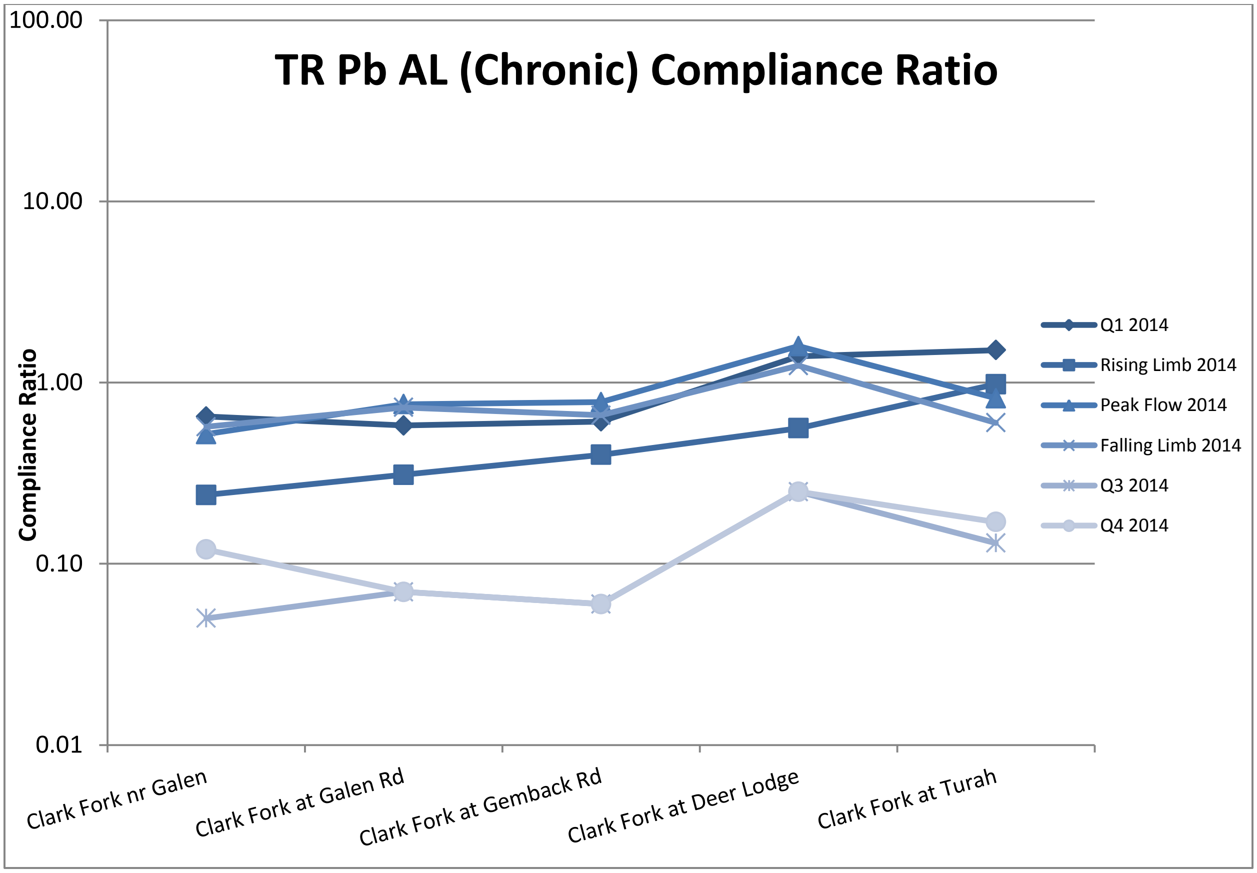

Figure 2-65. Total recoverable (TR) lead (Pb) compliance ratio in the Clark Fork River (CFR) mainstem sites, 2014. Compliance ratio is based on the chronic aquatic life standard (ALS) [MDEQ, 2012b].

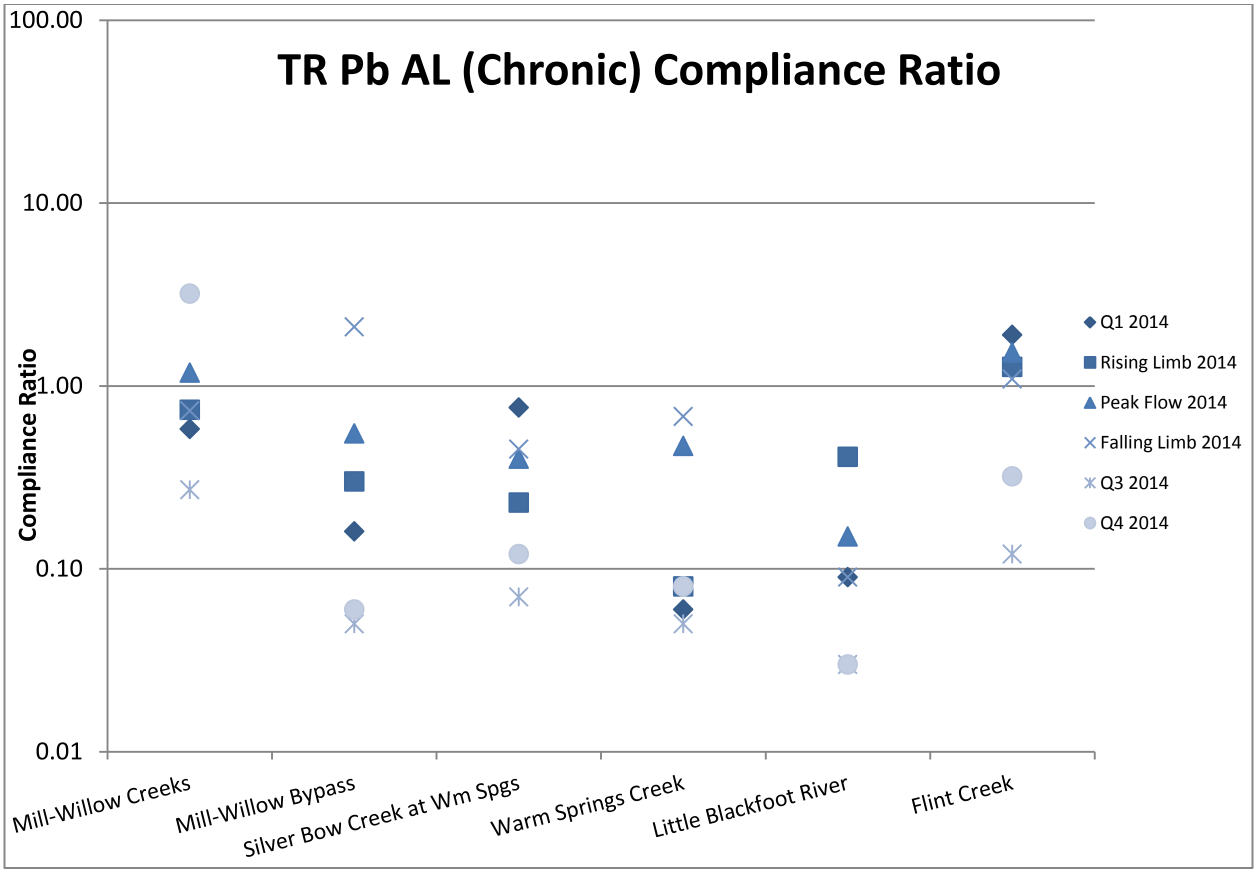

Figure 2-66. Total recoverable (TR) lead (Pb) compliance ratio in Clark Fork River (CFR) tributary sites, 2014. Compliance ratio is based on the chronic aquatic life standard (ALS) [MDEQ, 2012b].

2.3.6.5 Zinc

Zinc concentrations in the Clark Fork River mainstem increased at each monitoring station throughout Reach A, from near Galen to Deer Lodge, and then decreased downstream at Turah in 2014 [Table 2-14; Figure 2-67]. Lowest concentrations at mainstem monitoring sites were seen in the Clark Fork near Galen, while highest concentrations were observed at the Deer Lodge site. All samples from the CFROU tributary sites had low zinc concentrations in 2014, with two exceptions [Table 2-14; Figure 2-68]. These included the Mill-Willow Creek at Frontage Road site in Q4 during the high turbidity event, and Silver Bow Creek at Warm Springs in Q1 which may have corresponded to spring turnover in the Warm Springs Ponds based on other parameters. Like most of the COC metals during 2014 monitoring events, the highest zinc concentrations in 2014 were usually observed during the Q1 monitoring event. This temporal pattern was not distinct for the tributary sites where zinc concentrations were lower overall.

A relatively high proportion of the zinc present at many of the mainstem monitoring stations during many of the quarterly monitoring events was present in a dissolved state [Figure 2-67]. This was less pronounced during higher flow conditions in Q1 and Q2 when more of the zinc was present in a sediment associated state. The highest total recoverable zinc concentration at CFROU monitoring stations in 2014 (0.075 mg/L) was higher than the maximum concentration in 2013 (0.04 mg/L), but much lower than the maximum concentrations in 2010 (0.17 mg/L), 2011 (0.25 mg/L) and 2012 (0.22 mg/L). The minimum analytical reporting limit for zinc was lowered in 2014 to 0.008 mg/L from the prior limit of 0.01 mg/L which applied to 2010-2013 monitoring years.

The zinc ALS compliance ratios for the Clark Fork River mainstem stations near Galen, at Deer Lodge, and at Turah appear to have declined somewhat since 2010 [Figure 2-69 through Figure 2-72]. The tributary station on Silver Bow Creek at Warm Springs did not show a similar declining trend [Figure 2-69]. The seasonal and spatial trends in ALS compliance ratios for total recoverable zinc during the six 2014 monitoring events were similar to the patterns noted for cadmium, copper, and lead. The Clark Fork River at Gemback Road and at Deer Lodge most frequently had the highest zinc ALS compliance ratios during 2014, and the highest mainstem ratios occurred during the Q1 monitoring events [Figure 2-73]. All of the tributaries had compliance ratios that were consistently below 0.1 [Figure 2-74]. The mainstem stations also had compliance ratios during 2014 that were consistently below 1.0. Compliance ratios at all of the mainstem Clark Fork River stations examined appear to have declined since 2010 [Figure 2-70; Figure 2-71; Figure 2-72]. Compliance ratios at the Silver Bow Creek at Warm Springs station appear unchanged since 2011 [Figure 2-69]. The overall frequency of exceedances of the zinc ALS at CFROU monitoring stations in 2014 (0 of 66 samples) was comparable to 2013 (0 of 60 samples), but lower than in each of 2010 (2 of 24 samples), 2011 (2 of 28 samples), and 2012 (3 of 60 samples).

Table 2-14. Total recoverable zinc concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	0.037	0.014	0.011	0.013	ND	0.019
CFR-07D	Clark Fork River at Galen Road	0.036	0.021	0.018	0.027	ND	0.015
CFR-11F	Clark Fork River at Gemback Road	0.041	0.023	0.021	0.020	ND	0.015
CFR-27H	Clark Fork River at Deer Lodge	0.075	0.033	0.040	0.035	0.015	0.027
CFR-116A	Clark Fork River at Turah	0.060	0.027	0.019	0.016	0.011	0.015
Tributary Sites							
SS-25	Silver Bow Creek at Warm Springs	0.041	0.014	0.008	0.011	ND	0.027
MCWC-MWB	Mill-Willow Creek at Frontage Road	0.021	ND	ND	0.010	ND	0.054
MWB-SBC	Mill-Willow Bypass near mouth	0.017	ND	ND	0.014	ND	0.010
WSC-SBC	Warm Springs Creek near mouth	0.009	ND	ND	0.010	ND	ND
LBR-CFR	Little Blackfoot River near Garrison	ND	ND	ND	ND	ND	ND
FC-CFR	Flint Creek near mouth	0.029	0.016	0.017	0.015	ND	ND

ND Not detected at analytical reporting limit.

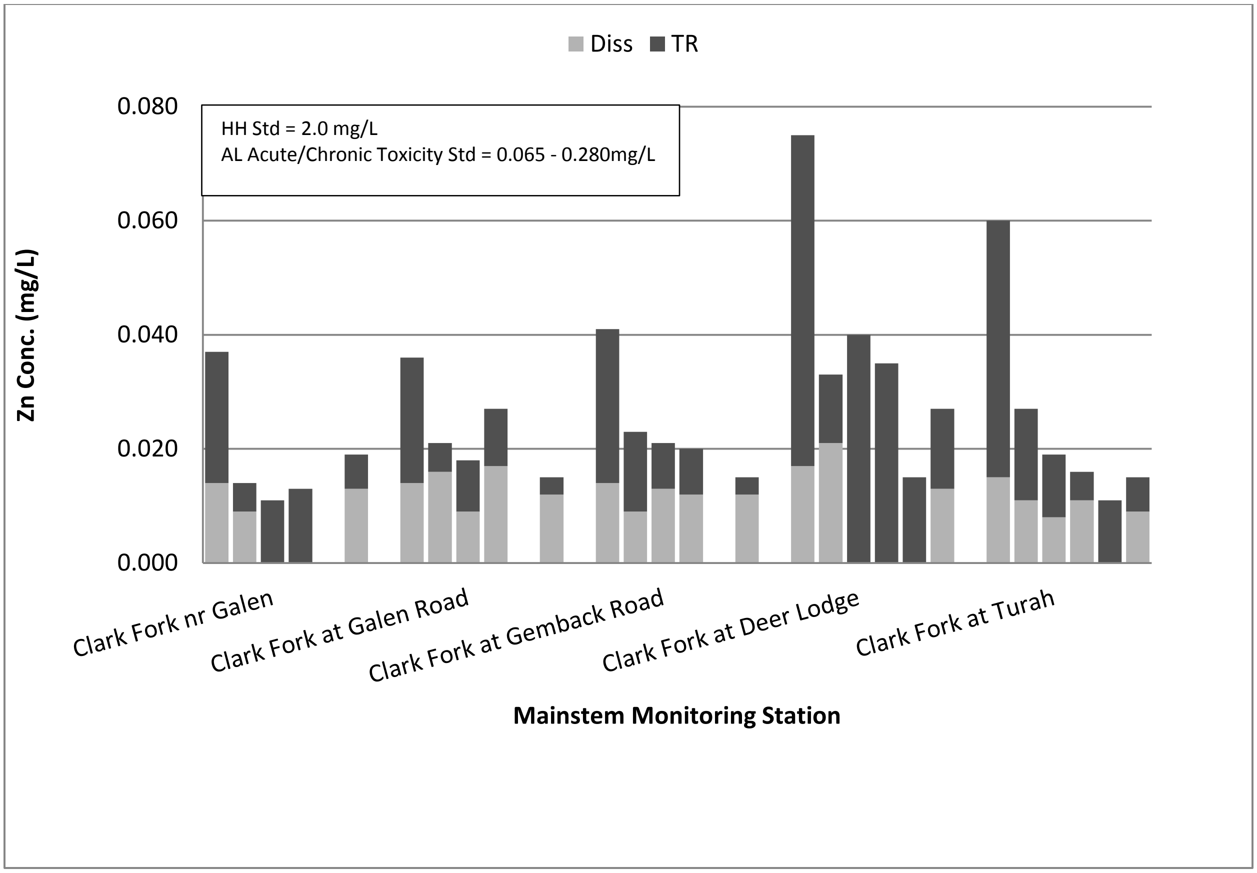

Figure 2-67. Total recoverable (TR) and dissolved (Diss) zinc concentrations at mainstem sampling sites in the Clark Fork River Operable Unit, 2014. No bars indicate concentrations below the analytical reporting limit. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

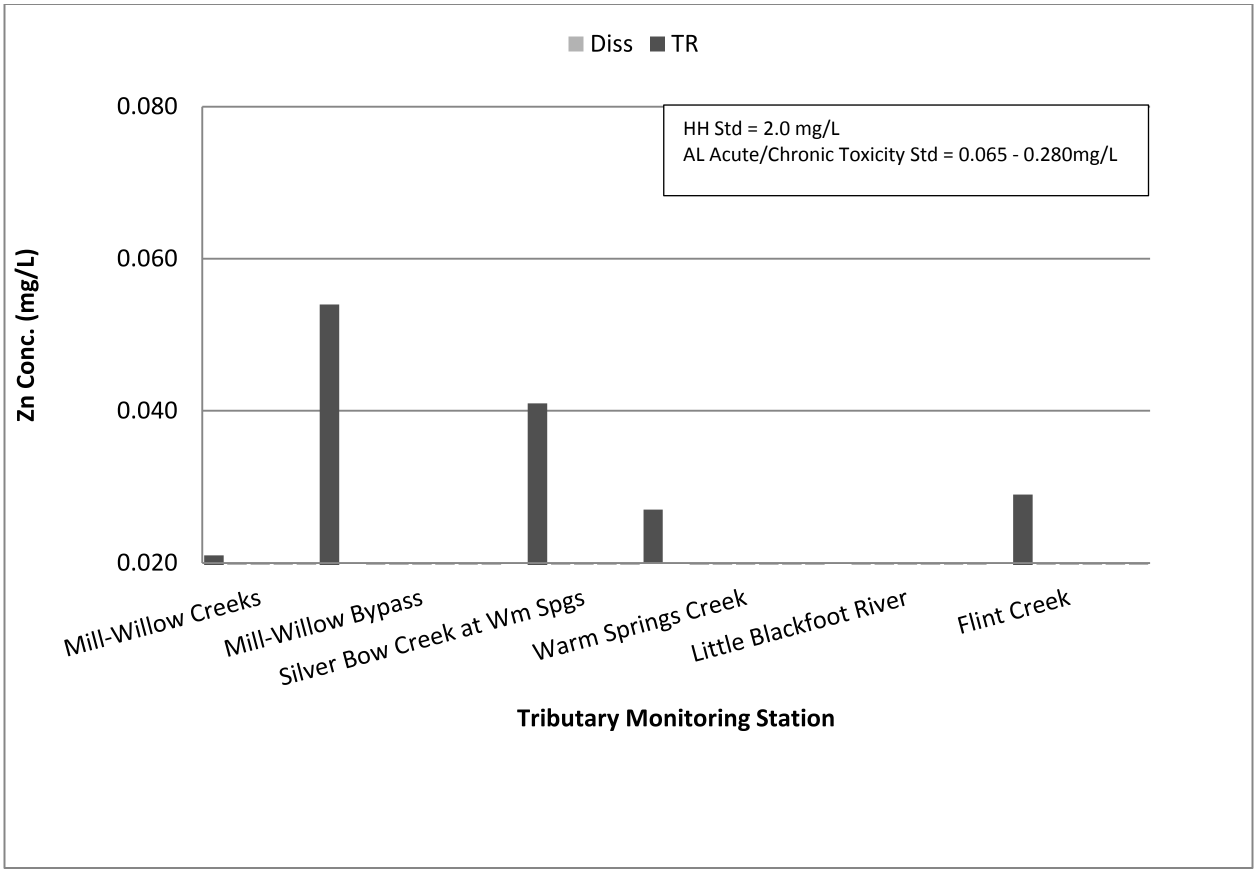

Figure 2-68. Total recoverable (TR) and dissolved (Diss) zinc concentrations at tributary sampling sites in the Clark Fork River Operable Unit, 2014. No bars indicate concentrations below the analytical reporting limit. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

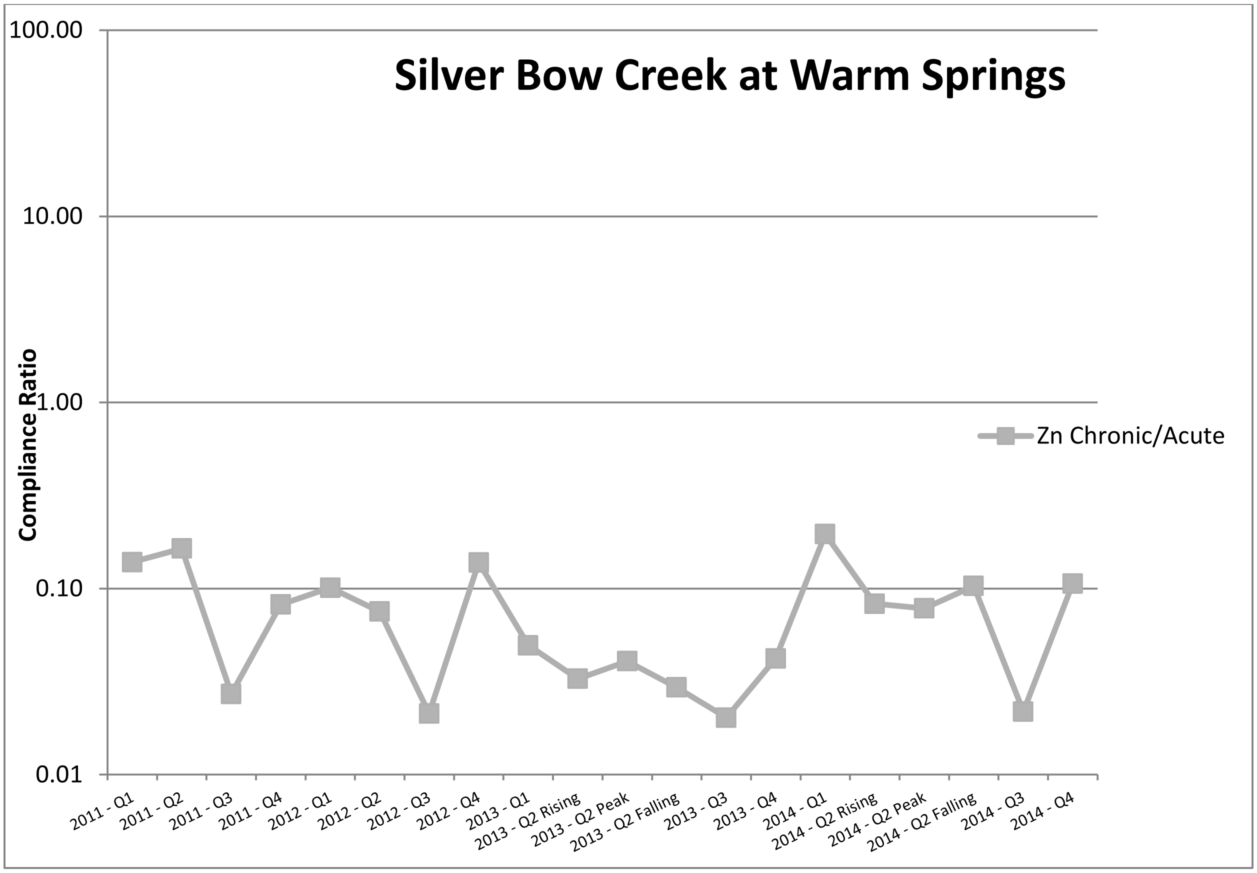

Figure 2-69. Total recoverable zinc (Zn) compliance ratios for Silver Bow Creek at Warm Springs site, 2011-2014. Compliance ratios are based on the aquatic life standards [MDEQ, 2012b].

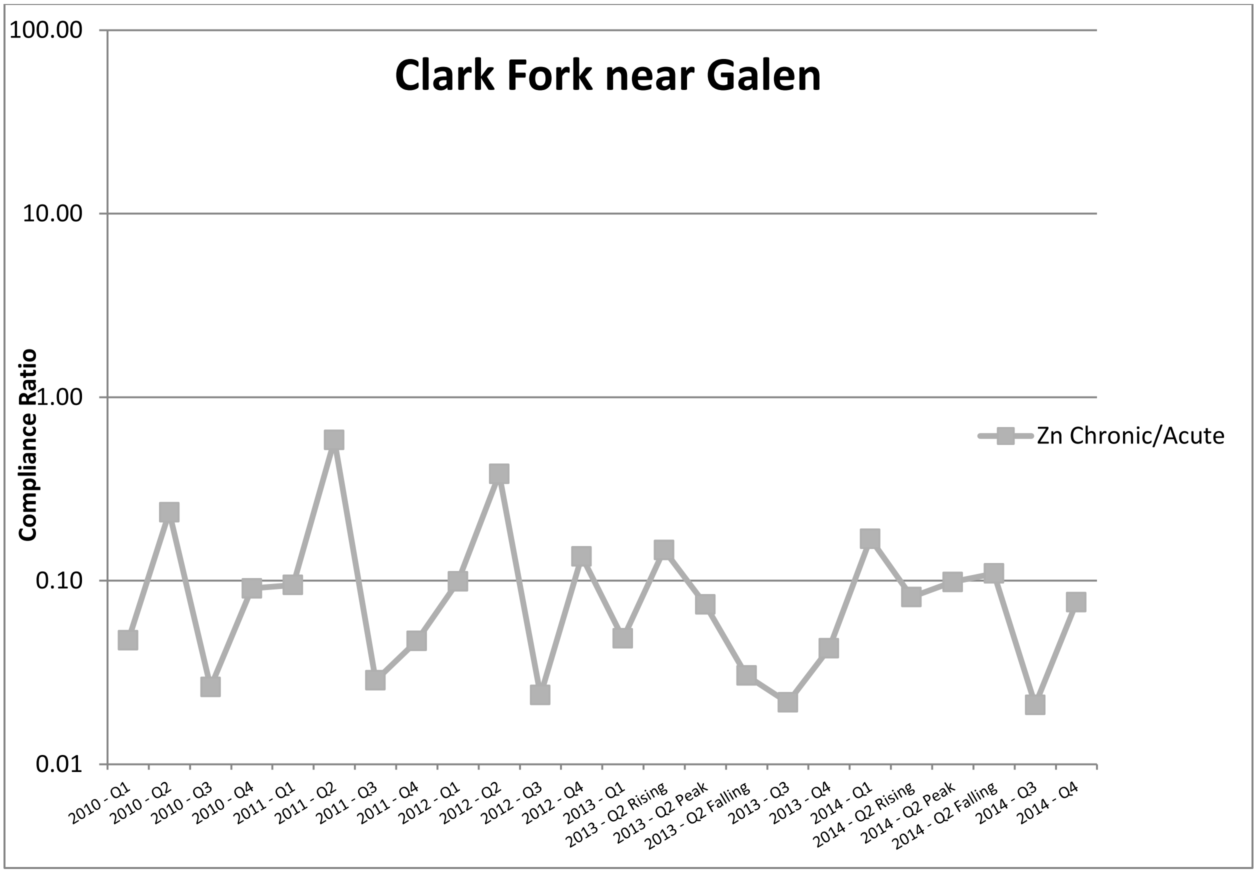

Figure 2-70. Total recoverable zinc (Zn) compliance ratios for Clark Fork River near Galen site, 2010-2014. Compliance ratios are based on the aquatic life standards [MDEQ, 2012b].

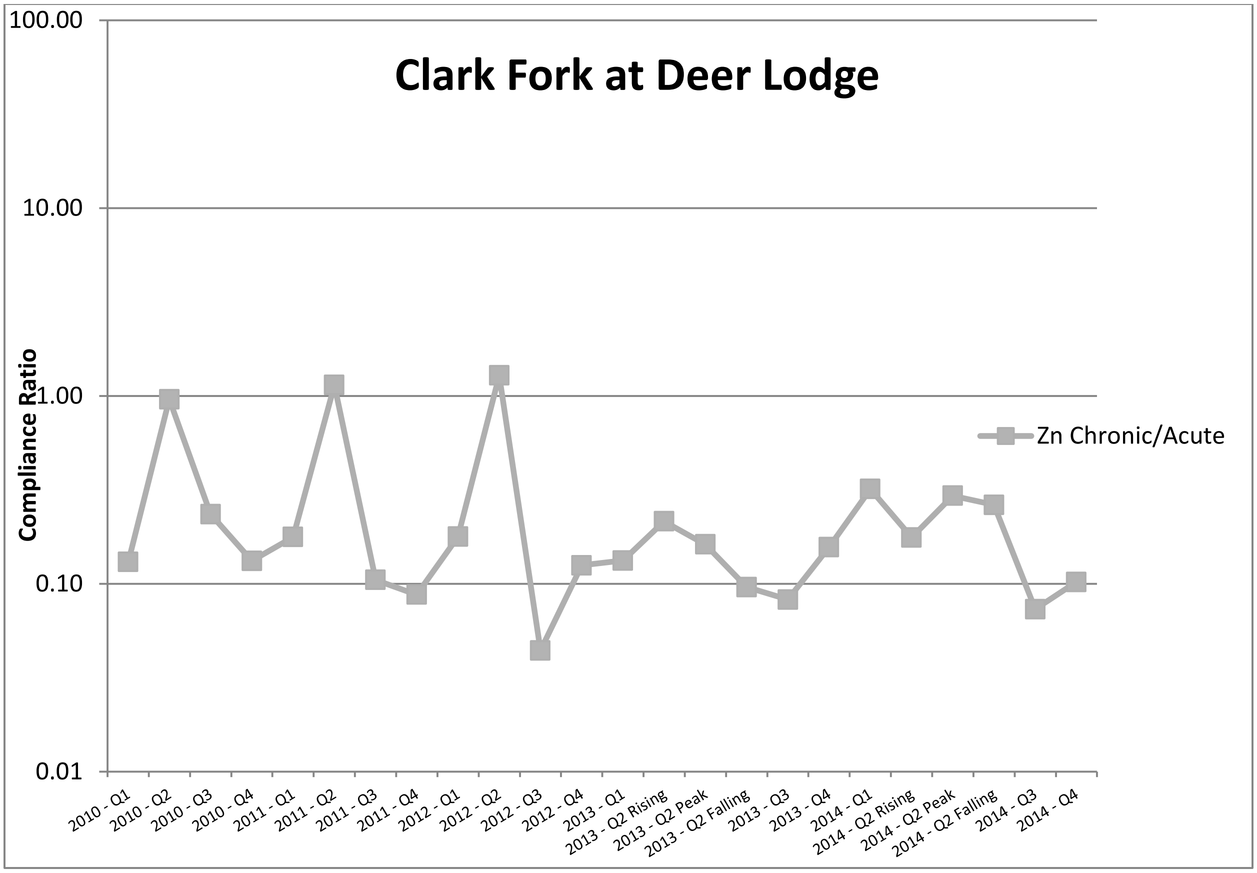

Figure 2-71. Total recoverable zinc (Zn) compliance ratios for Clark Fork River at Deer Lodge site, 2010-2014. Compliance ratios are based on the aquatic life standards [MDEQ, 2012b].

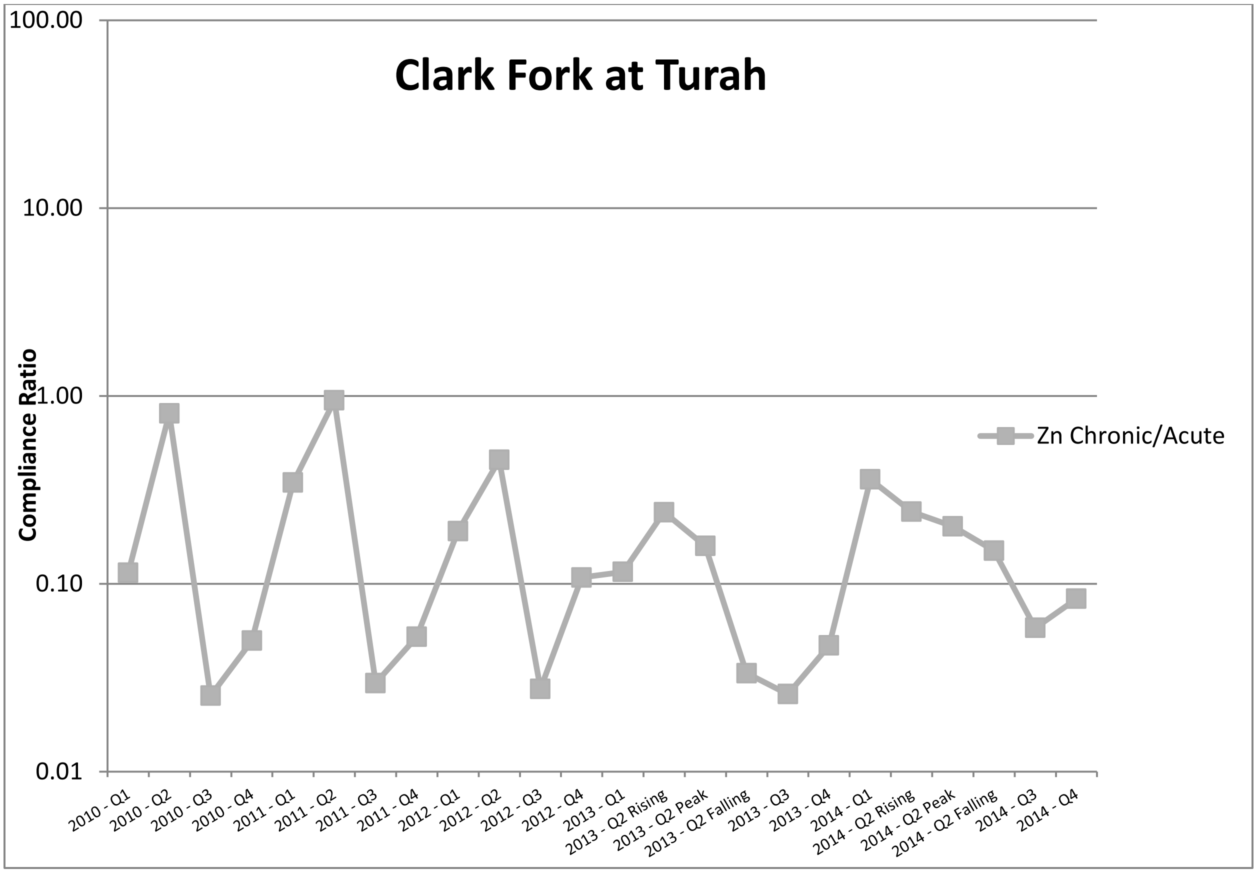

Figure 2-72. Total recoverable zinc (Zn) compliance ratios for Clark Fork River at Turah site, 2010-2014. Compliance ratios are based on the aquatic life standards [MDEQ, 2012b].

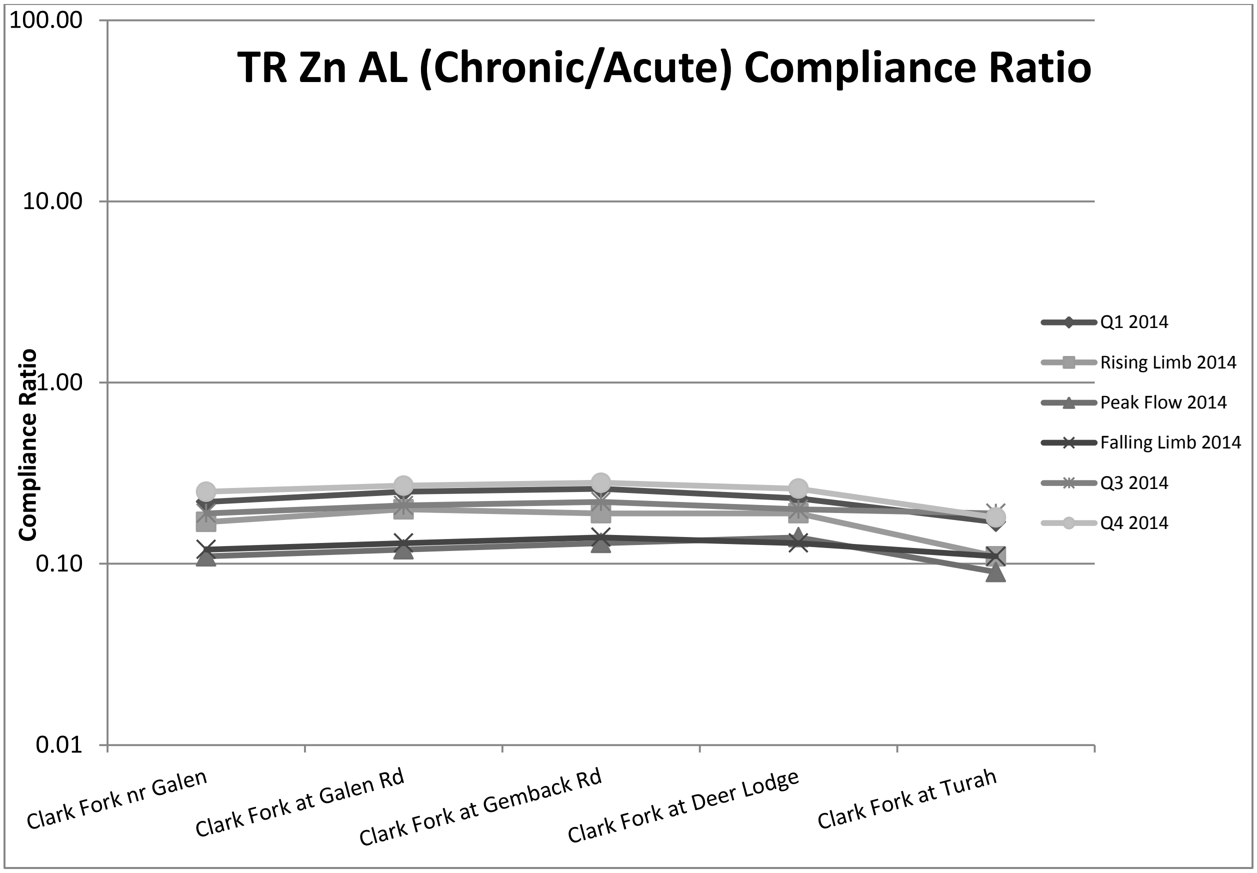

Figure 2-73. Total recoverable (TR) zinc (Zn) compliance ratio in the Clark Fork River (CFR) mainstem sites, 2014. Compliance ratio is based on the chronic and acute aquatic life standard (ALS) [MDEQ, 2012b].

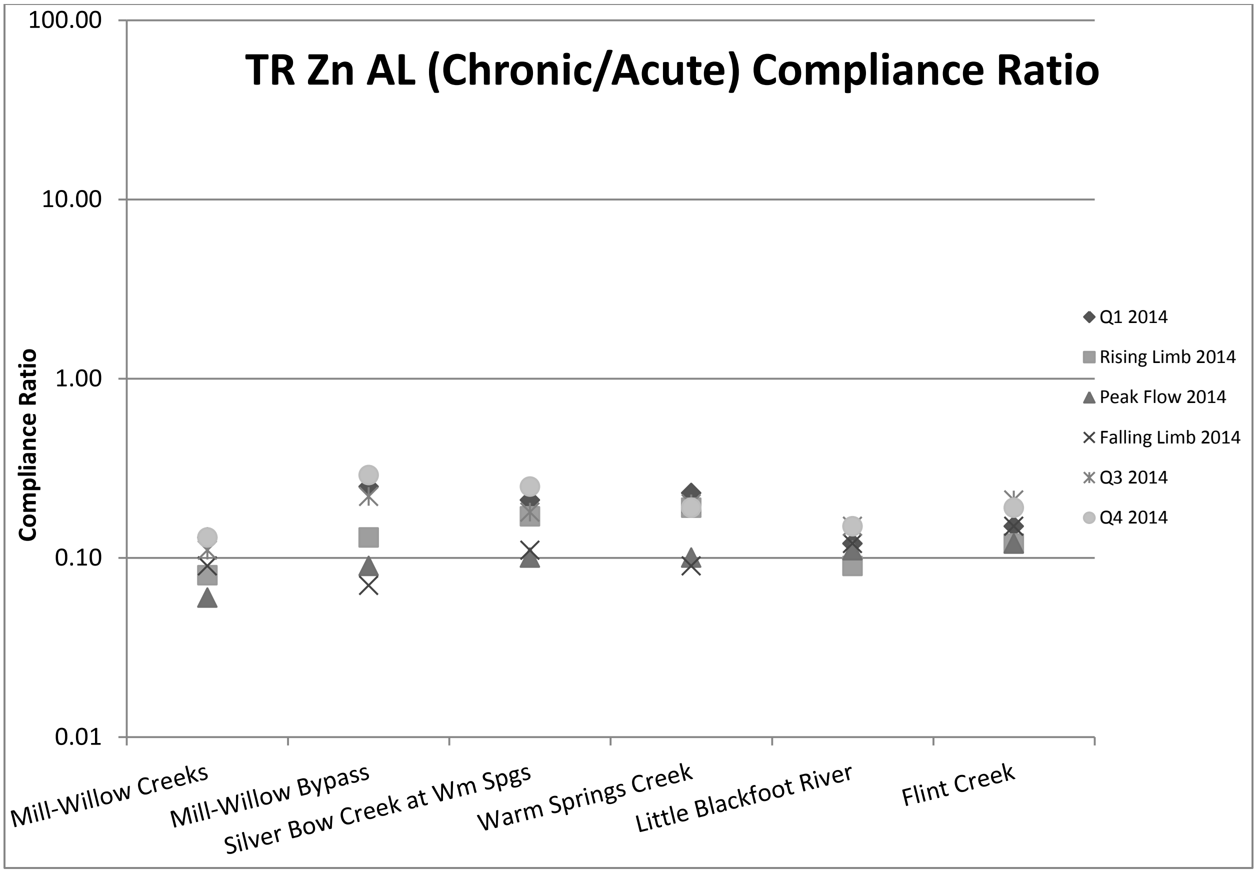

Figure 2-74. Total recoverable (TR) zinc (Zn) compliance ratio in Clark Fork River (CFR) tributary sites, 2013. Compliance ratio is based on the chronic and acute aquatic life standard (ALS) [MDEQ, 2012b].

2.3.7 Other Metals

2.3.7.1 Mercury

Monitoring for mercury at CFROU monitoring stations began in 2012. In 2013-2014, mercury monitoring was reduced to two stations: Flint Creek near mouth and Clark Fork River near Drummond. In 2014, the minimum analytical reporting level for mercury was lowered from 0.000010 mg/L to 0.000005 mg/L.

With the lower reporting levels, mercury was detected in 12 of the 12 (100%) samples collected in 2014 [Table 2-15]. The highest mercury concentrations at both monitoring sites in 2014 occurred during the Q1 monitoring event. The second highest mercury concentration occurred in Flint Creek during the Q2-Peak monitoring event [Figure 2-75]. Flint Creek mercury concentrations were consistently higher than the Clark Fork River near Drummond concentrations, with Flint Creek the likely source of mercury at the latter, downstream site.

All 2014 samples from Flint Creek exceeded the mercury HHSWS [Table 2-15]. One of six samples from the Clark Fork River near Drummond (Q1) exceeded the HHSWS in 2014; however, all three Q2 sample concentrations (ranging from 0.000037-0.000050 mg/L) approached or attained the HHSWS (0.000050 mg/L). Overall, mercury concentrations at these two stations in 2014 were within the range of concentrations observed at these stations in 2012-2013. The maximum concentration measured in 2014 was also similar to the highest concentration measured in 2013. In 2013, Flint Creek had four of six samples exceeding the HHSWS and the Clark Fork River near Drummond showed no excursions. In 2012, Flint Creek had two of four samples exceeding the HHSWS and the Clark Fork River near Drummond showed one of four excursions. Compliance ratios for mercury at the Flint Creek near mouth and Clark Fork River near Drummond sites in 2012-2014 did not demonstrate apparent upward or downward temporal trends [Figure 2-76; Figure 2-77].

Table 2-15. Total mercury concentrations (mg/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-84F	Clark Fork River near Drummond	0.000160	0.000050	0.000041	0.000037	0.000020	0.000013
Tributary Sites							
FC-CFR	Flint Creek near mouth	0.000400	0.000230	0.000360	0.000220	0.000058	0.000190

(shaded) Exceeds human health surface water standard [MDEQ, 2012b].

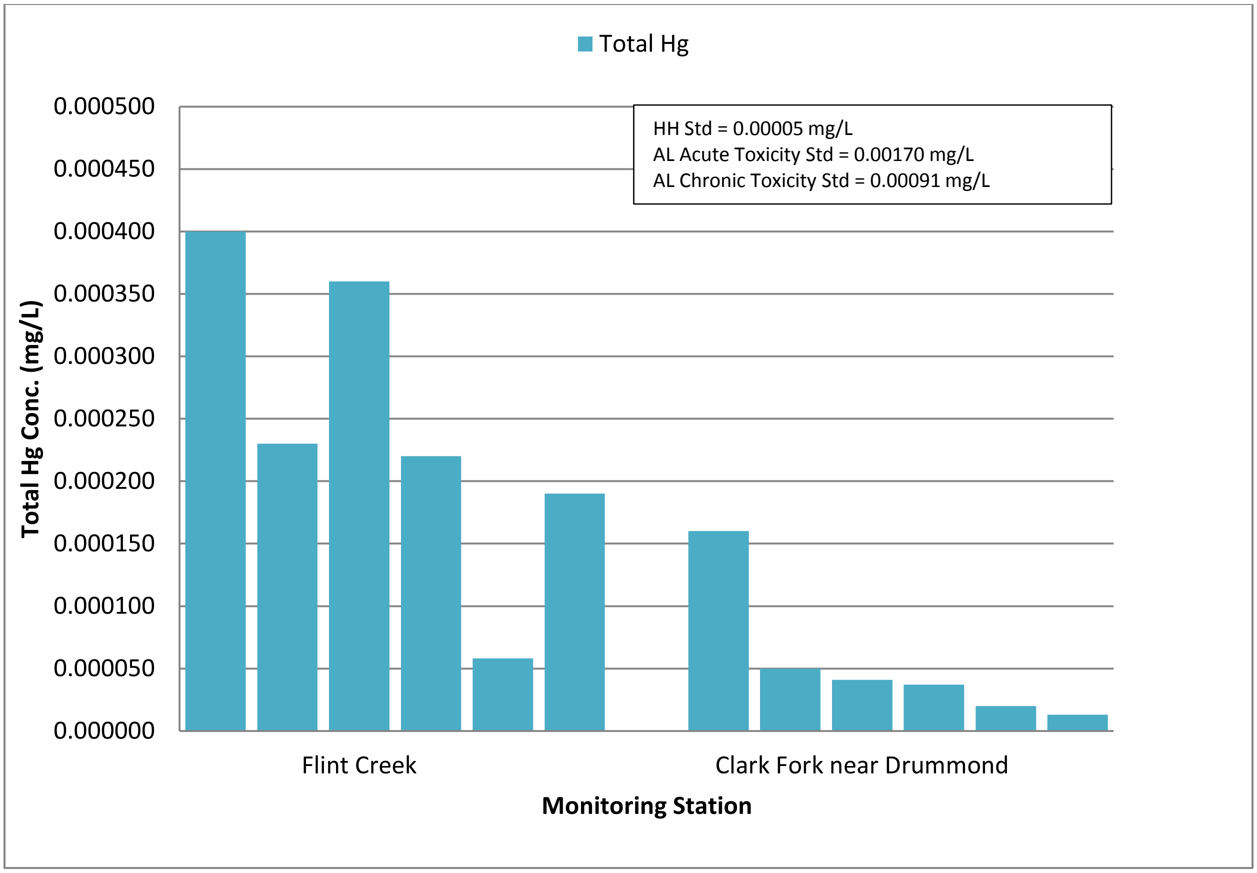

Figure 2-75. Total mercury (Hg) concentrations at sampling sites in the Clark Fork River Operable Unit, 2014. Applicable water quality standards are the aquatic life standards (ALS) and the human health surface water standard (HHSWS) [MDEQ, 2012b].

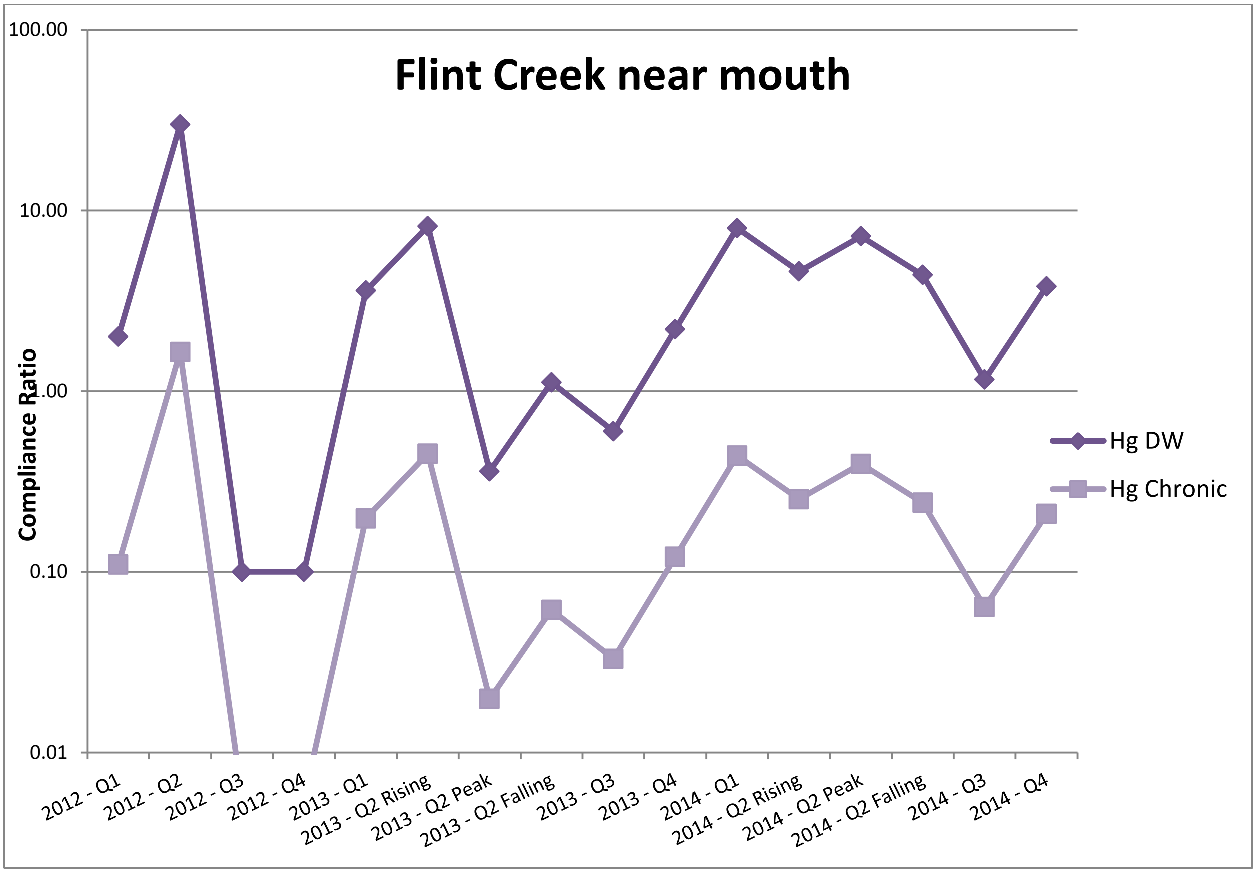

Figure 2-76. Total mercury (Hg) compliance ratios for Flint Creek near mouth site, 2012-2014. Compliance ratios are based on the chronic aquatic life standard and the human health surface water standard, or the drinking water standard (DW) [MDEQ, 2012b].

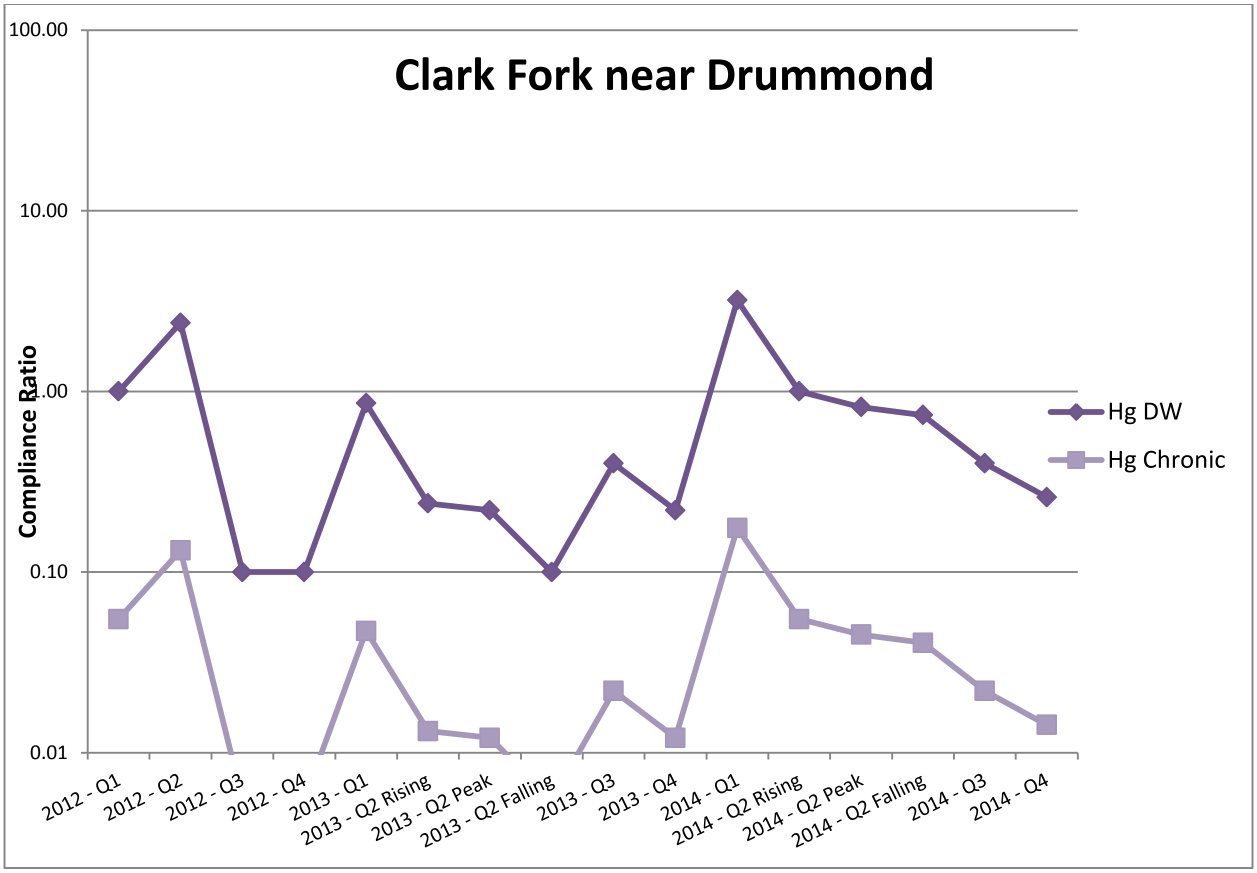

Figure 2-77. Total mercury (Hg) compliance ratios for Clark Fork River near Drummond site, 2012-2014. Compliance ratios are based on the chronic aquatic life standard and the human health surface water standard, or the drinking water standard (DW) [MDEQ, 2012b].

2.3.7.2 Methylmercury

In 2014, methylmercury was detected in all samples collected from each of the Flint Creek and Clark Fork River near Drummond stations [Table 2-16; Figure 2-78]. Like total mercury, these two sites are the only sites sampled for methylmercury within the CFROU network of stations. Methylmercury concentrations were highest during the Q2-Peak monitoring event in Flint Creek, and highest in Q1 at the Clark Fork River near Drummond site. Flint Creek consistently had methylmercury concentrations that were nearly two-fold to nearly four-fold the concentrations of the Clark Fork River near Drummond site [Table 2-16].

Methylmercury concentrations in 2014 were within the range of concentrations observed in samples from those sites in 2012 and 2013. However, the maximum 2014 methylmercury concentrations at each site were lower in 2014 than in either of 2012 or 2013.

Table 2-16. Methylmercury concentrations (ng/L) at Clark Fork River Operable Unit monitoring stations, 2014.

Site ID	Site Location	Sample Period					
		Q1	Q2			Q3	Q4
			Rising	Peak	Falling		
Mainstem Sites							
CFR-84F	Clark Fork River near Drummond	0.615	0.343	0.323	0.319	0.237	0.151
Tributary Sites							
FC-CFR	Flint Creek near mouth	1.140	0.807	1.190	0.990	0.455	0.547

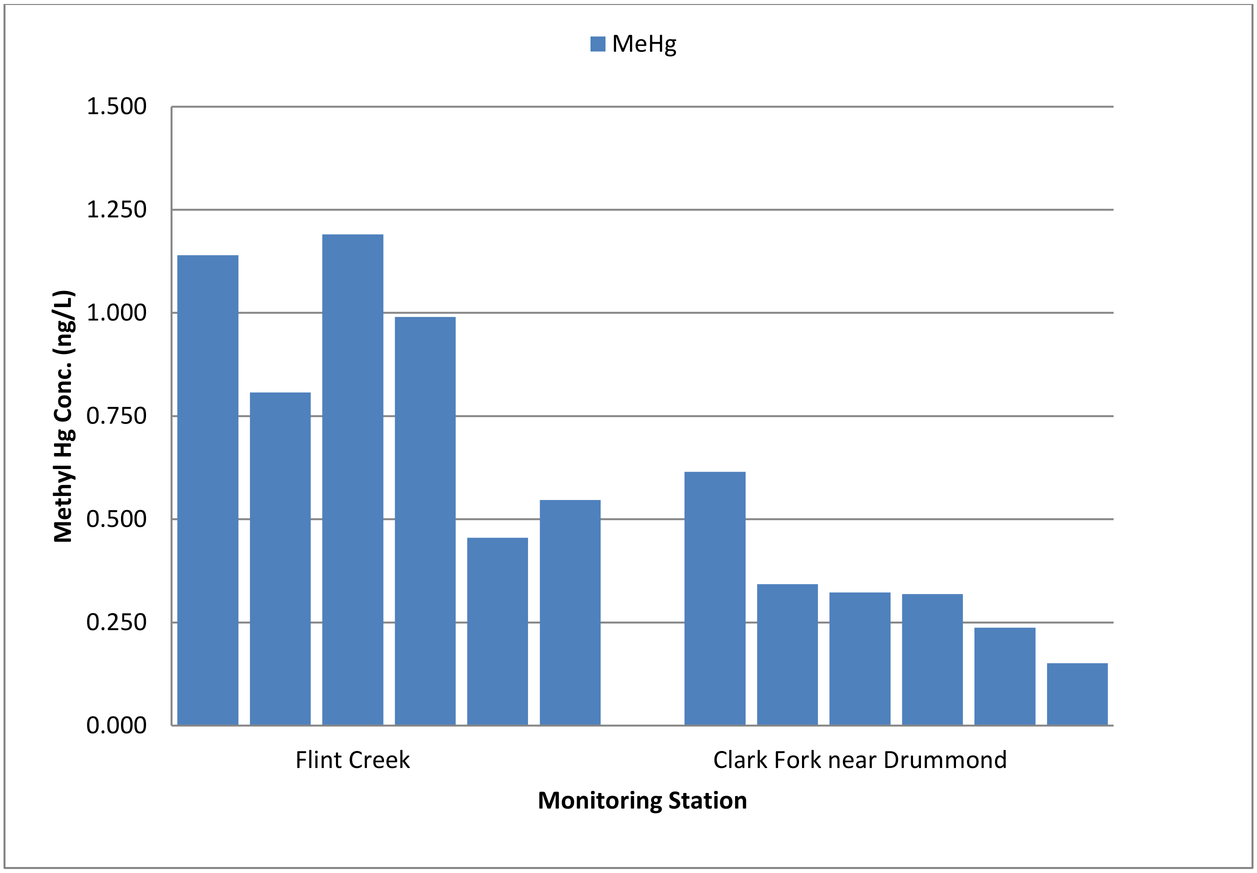

Figure 2-78. Methylmercury concentrations at sampling sites in the Clark Fork River Operable Unit, 2014.

2.3.8 Data Validation

Data derived from laboratory analysis of surface water samples collected at upper Clark Fork River locations were validated through field quality control samples (i.e., field duplicates and field blanks) and laboratory control samples (lab duplicates, blanks, spikes, and reference and calibration standards. Analysis of field quality measures are described in Appendix A. Results of laboratory quality control measures are described in Appendix B.

Analysis results for surface water field duplicate samples were within acceptable limits for the majority of chemical parameters during all quarters of 2014. In total 288 field sample and field duplicate pairs were compared and 101 of those pairs had analyte concentrations which were less than five times the reporting limit and therefore relative percent difference (RPD) comparisons were not valid according to the project QAPP [DeArment et al., 2013]. Of the remaining 187 sample and duplicate pairs, 177 (95%) had RPDs <25%. Sample and duplicate pairs with RPD >25% were total mercury (three pairs with RPDs of 34%, 37%, and 74%), methylmercury (two pairs with RPDs of 36% and 40%), total nitrogen (three pairs with RPDs of 37%, 38%, and 71%), and total suspended sediment (two pairs with RPDs of 13% and 40%).

Analyte concentrations were below reporting limits (RLs) in 267 of 288 (93%) of the field blank samples (i.e., deionized water samples prepared in the same manner as field sample) in

2014. Analyte concentrations in field blanks which exceeded the reporting limits in 2014 included dissolved organic carbon (six samples with concentrations ranging from 0.3-0.5 mg/L; RL = 0.1 or 0.5 mg/L), chloride (one sample with concentration of 7 mg/L; RL = 1 mg/L), total nitrogen (two samples with concentrations of 0.08 and 0.11 mg/L; RL = 0.05 mg/L), total phosphorus (one sample with concentration of 0.05 mg/L; RL = 0.05 mg/L), total suspended sediment (two samples with concentrations of 3 mg/L and 3 mg/L; RL = 1 mg/L), and dissolved zinc (nine samples with concentrations ranging from 0.009-0.19 mg/L; RL = 0.008 mg/L).

2.4 DISCUSSION

2.4.1 Streamflows

Streamflows in the upper Clark Fork River watershed were normal or above normal at all sites during almost all monitoring periods in 2014. The streamflows were also higher than in 2013, but much lower than some prior years such as 2011. Higher streamflows presumably contributed to slightly higher COC concentrations in 2014 compared to 2013. Average to above average streamflows also almost certainly influenced other parameters such as water temperatures, nutrient levels, conductivity, turbidity, common ion concentrations, and total suspended sediment concentrations.

2.4.2 Field Parameters

2.4.2.1 Water Temperature

Water temperature has considerable chemical and biological significance in riverine systems. Stream temperatures reflect seasonal changes in net solar radiation as well as daily changes in air temperature, and vary as a function of stream morphological characteristics, groundwater inputs, shading, the presence of particulate matter in the water column, and other variables. Optimal water temperatures for most trout species is approximately 12–14 C. Sustained temperatures in the 20–25 C temperature range can be fatal for trout.

Temperature monitoring results for the upper Clark Fork River monitoring stations during 2014 indicated modest seasonal and spatial variations that were generally within the preferred range for cold water organisms such as trout. The maximum recorded water temperature was 16.9 C at the Clark Fork River at Deer Lodge site. However, stream temperatures are extremely variable as a result of weather and diel variation and this monitoring program is not intended to capture extreme temperature swings. More detailed hourly temperature data collected by Montana Fish, Wildlife and Parks indicated that water temperatures in the Clark Fork River and tributaries are extremely stressful for trout, regularly exceeding 20 C and may occasionally exceed 25 C in the summer months at many of these sites (see Section 8.0).

2.4.2.2 Acidity

Water pH measures the acidity of water as the concentration of hydrogen ions on a logarithmic scale. Acidity is influenced by water temperature, although the relationship is not linear, and typically shows a weak inverse relationship to streamflow as concentrations of base minerals tend to become diluted during runoff conditions. Acidity typically fluctuates on a diel cycle in relation to stream metabolism, with pH highest during the day. As dissolved carbon dioxide (a weak acid) levels increase during the night (because photosynthesis does not occur), pH levels decrease. Stream pH has direct and indirect effects on water chemistry and the biota of aquatic systems. Declines in pH below 6.5 may reduce salmonid egg production and hatching, and can reduce the emergence of some aquatic insects. The solubility of some metals varies with pH. This is important in systems such as the Clark Fork River where metal concentrations in sediments are elevated. Stream pH also affects a variety of other instream chemical equilibria, for example the proportion of ammonia present in the toxic (un-ionized) form.

The Montana Department of Environmental Quality has concluded that pH levels need to be maintained within the 6.5-9.0 range to protect aquatic life. Generally, pH measured in the Clark Fork River during 2014 monitoring events was within these recommended levels. However, pH in Silver Bow Creek immediately upstream from the Clark Fork River mainstem regularly exceeds 9.0 during the summer (S. Lubick, Pioneer-Technical Services, unpublished data). Two measurements from Silver Bow Creek at Warm Springs site had pH values of 9.38 and 9.48 in Q2-Falling and Q3, while two Q3 measurements in the Clark Fork River near Galen and at Gemback Road had values of 9.04 and 9.06, respectively. It is unclear if elevated daytime pH in Silver Bow Creek below the Warm Springs Ponds and at downstream Clark Fork River mainstem sites is the result of excessive liming, diel cycles related to high productivity from nutrient enrichment, or both [Nimmick et al., 2011; Chatham, 2012].

2.4.2.3 Conductivity

Conductivity is a quantitative measure of the ability of an aqueous solution to convey an electrical current and is a function of water temperature and the concentration of dissolved ions in water. Conductivity provides an approximation of the concentration of dissolved solids in water as well as its potential suitability for uses that may be limited by excessive salinity. Conductivity also gives general insight into spatial and seasonal changes in water chemistry.

Elevated levels of conductivity reflecting high dissolved solids may limit some water uses, such as irrigation, or drinking water. Very low conductivity, as affected by watershed geology, may contribute to low productivity of associated biological systems. Conductivity tends to be inversely proportional to streamflow due to dilution from spring snowmelt runoff. Conductivity in the upper Clark Fork River in 2014 reflected seasonal variation consistent with annual snowmelt runoff. Conductivity in the Clark Fork River mainstem in 2014 ranged from 168-579 µS/cm. In comparison, the USEPA states, “Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a (conductivity) range between 150 and 500 µS/cm” [USEPA, 2015].

2.4.2.4 Dissolved Oxygen

Dissolved oxygen refers to the amount of oxygen dissolved in water. The capacity of water to hold oxygen in solution is inversely proportional to water temperature. In addition to water temperature, instream dissolved oxygen concentrations are affected by respiration of organisms, photosynthesis of aquatic plants, the biochemical oxygen demand of substances in the water, and the dissolution of atmospheric oxygen in the water by rapid movement. Dissolved oxygen levels fluctuate seasonally and over diel cycles due to variation in rates of stream metabolism.

Acceptable levels of dissolved oxygen for the protection of aquatic life are defined in the Montana water quality standards [MDEQ, 2012b]. Values that apply to the upper Clark Fork River range from a high of 9.5 mg/L, measured as a seven-day mean concentration where sensitive early life stages are present, to a low of 4.0 mg/L measured as a one day minimum for settings where other than early life stages of aquatic life are present [MDEQ, 2012b].

Adequate levels of dissolved oxygen are required by biological stream communities and for the decomposition of organic matter in the stream. No dissolved oxygen measurements in the CFROU in 2014 indicated water quality or water use limitations associated with low oxygen concentrations (overall range of 8.3-15.2 mg/L). However, the lowest dissolved oxygen concentrations generally occur in the pre-dawn hours and monitoring occurred in the daytime at all sites.

2.4.2.5 Turbidity

Turbidity refers to the amount of light that is absorbed or scattered by water, and is an optical property of water. Increasing turbidity or "cloudiness" in surface waters usually results from the presence of suspended silt or clay particles, organic matter, colored organic compounds, and microorganisms. Turbidity does not always correlate well with the weight of suspended matter in solution because of different particle sizes, weights and refractive properties of the substances that contribute to turbidity.

Elevated turbidity levels can impede recreational and aesthetic uses of water, and turbidity is an important parameter for drinking water. High turbidity adversely affects feeding, growth, and suitable habitat of salmonid fishes, and it may contribute to increases in surface water temperatures. The MDEQ has established maximum allowable increases above naturally occurring turbidity. The allowable increase is 10 nephelometric turbidity units (NTU) for C-2 class streams (Clark Fork River from Warm Springs Creek to Cottonwood Creek), and five units for C-1 (Clark Fork River from Cottonwood Creek to the Little Blackfoot River) and B-1 (remainder of Clark Fork) class streams [ARM 17.30.623, 2007; ARM 17.30.626–627, 2007].

Turbidity during the 2014 Q1 monitoring event was significantly elevated compared to other monitoring events presumably due to an early lowland snowmelt runoff event prior to sampling. Although the hydrograph had declined from earlier highs during the Q1 monitoring event, streamflows were still higher than normal for that time of the year. Turbidity was generally low during the other five monitoring events. One exception to this pattern was Mill-Willow Creek at Frontage Road which had elevated turbidity in Q4, the cause of which is unknown.

2.4.3 Total Suspended Sediment

Suspended sediment refers to sediment suspended in the water column, as opposed to sediment transported along the stream bottom, which is known as bedload. Suspended sediment in streams generally includes a range of particle sizes which will vary with watershed geology, stream velocity, bed form, and turbulence. Excess fine sediment interferes with most water uses and has particularly adverse effects on benthic invertebrate and salmonid fish growth and reproduction. Increased suspended sediment can reduce light penetration and affect primary production by aquatic plants, and may affect the morphology of alluvial stream channels. In the Clark Fork River system, transport of many of the COCs is directly correlated with suspended sediment.

Total suspended sediment concentrations during most 2014 sampling events at most sites were similar to prior years and generally as expected given streamflow conditions. Spatial and seasonal patterns were similar to those for turbidity, with highest total suspended sediment concentrations observed in Q1. Mill-Willow Creek at Frontage Road also had greatly elevated total suspended sediment in Q4, as was noted for turbidity. The source of that apparently episodic, localized event remains unknown.

2.4.4 Common Ions

Common ions describe basic water chemistry. Certain ions, such as sulfate, may indicate the presence of mine related contaminants. Calcium and magnesium ions contribute to water hardness, which helps to buffer the toxic effects of some metals. Aquatic life toxicity criteria for metal COCs vary directly in relation to hardness. Hardness mitigates metals toxicity by impeding the rate at which aquatic organisms absorb metals through the gills. Carbonate and bicarbonate alkalinity contribute to the buffering system of surface waters to resist changes in pH. Levels of water hardness and alkalinity also strongly influence the productivity of aquatic systems. Western freshwater fisheries typically have alkalinity of 100–200 mg/L. In 2014, the Clark Fork mainstem alkalinity ranged from 68-170 mg/L. Based on previous monitoring, calcium is the dominant cation at the upper Clark Fork River monitoring network stations.

Water hardness at the Clark Fork River mainstem stations in 2014 would be categorized as "hard" to "very hard" except during major runoff conditions. In comparison, most rivers in western Montana have "moderately hard" to "hard" water [USGS, 2015a]. The moderately elevated water hardness in the Clark Fork River relative to other regional rivers is likely beneficial overall for aquatic life because water hardness mitigates toxicity of heavy metals [USEPA, 1986]. Moderate alkalinity in the upper mainstem Clark Fork River reflect a well buffered system, with good potential for fish production barring other limitations. Sulfate is the second most prevalent anion in the upper Clark Fork River watershed, behind bicarbonate.

2.4.5 Nutrients

Numeric water quality standards have been adopted for nutrients in the Clark Fork River from the Warm Springs Creek confluence to the Blackfoot River confluence, a river section which encompasses most of the CFROU (ARM 17.30.631). The standards apply only to the summer season (June 21 through September 21). The standards for this segment of the Clark Fork River are 0.300 mg/L for total nitrogen and 0.020 mg/L for total phosphorus (ARM 17.30.631). The standards do not apply to sample sites located on tributaries to the Clark Fork River. Instead, summertime base numeric nutrient standards for the Middle Rockies Ecoregion apply to the tributaries during the July 1 to September 30 time period. These standards are 0.300 mg/L for total nitrogen and 0.030 mg/L for total phosphorus [MDEQ, 2014b].

Total nitrogen concentrations were highest during the Q1 and Q4 monitoring events. The maximum total nitrogen concentrations were observed in the Clark Fork River at Deer Lodge and in Silver Bow Creek at Warm Springs in Q1. The Clark Fork River at Deer Lodge site exceeded the total nitrogen water quality standard in Q2-Falling and Q3. No other mainstem or tributary sites exceeded the relevant total nitrogen standards during 2014 monitoring events.

Concentrations of total phosphorus were highest in the Clark Fork River at Turah, Silver Bow Creek at Warm Springs, and Flint Creek near its mouth, all during the Q1 2014 monitoring event. All of the Clark Fork River mainstem monitoring sites, plus Silver Bow Creek at Warm Springs and Flint Creek near its mouth, exceeded the summertime total phosphorus water quality standard in either or both of the applicable Q2-Falling (late-June) and Q3 (September) monitoring events.

Ammonia concentrations exceeded the chronic toxicity aquatic life standard in Silver Bow Creek at Warm Springs during the Q1 2014 monitoring event. Since no ammonia was detected upstream in the Mill-Willow Bypass, we assume the high level of ammonia in Silver Bow Creek originated from the Warm Springs Pond discharge. The streamflow in Mill-Willow Bypass on March 19 was 22.63 cfs, compared to 143.63 cfs in Silver Bow Creek at Warm Springs. Therefore, the Pond 2 discharge streamflow was approximately 121 cfs. These exceedances occurred in the spring and may have occurred in association with dimictic mixing (lake overturning) in the Warm Springs Ponds although. Ammonia had not previously been detected at any of the mainstem Clark Fork River monitoring stations in any other monitoring event since 2011.

2.4.6 Contaminants of Concern

Surface water monitoring data collected in 2014 represent the fifth year of monitoring in the CFROU. Remediation activities in the CFROU began in early 2013. Active remediation was in progress in the uppermost 1.6 mile reach of the Clark Fork River (Phase 1 of Reach A), immediately downstream from the Warm Springs confluence, through 2013. The Phase 1 cleanup activities were completed on April 4, 2014. Additional vegetation was planted in April, May and in the fall of 2014. This portion of the river, from just below the Warm Springs Ponds and running 1.2 miles north of the Morel Road Bridge, is closed to the public until September 15, 2015. This closure includes the floodplain and streambanks.

Overall, Reach A, extending from the Warm Springs Creek confluence to the Little Blackfoot River confluence, has the largest volume of streamside tailings in the CFROU. In particular, the uppermost portion of the river located upstream from the town of Deer Lodge has been identified as an area of relatively heavy COC loading to the Clark Fork River [Sando et al., 2014]. Construction work for Phases 5 and 6 began in summer 2014. Phases 5 and 6 involve two private landowners and cleanup on working ranches. The remediation project will consist of tailings removal on 4.5 river miles and is scheduled to last 400 calendar days. As of December 2014, 50,000 cubic yards of contaminated material had been removed from the Clark Fork River floodplain and over 5,000 linear feet of stream banks had been rebuilt. In addition, internal haul roads have been completed and on-site borrow areas have been developed. This phase will continue through winter 2015 with an anticipated completion date of Fall 2015. MDEQ is currently working with private landowners and the Grant-Kohrs Ranch on the Preliminary Design Plans for Phases 2, 7, 15 and 16. These plans begin to lay out the design for the phases where future remediation work will be conducted.

Monitoring from 2010-2012 represented baseline conditions in the CFROU, immediately prior to the start of remediation. Because remedial activities were just beginning in 2013, it was considered unlikely that monitoring in 2013 would demonstrate much change in COC levels in the river. The 2014 monitoring was the first year following complete cleanup of the Phase 1 project area.

In 2014, exceedances of performance goals were rare for all COCs except arsenic and copper. Of 30 samples collected in the Clark Fork River in 2014 (from five sites during six sample periods) no samples (0%) had zinc concentrations exceeding the performance goal, only one sample (3%) had cadmium concentrations exceeding the performance goal, and only four (13%) had lead concentrations exceeding the performance goal.

Arsenic commonly exceeded the performance goals in 2014 in mainstem sites in Reach A. Of 24 samples collected in the Clark Fork River in Reach A (four sites during six sample periods), 96% exceeded the dissolved arsenic and 46% exceeded the total recoverable arsenic performance goals [USEPA, 2004]. Silver Bow Creek and the Mill-Willow Creek were clearly sources of arsenic to the Clark Fork River as 94% (17 of 18) samples from those sites exceeded the dissolved arsenic and 78% (14 of 18) exceeded the total recoverable performance goals in those sites [USEPA, 2004]. These results support findings of the USGS monitoring program. Recent analysis by the USGS identified the Warm Springs Ponds, the Mill-Willow Bypass, and groundwater in the vicinity of the Warm Springs Ponds as substantial arsenic sources to the upper Clark Fork River [Sando et al., 2014].

In addition to arsenic contamination in the Clark Fork River mainstem in 2014, total recoverable copper exceeded the chronic ALS in the mainstem Clark Fork River sites in 95% (19 of 20) of the samples collected in Q1 and Q2, but only at Deer Lodge in Q3 and Q4. In Q1 and Q2, total recoverable copper exceeded the acute ALS in 70% (14 of 20) of the samples. These results support conclusions of Sando et al. [2014] that the Clark Fork River reach upstream from Deer Lodge is a major source of copper loading and copper concentrations throughout the river are strongly related to streamflows.

2.4.7 Other Metals

Monitoring data continues to implicate Flint Creek as a primary source of mercury and methylmercury to the Clark Fork River. Mercury concentrations in Flint Creek exceeded the HHSWS [MDEQ, 2012b] during all sample periods, by as much as 8.0 times in Q1. In the Clark

Fork River near Drummond, the mercury HHSWS was only exceeded in Q1. Methylmercury concentrations were typically 2-3 times higher in Flint Creek compared to the Clark Fork River near Drummond.

2.4.8 Data Validation

Generally, this monitoring program has satisfied the data quality objectives and data quality indicators specified in the QAPP [DeArment et al., 2013]. However, quality control procedures have consistently demonstrated that trace level contamination of dissolved field samples with zinc occurs. We continue to suspect that the field filtering apparatus is responsible for the zinc contamination and over the last two years we have implemented additional steps in an attempt to reduce zinc contamination in the dissolved samples. Beginning in Q4 2012, all field filters were rinsed with deionized water prior to filtration of dissolved samples. However, this approach did not reduce the frequency of dissolved zinc contamination in 2013. In 2014, all dissolved sample bottles, field filters, and syringes were triple rinsed with laboratory pure deionized water stored only in sterilized glass bottles in a further attempt to reduce zinc contamination in filtered samples. This approach also does not appear to have reduced zinc contamination in the dissolved samples; zinc was still detected at concentrations above the reporting limits in 75% (9 of 12) of the field blanks in 2014. This rate of zinc detections in the dissolved blanks was higher than in prior years and this was partially due to a reduced analytical reporting limit for zinc in 2014 (from 0.01 mg/L in 2013 to 0.008 mg/L in 2014). However, even at the prior reporting limit (0.01 mg/L) 58% (7 of 12) of the dissolved field blank samples in 2014 would have had detectable levels of zinc. It is worth noting that although the contamination of dissolved samples with zinc introduces a slight positive bias (i.e., reported dissolved zinc concentrations are higher than what actually occurs in the river), all field sample dissolved and total recoverable zinc concentrations were well below the performance goals in 2014 indicating that the zinc contamination in the dissolved samples is minimal relative to the action levels.

3.0 SEDIMENT

3.1 INTRODUCTION

No specific remediation performance standards were established within the CFROU ROD for concentrations of COC metals in instream sediments [USEPA, 2004]. In lieu of performance standards the "threshold effect concentration" (TEC) and "probable effect concentration" (PEC), consensus-based sediment quality guidelines for benthic organisms [MacDonald et al., 2000], provide useful reference values for instream sediment quality [Table 3-1]. At metal COC concentrations above the TEC, benthic organisms may be affected by that COC. At metal COC concentrations above the PEC, benthic organisms are likely to be affected by that COC.

Remedial actions within the CFROU to remove floodplain tailings deposits and reduce streambank erosion are expected to result in reduced COC concentrations in instream sediments within the Clark Fork River. Therefore, instream sediment COC concentrations will be monitored in the CFROU prior to, during, and following remediation. This report reviews spatial and temporal trends in instream sediment metals concentrations in the CFROU during the 2014 and prior monitoring years.

Table 3-1. Reference values for contaminant of concern (COC) concentrations (expressed as dry weight concentrations [DW]) in instream sediments within the Clark Fork River Operable Unit. The threshold effect concentration (TEC) and probable effect concentration (PEC) were described in MacDonald et al. [2000].

Contaminant of Concern	Threshold Effect Concentration (mg/kg-DW)	Probable Effect Concentration (mg/kg-DW)
Arsenic	9.79	33
Cadmium	0.99	4.98
Copper	31.6	149
Lead	35.8	128
Zinc	121	459

3.2 METHODS

3.2.1 Monitoring Locations

Instream sediment was monitored at 14 CFROU sites in 2014 [Table 3-2; Figure 3-1]. The monitoring network includes six sites on the Clark Fork River mainstem and eight sites on tributary streams [Table 3-2]. The monitoring site locations in 2014 were the same as the monitoring site locations in 2013. However, monitoring sites changed between 2012 and 2013 to provide a more detailed spatial representation of the Clark Fork River mainstem in Reach A. Additionally, some sites were removed from the monitoring network to avoid duplication of water quality sampling efforts by the USGS. A record of changes to this monitoring program since monitoring began in 2010 is provided in Appendix A of the project sampling and analysis plan [Naughton et al., 2014].

Table 3-2. Instream sediment sampling locations in the Clark Fork River Operable Unit, 2014.

Site ID	Site Location	Co-located USGS Streamflow Gauge	Location (GPS coordinates, NAD 83)	
			Latitude	Longitude
Mainstem Sites				
CFR-03A	Clark Fork River near Galen	12323800	46.20877	-112.76740
CFR-07D	Clark Fork River at Galen Road	none	46.23725	-112.75302
CFR-11F	Clark Fork River at Gemback Road	none	46.26520	-112.74430
CFR-27H	Clark Fork River at Deer Lodge	12324200	46.39796	-112.74283
CFR-84F	Clark Fork River near Drummond	12331800	46.71204	-113.33137
CFR-116A	Clark Fork River at Turah	12334550	46.82646	-113.81424
Tributary Sites				
SS-25	Silver Bow Creek at Warms Springs	12323750	46.18123	-112.77917
MCWC-MWB	Mill-Willow Creek at Frontage Road	none	46.12649	-112.79876
MWB-SBC	Mill-Willow Bypass near mouth	none	46.17839	-112.78270
WSC-SBC	Warms Springs Creek near mouth	12323770	46.18041	-112.78592
LC-7.5[9]	Lost Creek near mouth	12323850	46.21862	-112.77384
RTC-1.5[10]	Racetrack Creek near mouth	none	46.28395	-112.74921
LBR-CFR[11]	Little Blackfoot River near Garrison	12324590	46.51964	-112.79312
FC-CFR	Flint Creek near mouth	12331500	46.62891	-113.15151

[9] In 2013, LC-7 (GPS Location: 46.22665, -112.76017) was replaced LC-7.5. Site LC-7 was replaced because it appeared to be located within the Clark Fork River floodplain.

[10] In 2013, RTC-1 (GPS Location: 46.28406, -112.74484) was replaced by RTC-1.5. Site RTC-1 was replaced because IT appeared to be located within the Clark Fork River floodplain.

[11] Site LBR-CFR was replaced by site LBR-CFR-02 (GPS Location: 46.53710, -112.72443) on June 24, 2014.

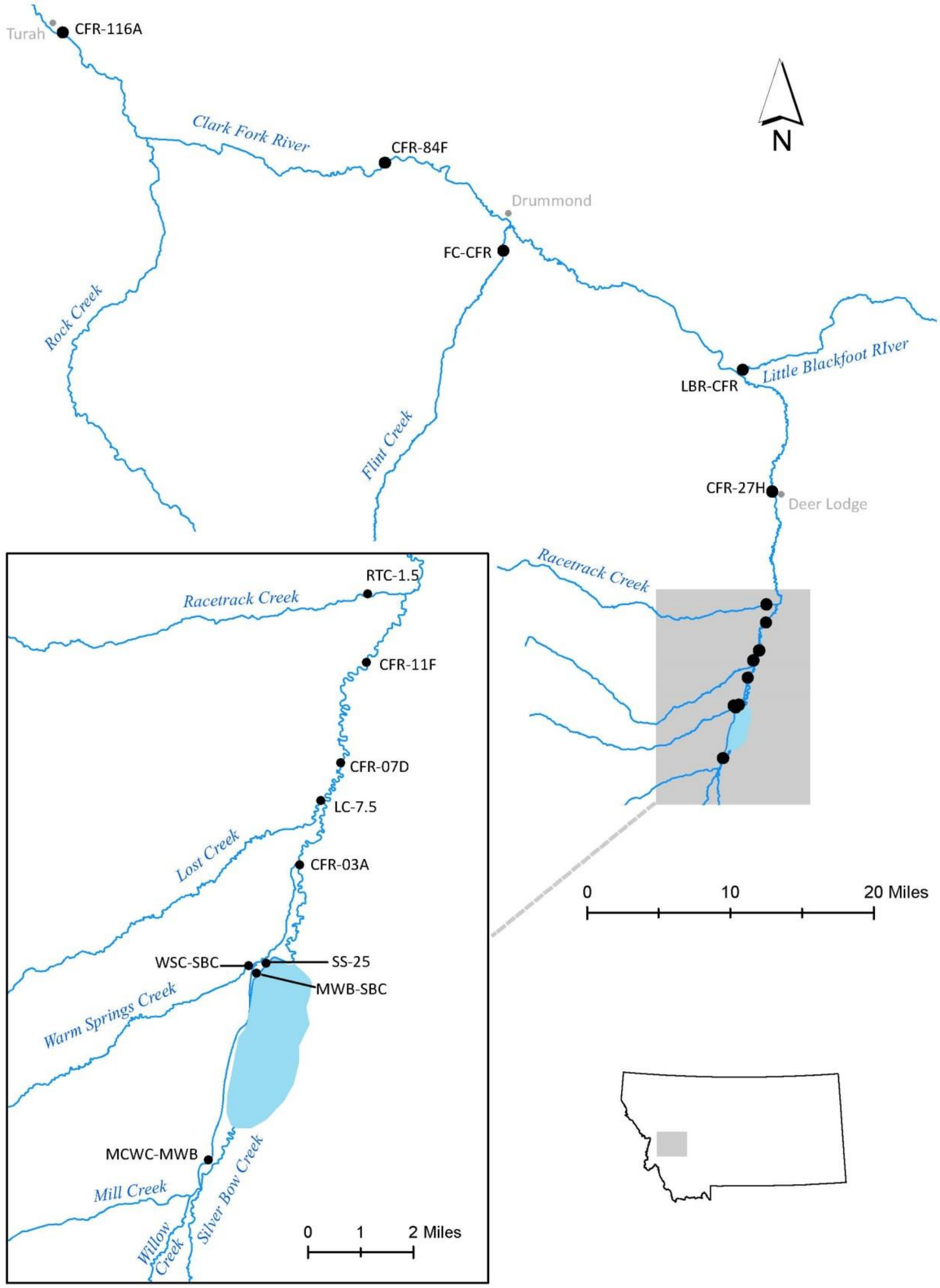

Figure 3-1. Instream sediment sampling locations in the Clark Fork River Operable Unit, 2014.

3.2.2 Monitoring Schedule

At least one surface water monitoring event occurred during each calendar quarter of 2014. Instream sediment samples were collected during the first quarter (Q1) and third quarter (Q3) surface water monitoring events. Each quarterly monitoring event occurred near the end of each quarter, except during the second quarter (Q2). The first monitoring event (Q1) occurred in the late winter, prior to spring runoff, from March 18-19. Three monitoring events were conducted in Q2 to capture the rising (Q2-Rising), peak (Q2-Peak), and falling (Q2-Falling) portions of the spring runoff hydrograph. The Q2 monitoring events were conducted on May 13-14 (Q2-Rising), June 10-11 (Q2-Peak), and June 24-25 (Q2-Falling). The late summer (Q3) monitoring event was scheduled during low streamflow conditions on September 16-17. The late fall (Q4) monitoring event occurred on December 1-2.

3.2.3 Monitoring Parameters

Instream sediment samples were analyzed for wet weight (WW) and dry weight (WW) total extractable metal (arsenic, cadmium, copper, lead, and zinc) concentrations.

3.2.4 Sample Collection and Analysis

Sediment samples were collected by compositing subsamples from at least five deposition zones in wadeable locations at each monitoring site. Sediment was scooped from the streambed with a plastic spoon following the MDEQ standard operating procedure [MDEQ, 2012a]. The fine fraction (particle diameter <0.065 mm) portion of each sample was isolated from each composite sample by wet sieve in the laboratory shortly after collection and retained for analysis of metal concentrations. Each sample was analyzed for total extractable wet weight concentrations (mg/kg-WW) and dry weight concentrations (mg/kg-DW) of arsenic, cadmium, copper, lead, and zinc following methods identified in Table 3-3. The relative proportion (by weight) of the fine fraction sediment in each sample was also determined. Sediment samples were analyzed by Energy Laboratories (Helena, Montana). Prior to 2013, each sediment sample was sieved into three size fractions (<0.065 mm, 0.065–1 mm, and 1–2 mm), and each size fraction was independently analyzed for metal concentrations.

From 2010-2013, all CFROU sediment metals samples have been analyzed on a wet weight (WW) basis. Wet weight analyte concentrations are normally lower than dry weight (DW) analyte concentrations because the sample drying process reduces the total mass of the sample without reducing the mass of the analyte. The TEC and PEC sediment performance goals are expressed on a DW basis. In 2014, the sediment samples were analyzed for both WW and DW concentrations to allow direct comparison with the TEC and PEC reference values. In addition, analysis of both WW and DW concentrations in the CFROU in 2014 will provide data to inform estimation of DW concentrations from measured WW concentrations when the corresponding DW concentration was not measured (i.e., all CFROU sediment samples from 2010-2013). This analysis was conducted using the CFROU and Streamside Tailings Operable Unit data [Ingman et al., 2015a]. Wet weight COC concentrations from 2014 monitoring in the CFROU are presented in Appendix D.

Table 3-3. Sediment analysis methods for determination of metals concentrations in the Clark Fork River Operable Unit, 2014.

Parameter	Category	Method
Arsenic	Contaminant of Concern	SW6020 or SW6010B
Cadmium		SW6020 or SW6010B
Copper		SW6020 or SW6010B
Lead		SW6020 or SW6010B
Zinc		SW6020 or SW6010B

3.2.5 Data Analysis

Data were analyzed to assess spatial and temporal patterns in sediment COC concentrations. In addition, COC concentrations at each sample site were compared to the TEC and PEC reference values [Table 3-1] to assess exceedances.

Analysis of both WW and DW concentrations in the CFROU in 2014 provided data to inform estimation of DW concentrations from measured WW concentrations when the corresponding DW concentration was not measured (i.e., all CFROU sediment samples from 2010-2013). This analysis was conducted using the CFROU and Streamside Tailings Operable Unit data in 2014 [Ingman et al., 2015a].

3.2.6 Data Validation

Data quality objectives (DQOs) were established in the CFROU quality assurance project plan (QAPP) for “data representativeness”, “comparability”, “completeness”, “sensitivity”, “precision”, “bias”, and “accuracy” [DeArment et al., 2013]. Methods for field and laboratory quality assurance and quality control (QA/QC) procedures are also described in detail in the project QAPP. A completed QA/QC checklist, summary tables of field duplicate and field blank results, and assessments of data quality objectives are included in Appendix A.

Variability in sediment metals concentrations among samples was assessed by comparing field duplicate samples to field samples. Field duplicate samples were collected at the same location and at the same time as field samples and were processed and analyzed by the same methods. The relative percent difference (RPD) between the concentration in the field duplicate and field sample pair was determined for each metal. Two field duplicate samples were collected during each sampling event and RPD statistics were calculated for each field duplicate and field sample pair.

3.3 RESULTS

3.3.1 Sample Size Fraction

The proportion of sediment by size fraction in each 2014 CFROU sediment sample is displayed in Table 3-4.

Table 3-4. Proportion of each sample collected in the Clark Fork River Operable Unit composed of fine fraction (<0.065 mm) sediment particles, 2014.

Site ID	Site Location	Sample proportion (%)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	31.8	6.9
CFR-07D	Clark Fork River at Galen Road	15.7	3.5
CFR-11F	Clark Fork River at Gemback Road	6.2	7.7
CFR-27H	Clark Fork River at Deer Lodge	33.4	1.2
CFR-116A	Clark Fork at Turah	41.4	26.7
Tributary Sites			
SS-25	Silver Bow Creek at Warm Springs	3.6	3.5
MCWC-MWB	Mill-Willow Creek at Frontage Road	2.0	1.8
MWB-SBC	Mill-Willow Bypass near mouth	2.3	1.2
WSC-SBC	Warm Springs Creek near mouth	2.9	22.8
LC-7.5	Lost Creek near mouth	11.6	3.0
RTC-1.5	Racetrack Creek near mouth	0.6	1.1
LBR-CFR	Little Blackfoot River near Garrison	8.4	2.4

3.3.2 Contaminants of Concern

3.3.2.1 Arsenic

The spatial trend for sediment arsenic concentrations at mainstem Clark Fork River monitoring sites was a decrease in concentrations from the near Galen site to the Turah site [Figure 3-2]. This spatial pattern was in contrast to the trend observed in 2013, when concentrations increased from near Galen to Deer Lodge, then declined at Turah [Ingman et al., 2015b]. Among the tributary stations that were monitored in 2014, the Mill-Willow Bypass showed the highest sediment arsenic concentrations, followed by Silver Bow Creek at Warm Springs and Mill-Willow Creek at the Frontage Road [Figure 3-3]. Mill-Willow Bypass had similar sediment arsenic concentrations to the Clark Fork near Galen, and these two sites represented the highest values observed among the sites examined in 2014. The Little Blackfoot River had the lowest sediment arsenic concentrations of all the sites.

There was no clear seasonal pattern for sediment arsenic concentrations at the mainstem and tributary monitoring stations in 2014. Concentrations were generally similar during each of the Q1 and Q3 monitoring events, with some exceptions.

Dry weight sediment arsenic concentrations exceeded the dry weight based TEC and PEC monitoring benchmarks at all mainstem Clark Fork River sites, and at all of the tributary sites except the Little Blackfoot River and Racetrack Creek, during both 2014 monitoring events [Table 3-5]. The Little Blackfoot River exceeded the TEC but not the PEC during both 2014 monitoring events. Racetrack Creek exceeded the PEC during the Q1 event, and the TEC during the Q3 event. Of the five COC sediment metals evaluated, arsenic showed the highest overall frequency of exceedances of the PEC at the CFROU monitoring sites during the 2014 monitoring events.

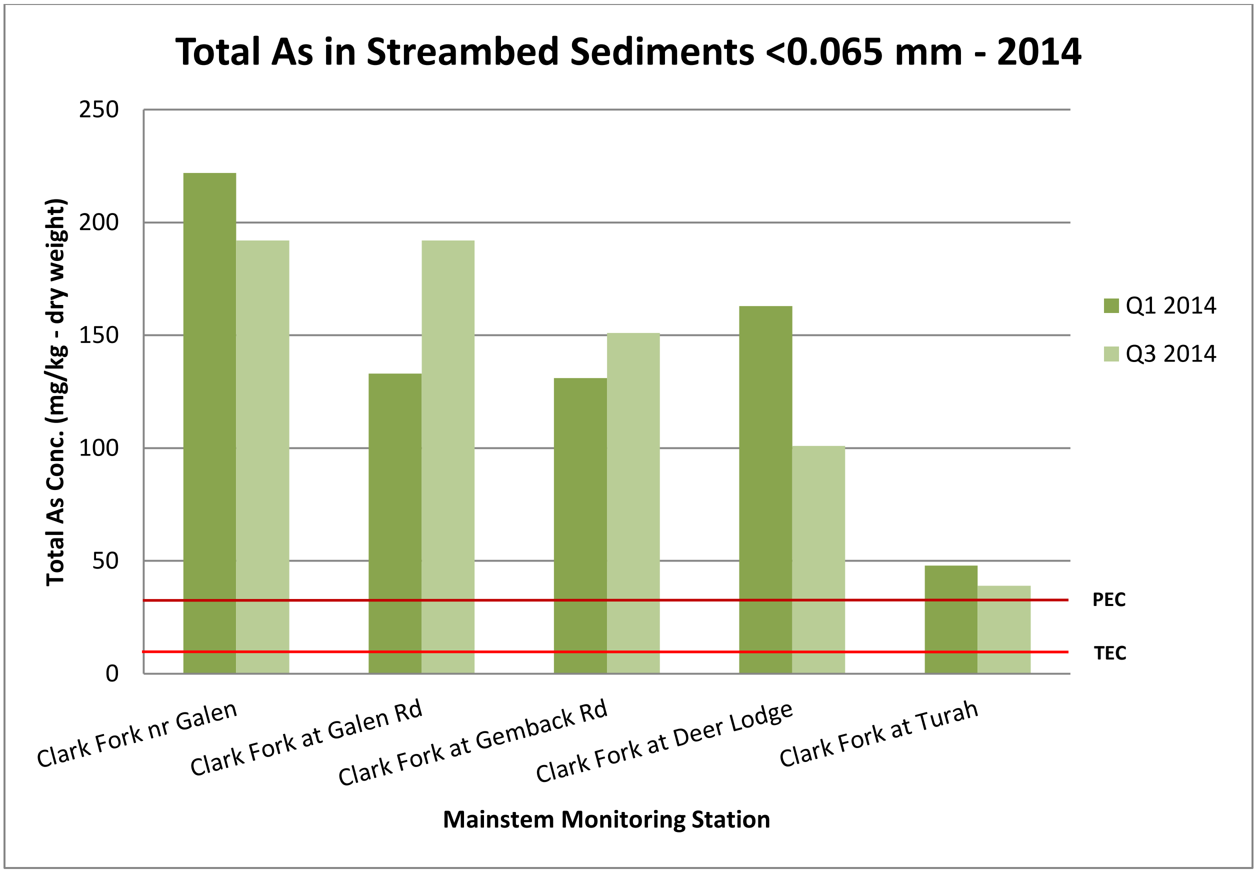

Figure 3-2. Total arsenic concentrations (dry weight) in Clark Fork River mainstem sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

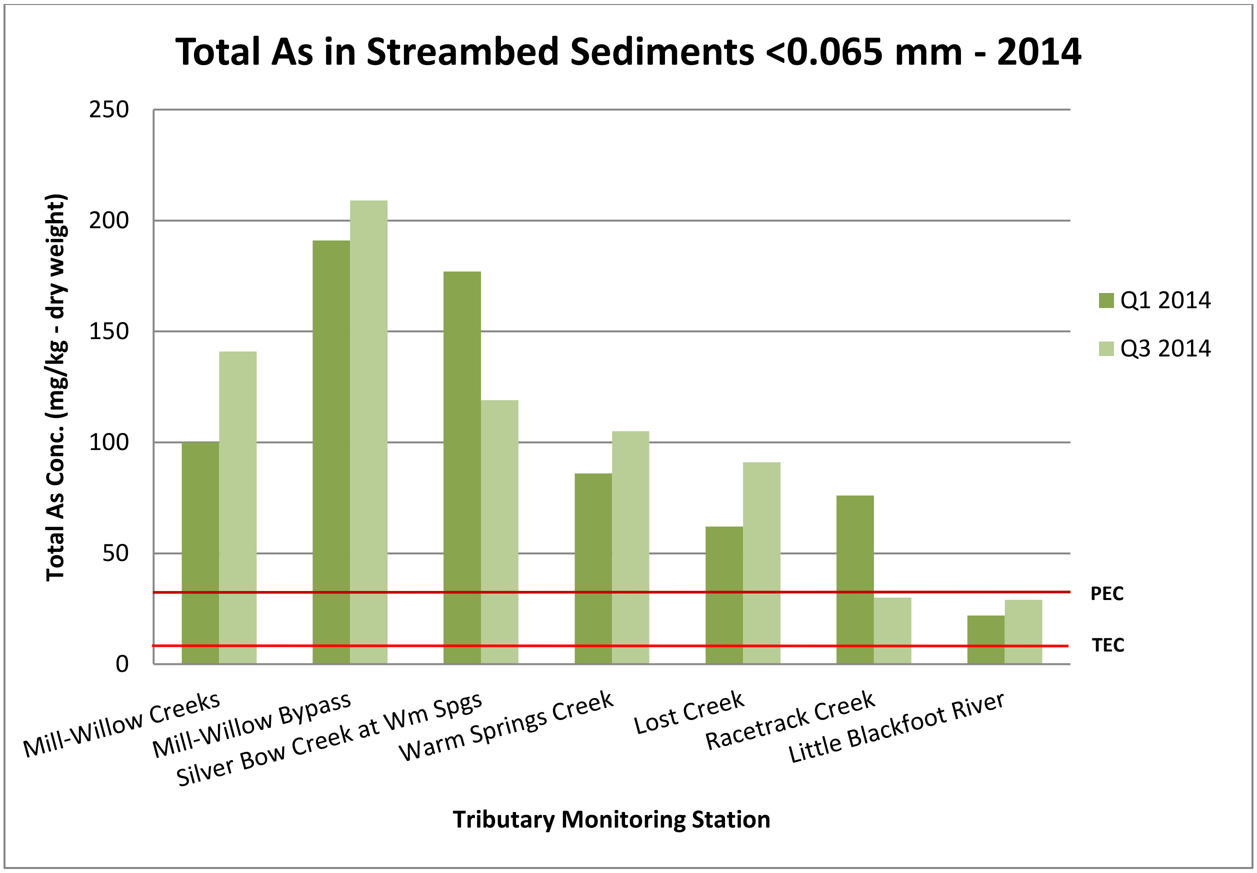

Figure 3-3. Total arsenic concentrations (dry weight) in Clark Fork River tributary sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

Table 3-5. Total arsenic concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2014.

Site ID	Site Location	Sample concentration (mg/kg-DW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	222	192
CFR-07D	Clark Fork River at Galen Road	133	192
CFR-11F	Clark Fork River at Gemback Road	131	151
CFR-27H	Clark Fork River at Deer Lodge	163	101
CFR-116A	Clark Fork at Turah	48	39
Tributary Sites			
SS-25	Silver Bow Creek at Warm Springs	177	119
MCWC-MWB	Mill-Willow Creek at Frontage Road	100	141
MWB-SBC	Mill-Willow Bypass near mouth	191	209
WSC-SBC	Warm Springs Creek near mouth	86	105
LC-7.5	Lost Creek near mouth	62	91
RTC-1.5	Racetrack Creek near mouth	76	30
LBR-CFR	Little Blackfoot River near Garrison	22	29

(yellow)	Exceeds threshold effect concentration [MacDonald et al., 2000].
(red)	Exceeds probable effect concentration [MacDonald et al., 2000].

3.3.2.2 Cadmium

The spatial trend for sediment cadmium concentrations at mainstem Clark Fork River monitoring sites was variable with no consistent trend. Highest concentrations were observed at the uppermost site near Galen. Lower and similar concentrations were observed at the next two sites at Galen Road and Gemback Road. Intermediate concentrations were measured at the Deer Lodge site, and lowest mainstem concentrations were measured at the Turah site [Figure 3-4].

Among the tributary stations monitored in 2014, the upper three sites on Mill-Willow Creek at Frontage Road, Mill-Willow Bypass, and Silver Bow Creek at Warm Springs showed the highest sediment cadmium concentrations [Figure 3-5]. These three tributary sites had similar sediment cadmium concentrations to the Clark Fork near Galen, and these four sites collectively represented the highest values observed among the 12 sites examined in 2014. The Little Blackfoot River had the lowest sediment cadmium concentrations of all the sites, followed by Racetrack Creek.

There was no clear seasonal pattern for sediment cadmium concentrations at the mainstem and tributary monitoring stations in 2014. Concentrations were generally similar during each of the Q1 and Q3 monitoring events.

Sediment cadmium concentrations exceeded the TEC reference values at all mainstem Clark Fork River sites, and at all of the tributary sites, during both 2014 monitoring events [Table 3-6]. All of the mainstem Clark Fork River sites, except Turah, exceeded the PEC during at least one of the two monitoring events. The upper three tributary sites (Mill-Willow Creek, Mill-Willow Bypass, and Silver Bow Creek at Warm Springs) exceeded the PEC during both 2104 monitoring events. Of the five COC sediment metals evaluated, cadmium showed the lowest overall frequency of exceedances of the PEC at the CFROU monitoring sites during the 2014 monitoring events.

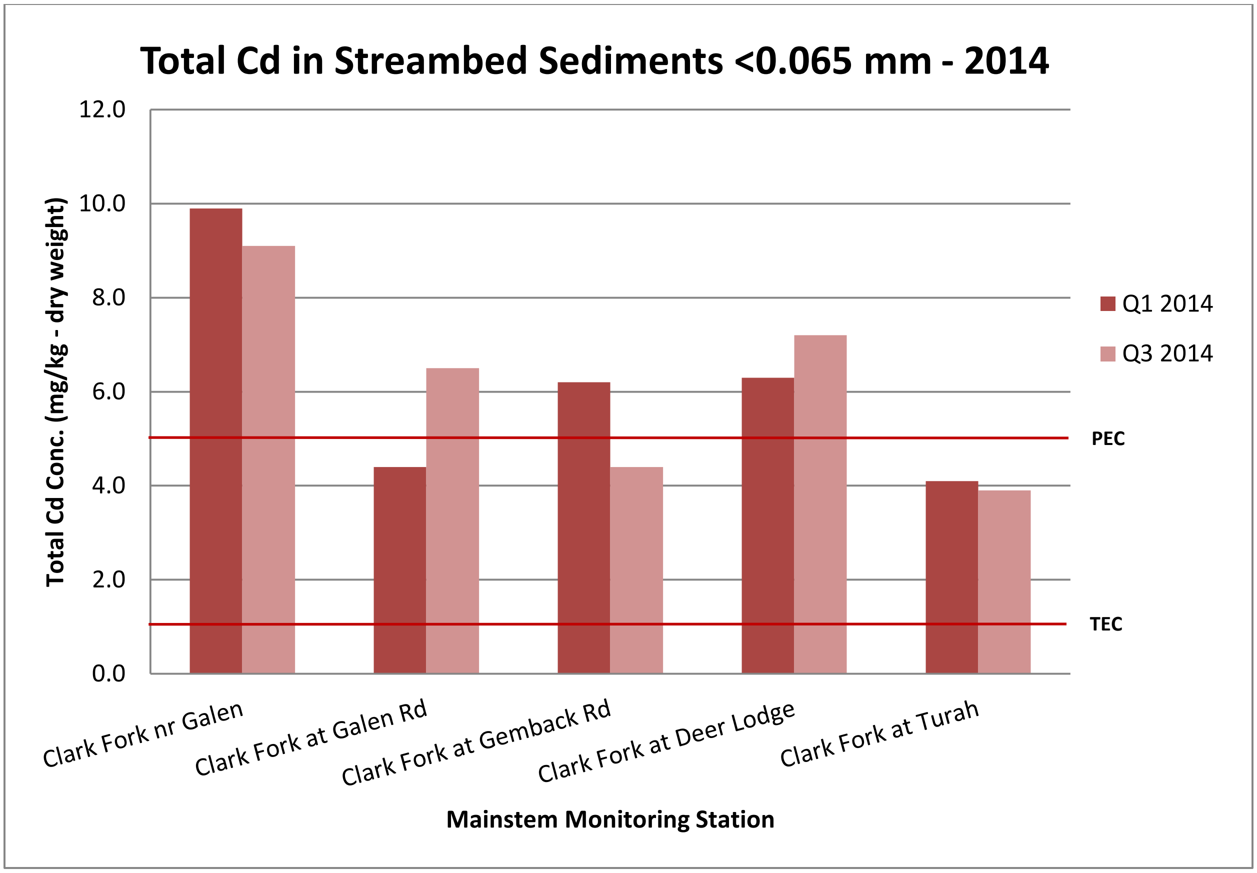

Figure 3-4. Total cadmium concentrations (dry weight) in Clark Fork River mainstem sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

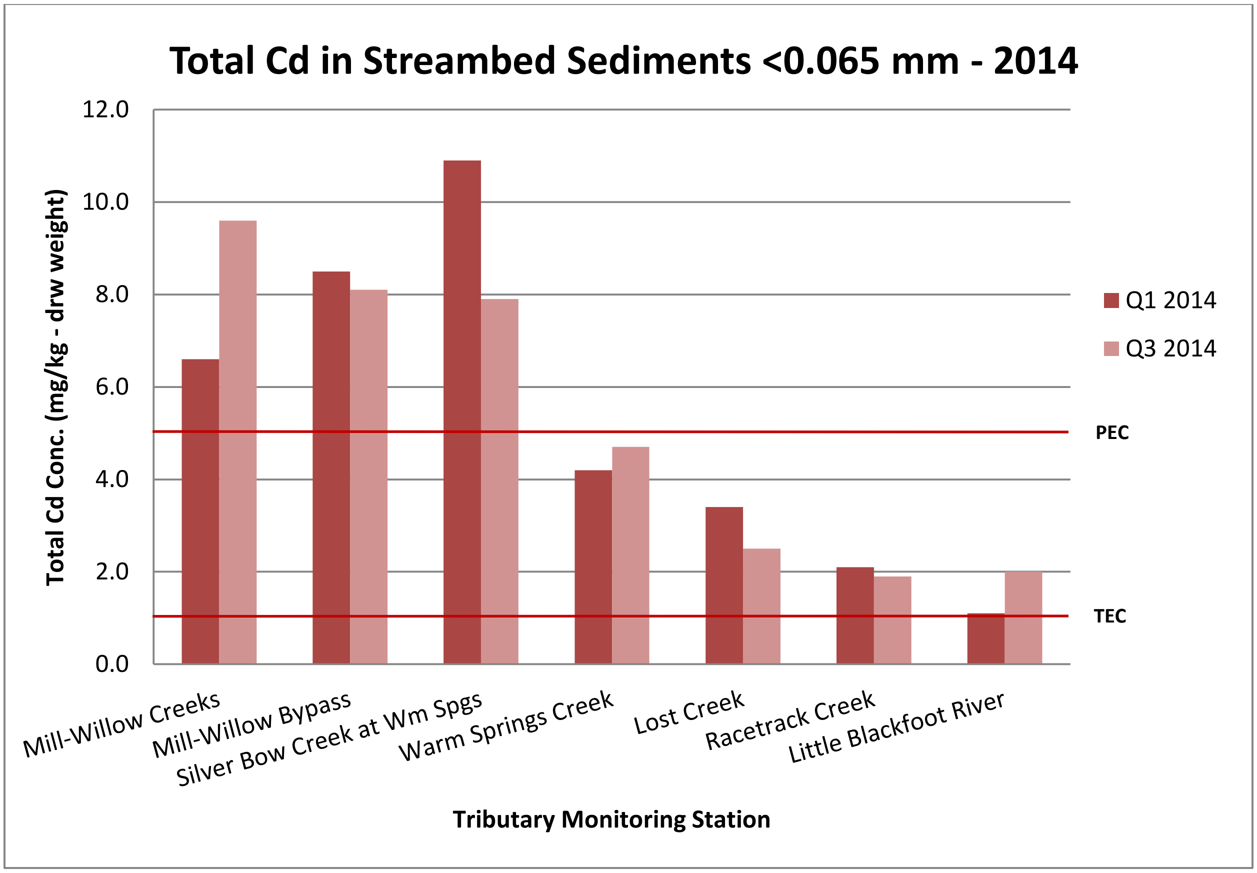

Figure 3-5. Total cadmium concentrations (dry weight) in Clark Fork River tributary sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

Table 3-6. Total cadmium concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2014.

Site ID	Site Location	Sample concentration (mg/kg-WW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	9.9	9.1
CFR-07D	Clark Fork River at Galen Road	4.4	6.5
CFR-11F	Clark Fork River at Gemback Road	6.2	4.4
CFR-27H	Clark Fork River at Deer Lodge	6.3	7.2
CFR-116A	Clark Fork at Turah	4.1	3.9
Tributary Sites			
SS-25	Silver Bow Creek at Warm Springs	10.9	7.9
MCWC-MWB	Mill-Willow Creek at Frontage Road	6.6	9.6
MWB-SBC	Mill-Willow Bypass near mouth	8.5	8.1
WSC-SBC	Warm Springs Creek near mouth	4.2	4.7
LC-7.5	Lost Creek near mouth	3.4	2.5
RTC-1.5	Racetrack Creek near mouth	2.1	1.9
LBR-CFR	Little Blackfoot River near Garrison	1.1	2.0

(Yellow) Exceeds threshold effect concentration [MacDonald et al., 2000].
(Red) Exceeds probable effect concentration [MacDonald et al., 2000].

3.3.2.3 Copper

The spatial trend for sediment copper concentrations at mainstem Clark Fork River monitoring sites was similar to that observed for cadmium. Highest concentrations were observed at the uppermost site near Galen. Lower and similar concentrations were observed at the next two sites at Galen Road and Gemback Road. Intermediate and only slightly higher concentrations were measured at the Deer Lodge site, and lowest mainstem concentrations were measured at the Turah site [Figure 3-6].

Among the tributary stations monitored in 2014, Warm Springs Creek near its mouth and Silver Bow Creek at Warm Springs showed the highest sediment copper concentrations [Figure 3-7]. The Little Blackfoot River had the lowest sediment copper concentrations of all the sites, followed by Racetrack Creek. Overall, the tributary sites had substantially lower sediment copper concentrations than all of the mainstem Clark Fork sites except Turah.

There was no clear seasonal pattern for sediment copper concentrations at the mainstem and tributary monitoring stations in 2014. Concentrations were generally similar during each of the Q1 and Q3 monitoring events, with some exceptions. The Clark Fork River site at Galen Road showed an approximately 55% higher sediment copper concentration in Q3 versus Q1. Warm Springs Creek and Silver Bow Creek at Warm Springs also showed appreciably higher concentrations in Q3 compared to Q1.

Dry weight sediment copper concentrations exceeded both the TEC and PEC by a large margin at all mainstem Clark Fork River sites during both 2014 monitoring events [Figure 3-7]. All of the tributary monitoring sites exceeded the TEC during both 2014 monitoring events, and all of the tributaries exceeded the PEC in both quarters, except the Little Blackfoot River and Racetrack Creek. Of the five COC sediment metals evaluated, copper showed the second highest overall frequency of exceedances of the PEC at the CFROU monitoring sites during the 2014 monitoring events.

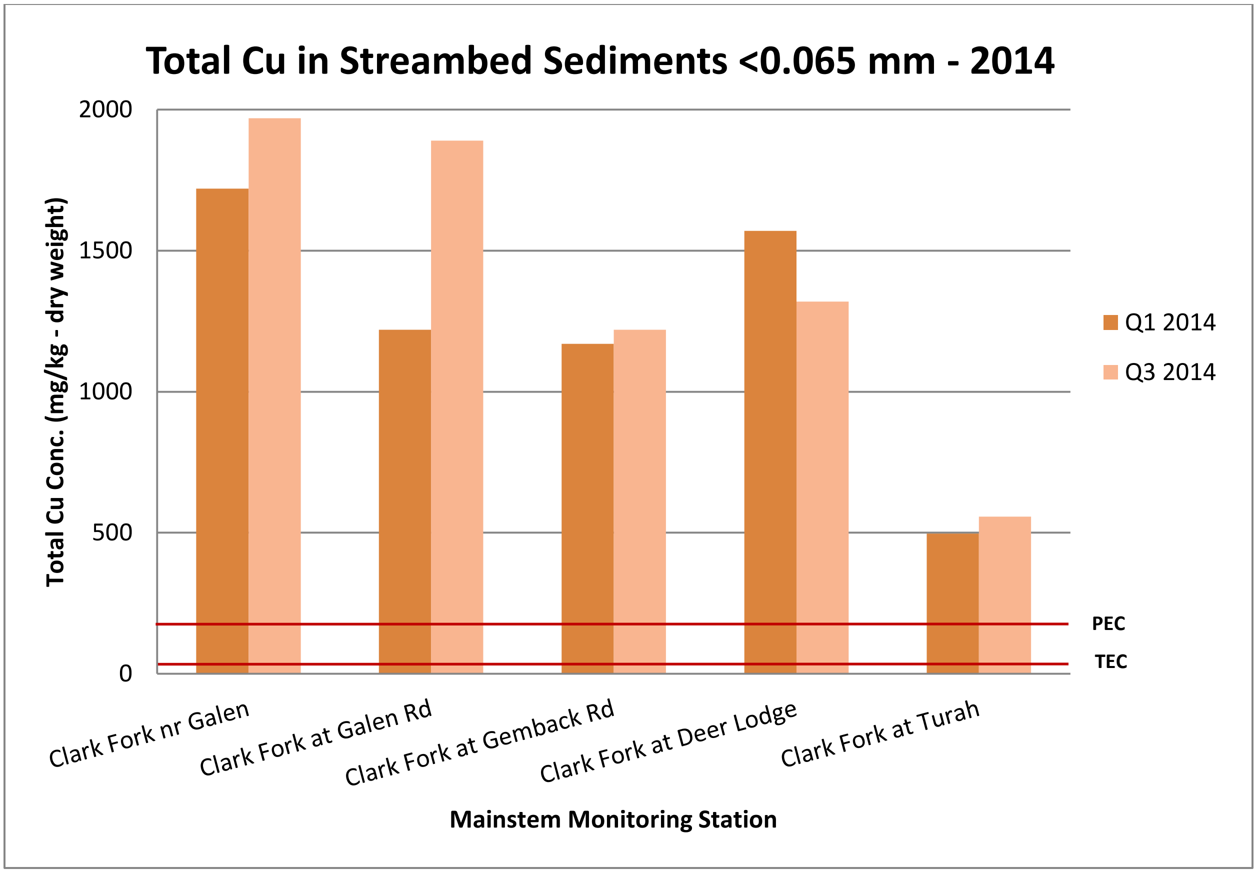

Figure 3-6. Total copper concentrations (dry weight) in Clark Fork River mainstem sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

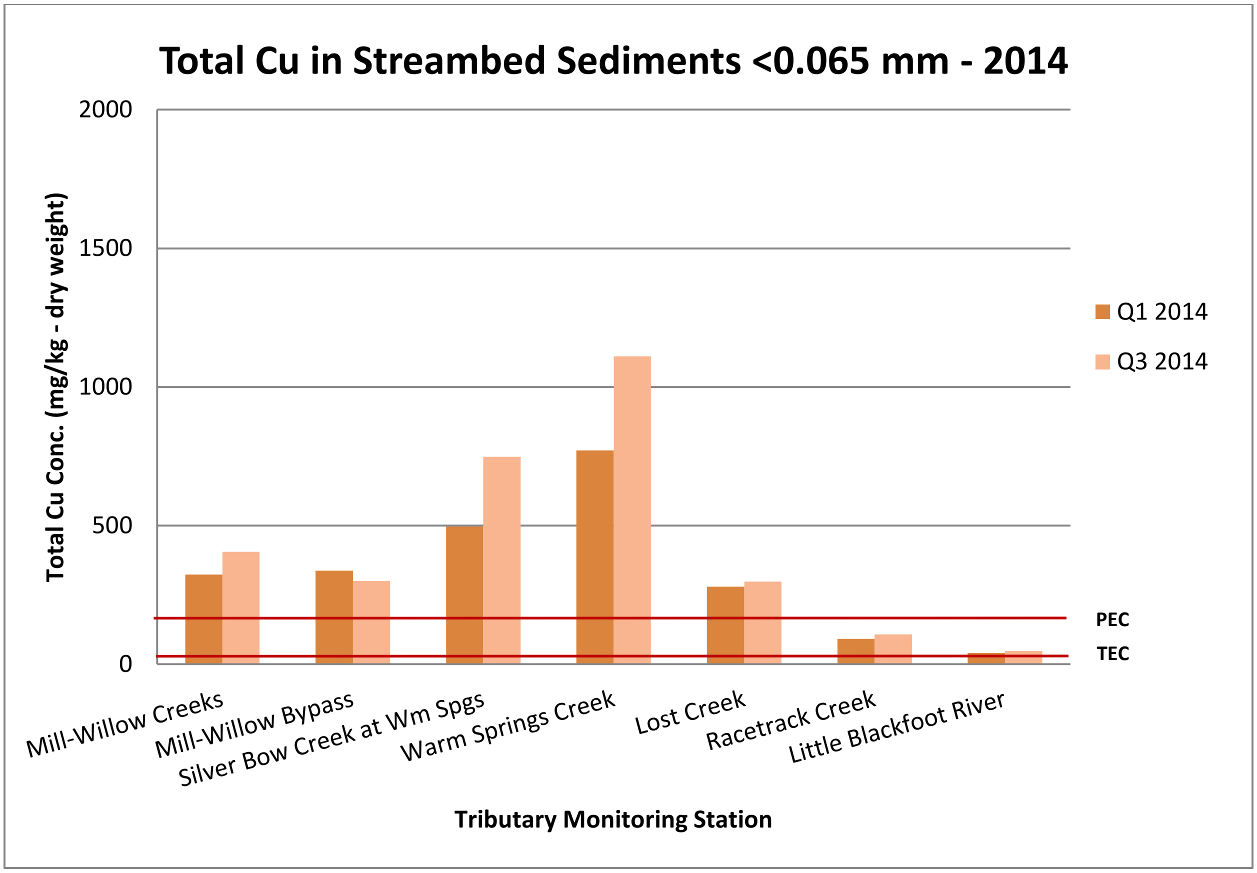

Figure 3-7. Total copper concentrations (dry weight) in Clark Fork River tributary sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

Table 3-7. Total copper concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2014.

Site ID	Site Location	Sample concentration (mg/kg-DW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	1720	1970
CFR-07D	Clark Fork River at Galen Road	1220	1890
CFR-11F	Clark Fork River at Gemback Road	1170	1220
CFR-27H	Clark Fork River at Deer Lodge	1570	1320
CFR-116A	Clark Fork at Turah	497	557
Tributary Sites			
SS-25	Silver Bow Creek at Warm Springs	497	748
MCWC-MWB	Mill-Willow Creek at Frontage Road	323	405
MWB-SBC	Mill-Willow Bypass near mouth	337	300
WSC-SBC	Warm Springs Creek near mouth	771	1110
LC-7.5	Lost Creek near mouth	279	298
RTC-1.5	Racetrack Creek near mouth	92	108
LBR-CFR	Little Blackfoot River near Garrison	41	47

(Yellow) Exceeds threshold effect concentration [MacDonald et al., 2000].

(Red) Exceeds probable effect concentration [MacDonald et al., 2000].

Values for CFR-03A through LC-7.5 are shaded red; values for RTC-1.5 and LBR-CFR are shaded yellow.

3.3.2.4 Lead

The spatial trend for sediment lead concentrations at mainstem Clark Fork River monitoring sites was similar to that observed for copper and cadmium. Highest concentrations were observed at the uppermost site near Galen. Lower and similar concentrations were observed at the next two sites at Galen Road and Gemback Road. Sediment lead concentrations at the Deer Lodge site were slightly higher than those two upstream sites in Q1 but slightly lower in Q3. Lowest mainstem concentrations were measured at the Turah site [Figure 3-8].

Among the tributary stations monitored in 2014, Silver Bow Creek at Warm Springs and Racetrack Creek near its mouth showed the highest sediment lead concentrations [Figure 3-9]. The Little Blackfoot River had the lowest sediment lead concentrations of all the sites, followed by the Clark Fork at Turah. Overall, Silver Bow Creek at Warm Springs, followed by the Clark Fork at Galen, had the highest sediment lead concentrations of the CFROU monitoring sites.

There was no clear seasonal pattern for sediment lead concentrations at the mainstem and tributary monitoring stations in 2014. Concentrations were generally similar during each of the Q1 and Q3 monitoring events, with some exceptions. The Mill-Willow Bypass site showed an approximately 42% lower sediment lead concentration in Q3 versus Q1. Eight CFROU monitoring sites showed slightly higher sediment lead concentrations in Q3 versus Q1, compared to four of 12 sites showing lower concentrations in Q3 compared to the Q1 monitoring event.

Dry weight sediment lead concentrations exceeded both of the dry weight based TEC and PEC reference values at all mainstem Clark Fork River sites except Turah during both 2014 monitoring events [Table 3-8]. The Turah site exceeded the TEC during both monitoring events, but not the PEC. All of the tributary monitoring sites also exceeded the TEC during both 2014 monitoring events. Mill-Willow Creek, Mill-Willow Bypass, Silver Bow Creek at Warm Springs, Warm Springs Creek, Lost Creek, and Racetrack Creek also exceeded the PEC during one (Warm Springs Creek) or both of the two monitoring events. Of the five COC sediment metals evaluated, lead showed the third highest overall frequency of exceedances of the PEC at the CFROU monitoring sites during the 2014 monitoring events.

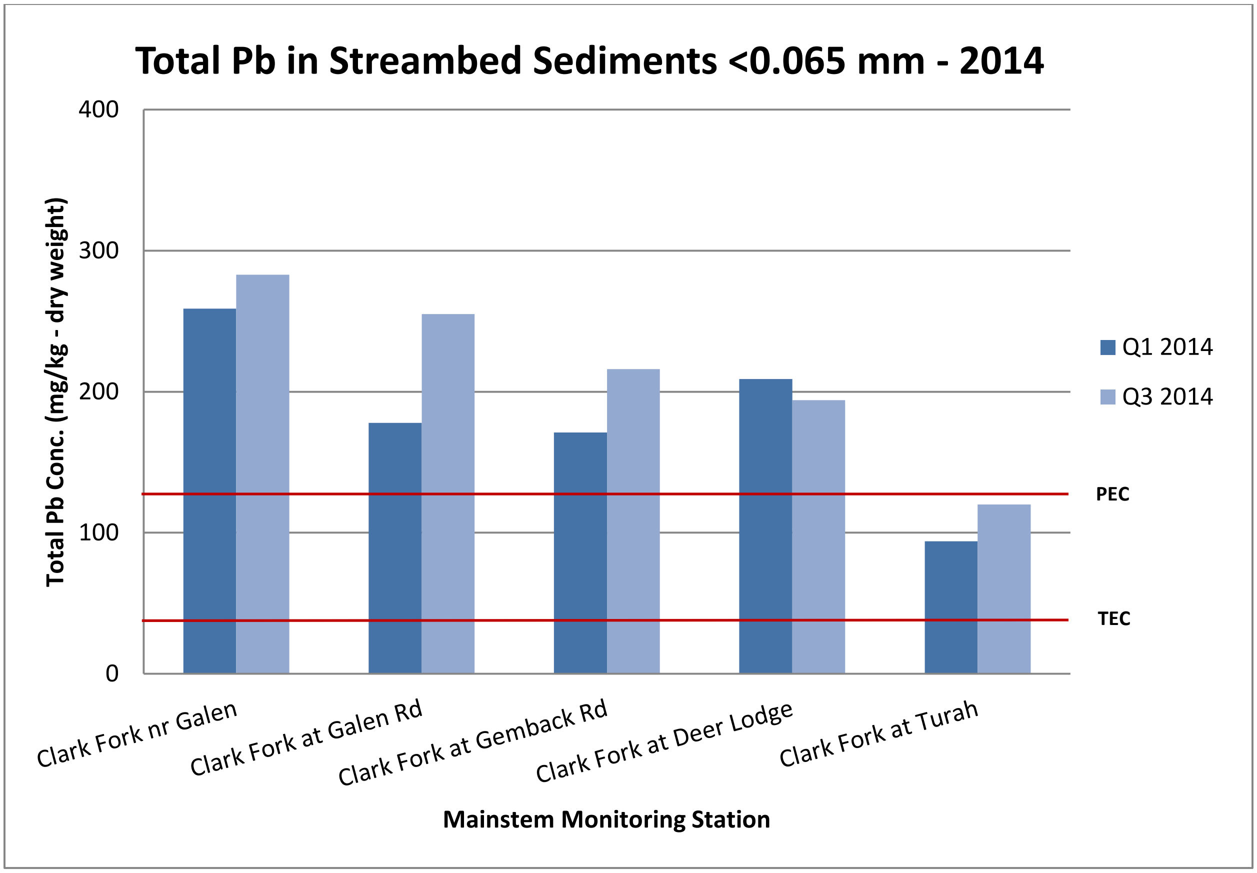

Figure 3-8. Total lead concentrations (dry weight) in Clark Fork River mainstem sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

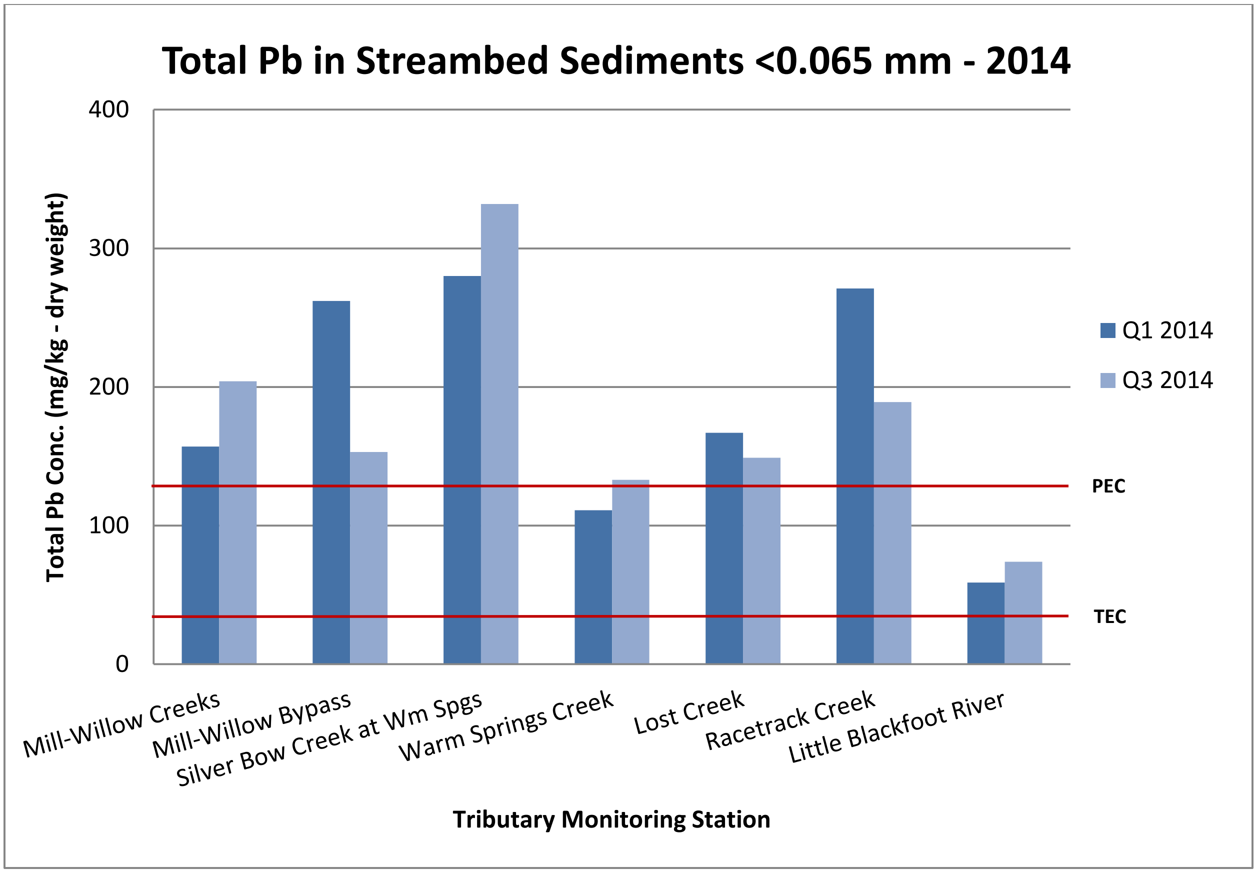

Figure 3-9. Total lead concentrations (dry weight) in Clark Fork River tributary sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

Table 3-8. Total lead concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2014.

Site ID	Site Location	Sample concentration (mg/kg-WW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	259	283
CFR-07D	Clark Fork River at Galen Road	178	255
CFR-11F	Clark Fork River at Gemback Road	171	216
CFR-27H	Clark Fork River at Deer Lodge	209	194
CFR-116A	Clark Fork at Turah	94	120
Tributary Sites			
SS-25	Silver Bow Creek at Warm Springs	280	332
MCWC-MWB	Mill-Willow Creek at Frontage Road	157	204
MWB-SBC	Mill-Willow Bypass near mouth	262	153
WSC-SBC	Warm Springs Creek near mouth	111	133
LC-7.5	Lost Creek near mouth	167	149
RTC-1.5	Racetrack Creek near mouth	271	189
LBR-CFR-02	Little Blackfoot River near Garrison	59	74

(yellow) Exceeds threshold effect concentration [MacDonald et al., 2000].
(red) Exceeds probable effect concentration [MacDonald et al., 2000].

3.3.2.5 Zinc

The spatial trend for sediment zinc concentrations at mainstem Clark Fork River monitoring sites in 2014 showed highest concentrations at the near Galen site, slightly lower concentrations at Galen Road, Gemback Road and Deer Lodge, and lowest concentrations at Turah [Figure 3-10]. The relative differences in sediment metals concentrations between sites were smaller for zinc than for the other COC metal and metalloids.

Among the tributary stations, Silver Bow Creek at Warm Springs had the highest sediment zinc concentrations by far [Figure 3-11]. Mill-Willow Bypass had the second highest sediment zinc concentrations. The Little Blackfoot River and Racetrack Creek had the lowest sediment lead concentrations of all the sites. Overall, Silver Bow Creek at Warm Springs, followed by the Clark Fork at Galen, had the highest sediment zinc concentrations of the CFROU monitoring sites.

Like the other four COC metals and metalloids, there was no clear seasonal pattern for sediment zinc concentrations at the mainstem and tributary monitoring stations in 2014. Concentrations were very similar during each of the Q1 and Q3 monitoring events at nearly all of the stations, with two exceptions. The Clark Fork at Galen Road site showed an approximately 57% higher sediment zinc concentration in Q3 versus Q1 [Figure 3-10]. The Silver Bow Creek at Warm Springs site showed an approximately 65% higher sediment zinc concentration in Q3 versus Q1 [Figure 3-11].

Dry weight sediment zinc concentrations exceeded both of the TEC and PEC reference values at all mainstem Clark Fork River sites during both 2014 monitoring events [Table 3-9]. All of the tributary monitoring sites exceeded the TEC during both 2014 monitoring events. Mill-Willow Creek, Mill-Willow Bypass, Silver Bow Creek at Warm Springs, Warm Springs Creek, and Lost Creek also exceeded the PEC during at least one of the two monitoring events. Of the five COC sediment metals evaluated, zinc showed the fourth highest overall frequency of exceedances of the PEC at the CFROU monitoring sites during the 2014 monitoring events.

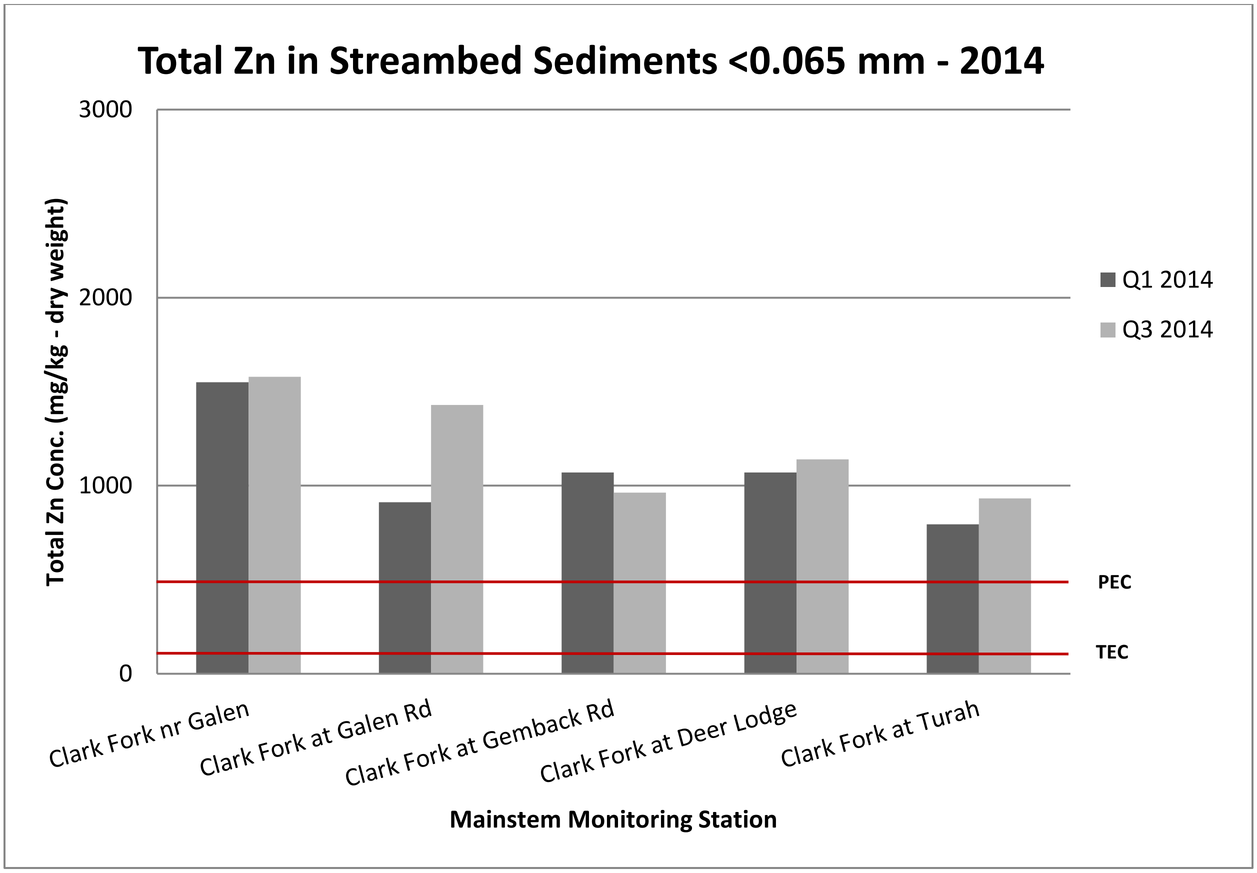

Figure 3-10. Total zinc concentrations (dry weight) in Clark Fork River mainstem sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

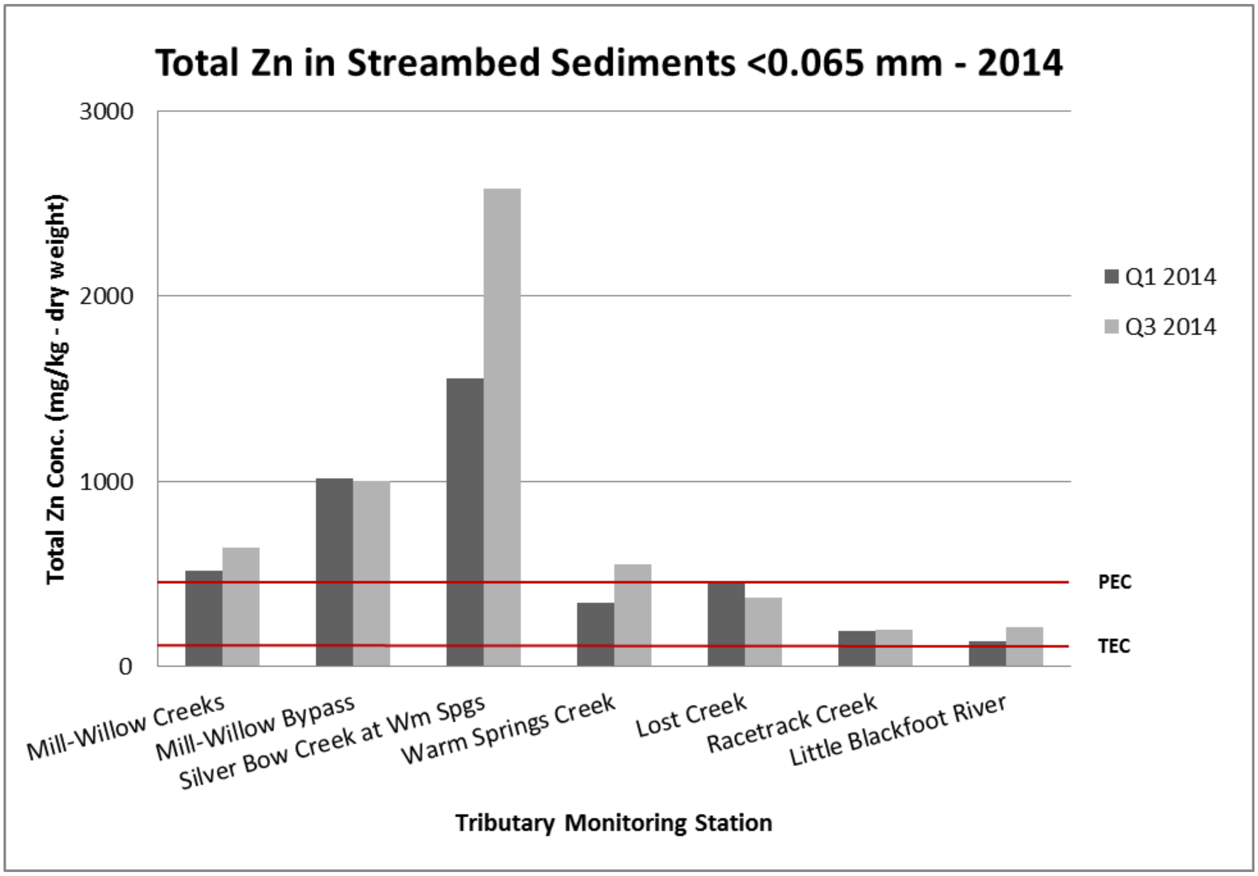

Figure 3-11. Total zinc concentrations (dry weight) in Clark Fork River tributary sediment samples, 2014. Red lines represent the "threshold effect concentration" (TEC) and the "probable effect concentration" (PEC) [MacDonald et al., 2000].

Table 3-9. Total zinc concentrations (mg/kg dry weight) in fine fraction (<0.065 mm) instream sediment samples from the Clark Fork River Operable Unit, 2014.

Site ID	Site Location	Sample concentration (mg/kg-WW)	
		Q1	Q3
Mainstem Sites			
CFR-03A	Clark Fork River near Galen	1550	1580
CFR-07D	Clark Fork River at Galen Road	912	1430
CFR-11F	Clark Fork River at Gemback Road	1070	963
CFR-27H	Clark Fork River at Deer Lodge	1070	1140
CFR-116A	Clark Fork at Turah	795	933
Tributary Sites			
SS-25	Silver Bow Creek at Warm Springs	1560	2580
MCWC-MWB	Mill-Willow Creek at Frontage Road	519	640
MWB-SBC	Mill-Willow Bypass near mouth	1020	1000
WSC-SBC	Warm Springs Creek near mouth	343	550
LC-7.5	Lost Creek near mouth	464	375
RTC-1.5	Racetrack Creek near mouth	191	201
LBR-CFR-02	Little Blackfoot River near Garrison	134	213

(Yellow) Exceeds threshold effect concentration [MacDonald et al., 2000].
(Red) Exceeds probable effect concentration [MacDonald et al., 2000].

3.3.3 Data Validation

All RPD comparisons between the field sample and field duplicate pairs concentrations for each COC in each analysis type (i.e., wet weight and dry weight) were below the project target (40%) specified in the SAP [DeArment et al., 2013]. Mean RPD among all pairs (n = 30) was 6.1% (range: 0-16.3%). Mean RPD of wet weight pairs (n = 15) was 6.7% (range: 0-14.6%). Mean RPD of dry weight pairs (n = 15) was 5.5% (range: 0-16.3%). Mean RPD of the wet weight samples in prior years was 9.7% in 2010, 9.9% in 2011, 9.6% in 2012, and 11.7% in 2013.

3.4 DISCUSSION

3.4.1 Sample Size Fraction

Variability in sediment metals concentrations at any given monitoring site during any particular sampling event may be influenced by channel morphology and depositional processes. These factors may cause variability in the size composition of the sample, which in turn influences the concentrations of metals in the sample as size fraction is strongly related (inversely) to metal concentration in sediment samples in the CFROU. The proportion of sediment in the fine size fraction (<0.065 mm) was highly variable among sites and among sample periods, and even among field sample and duplicate sample pairs collected at the same site during the same monitoring event. Sediment samples in the CFROU were analyzed in only the fine size fraction to minimize variability due to size fraction.

3.4.2 Contaminants of Concern

The highest dry weight sediment COC metals concentrations tended to be found at the upper river mainstem monitoring location at Galen Road, with second highest concentrations typically observed at Deer Lodge. The lowest mainstem sediment metals concentrations were consistently observed in the Clark Fork at Turah. Clark Fork tributaries in the CFROU monitoring network showed elevated sediment metals concentrations in Mill-Willow Creek at Frontage Road (arsenic, cadmium, copper, lead and zinc), the Mill-Willow Bypass (arsenic, cadmium, copper, lead and zinc), Silver Bow Creek at Warm Springs (arsenic, cadmium, copper, lead and zinc), Warm Springs Creek (arsenic, copper, lead and zinc), Lost Creek (arsenic, copper, and lead), and Racetrack Creek (arsenic and lead). The lowest overall concentrations of sediment metals were found in the Little Blackfoot River.

Concentrations of arsenic, copper, and zinc exceeded the PEC (the higher of the two reference values) at all of the Clark Fork mainstem monitoring stations during both the Q1 and Q3 2014 monitoring events. Concentrations of cadmium and lead exceeded the PEC at all of the Clark Fork mainstem monitoring stations except Turah during one or both of the Q1 and Q3 2014 monitoring events. Among the tributary monitoring stations, concentrations of arsenic and lead exceeded the PEC at all of the sites except the Little Blackfoot River during one or both of the Q1 and Q3 2014 monitoring events. Concentrations of copper and zinc exceeded the PEC at all of the tributary sites except the Little Blackfoot River and Racetrack Creek during one or both of the Q1 and Q3 2014 monitoring events. Concentrations of cadmium exceeded the PEC during both the Q1 and Q3 monitoring events at the Mill-Willow Creek, Mill-Willow Bypass, and Silver Bow Creek at Warms Springs tributary monitoring sites but not at the other tributary sites.

Examining COC metals exceedances at all CFROU monitoring stations during the two 2014 monitoring events, arsenic showed the highest frequency of exceedances of the PEC (21 of 24 site measurements). Copper showed the second highest frequency of exceedances of the PEC (20 of 24 samples), lead showed the third highest frequency of exceedances of the PEC (19 of 24 samples), zinc showed the fourth highest frequency of exceedances of the PEC (18 of 24 samples), and cadmium showed the lowest frequency of exceedance of the PEC (12 of 24 samples)

3.4.3 Data Validation

All RPDs from field sample and field duplicate pairs in 2014 were within 40% thus satisfying the project goal for “overall precision”. A complete analysis of data validation procedures and results is described in Appendix A.

4.0 GEOMORPHOLOGY

4.1 INTRODUCTION

Geomorphology monitoring was performed in Phase 1, Reach A of the Clark Fork River Operable Unit (CFROU) in 2014 to evaluate progress toward attainment of project performance targets, to assess ongoing maintenance needs, and to inform adaptive management decisions for design of other phases of the CFROU [Sacry et al., 2012]. The remedial design for Phase 1 covered the upstream-most 1.6 mile section of the CFROU [Sacry et al., 2012]. Geomorphology monitoring in 2014 represents the first year of monitoring in Phase 1.

Remediation in Phase 1 was intended primarily to reduce exposure of metal contaminants in floodplain tailings to humans and the environment. Approximately 330,000 cubic yards of contaminated materials were removed from the floodplain and streambanks of Phase 1 and approximately 189,000 cubic yards of clean soil and vegetative material were used to reconstruct and revegetate the floodplain and streambanks [Bartkowiak et al., 2013]. In Phase 1, no instream sediments were removed from the streambed and channel alignment was not altered. However, the streambanks on both sides of the channel were treated and the floodplain was reconstructed in 2013. Types of remedial streambank treatments included single (SVSL) and double (DVSL) vegetated soil lifts, brush trenches (BT), and preserve vegetation (PV). Descriptions of each streambank treatment type are provided in Section 5.0. Vegetative treatments on the floodplain were begun in 2013 and continued in 2014. Thus, only a portion of the vegetative treatments on the floodplain had been completed at the time geomorphology monitoring occurred in 2014.

Geomorphic and vegetative treatments are expected to have reciprocal benefits. Throughout Phase 1, the floodplain elevation was lowered because the river had been entrenched due to excessive floodplain aggradation [Sacry et al., 2012]. Lowering the floodplain elevation was intended to facilitate water, nutrient, and sediment exchange between the river and floodplain. Increased connectivity of the river and floodplain will likely facilitate growth of riparian and floodplain vegetation, which would result in improved streambank and floodplain stability. Additionally, dissipation of streamflows across the floodplain during high discharge periods will reduce scour and channel incision, promoting connectivity of the stream channel and floodplain over the long term.

The overall goal for geomorphology in Phase 1 is for minimal geomorphic adjustment in the short term (i.e., first 15 years after reconstruction) as streamside and floodplain vegetation becomes reestablished [Sacry et al., 2012]. Over the longer term, the goal is to allow for dynamic equilibrium [Sacry et al., 2012]. This monitoring program is intended to evaluate progress toward attainment of performance targets related to the short term goal for geomorphology in Phase 1.

4.2 METHODS

Geomorphology monitoring in Phase 1 was guided by the Phase 1 geomorphology and vegetation monitoring plan [Sacry et al., 2012] as amended in 2014 [Sacry et al., 2014].

4.2.1 Monitoring Locations

Geomorphology monitoring occurred throughout Phase 1, Reach A of the CFROU in 2014 [Figure 1-1].

4.2.2 Monitoring Schedule

The frequency of geomorphology monitoring for Phase 1 of the CFROU varies by monitoring metric [Sacry et al., 2012]. The 2014 monitoring season was the first year (Year 1) of monitoring for Phase 1. Additional monitoring will occur in Phase 1 in 2018 (Year 5), 2023 (Year 10), and 2028 (Year 15). For some metrics, monitoring will be required in Phase 1 only when the streamflow exceeds the bankfull design level (522 cfs) [Sacry et al., 2012].

Prior to data collection activities, a site visit occurred on May 21, 2014 to review conditions, monitoring protocols, and consider adaptations to the protocols based on recent conditions. The site visit included project managers from the Montana Department of Environmental Quality (MDEQ), members of the design team, and monitoring field staff.

Field data was collected during three site visits. On May 28, 2014, a survey of flood inundation area was conducted. Channel cross-section dimensions were measured on July 22, 2014 by Brown and Associates. The remainder of the field data was collected from August 19-20, 2014.

4.2.3 Monitoring Parameters

Monitoring metrics, and performance targets for those metrics, were selected by the design team and are described in Sacry et al. [2012] and amended in Sacry et al. [2014]. The monitoring metrics, performance targets, and timeline for monitoring are identified in Table 4-1. The monitoring metrics selected by the design team provide an assessment of stream channel dimensions, pool density and depth, floodplain connectivity and stability, and secondary channel stability. The timeframe for evaluation of performance targets varies by monitoring metric. For example, channel slope and sinuosity are not required for evaluation of performance targets in Year 1 but are required in Years 5, 10, and 15 [Table 4-1]. Additionally, some monitoring metrics (floodplain connectivity, floodplain stability, and secondary channel stability) are only to be monitored during years in which streamflows exceed the bankfull design level [Table 4-1]. Additional monitoring metrics will be evaluated in future monitoring years (Year 5, 10, and 15) including the longitudinal channel profile, channel planform, streambank erosion, and channel migration rate.

Table 4-1. Performance targets for geomorphic monitoring metrics in Phase 1 of the Clark Fork River Operable Unit following remediation [Source: Sacry et al., 2012].

Monitoring Metric	Year (post-remediation)			
	1	5	10	15
Cross-Sectional Area (square feet)	119-179	119-179	119-179	119-179
Bankfull Width (feet)	44-66	44-66	44-66	44-66
Mean Bankfull Depth (feet)	2.2-3.2	2.2-3.2	2.2-3.2	2.2-3.2
Width-Depth Ratio	18-27	18-27	18-27	18-27
Channel Slope (%)	-	0.17-0.19	0.17-0.19	0.17-0.19
Channel Sinuosity	-	2.20-2.44	2.20-2.44	2.20-2.44
Pool Density (pools/mile)	≥14.3	≥14.3	≥14.3	≥14.3
Residual Pool Depth (feet)	≥2.4	≥2.4	≥2.4	≥2.4
Bank Erosion and Channel Migration Rate (feet/year)[12]	-	≤0.8/1.3	≤0.8/1.3	≤0.8/1.3
Floodplain Connectivity (%)[13]	18-38	-	-	-
Floodplain Stability[14]				
Secondary Channel Stability (cfs)[15]	47-57			

4.2.4 Sample Collection and Analysis

The following sections describe methods for measurement of each monitoring metric.

4.2.4.1 Channel Cross-Sections

Prior to remediation (in 2009), a total of 16 stream channel cross-sections were surveyed using standard methods described by Harrelson [1994] and a survey-grade GPS unit. Each cross-section was resurveyed in 2014 to compare changes in cross-sectional area over time. These cross-sections will be resurveyed according to the schedule identified in Table 4-1.

For each cross-section, at least ten points (i.e., spatial coordinates including latitude, longitude, and elevation) were surveyed (accuracy ±3 cm) within the bankfull channel including points at the water edge, thalweg, and all substantial slope inflection points within the channel. For each channel cross-section surveyed, the bankfull width, mean bankfull depth, cross-

[12] The higher value applies in any year when streamflow exceeds the 10-year discharge (1,090 cfs).

[13] Floodplain connectivity will be assessed only during the first year when the bankfull design streamflow (522 cfs) is met.

[14] River channel remains free of any secondary channels which develop connectivity at both the upstream and downstream end of the primary channel when the bankfull design streamflow (522 cfs) is met.

[15] Secondary channel stability will be assessed only during the first year when the bankfull design streamflow (522 cfs) is met.

sectional area, and channel width to depth ratio was calculated. Photographs were collected at each cross-section including upstream and downstream views, and views from each streambank.

4.2.4.2 Channel Slope and Sinuosity

Channel slope and sinuosity were not evaluated in Year 1. In subsequent monitoring years these metrics will be determined by surveying a longitudinal profile of the stream channel throughout Phase 1. The longitudinal profile will include consistent measurement of survey points for the left and right channel bankfull indicators, water surface, and thalweg. A survey grade GPS will be used with a maximum spacing between survey points of 100-feet and points will be spaced more closely where the channel curves and secondary channels occur. The longitudinal profile will extend at least 300 feet upstream into Warm Springs Creek from the confluence with the Clark Fork River to include the Warm Springs Creek channel and floodplain that lies within the Clark Fork River 100-year floodplain. The longitudinal profile for lower Warm Springs Creek will be monitored for slope alterations, as any adjustments to this slope will be an indicator of channel profile adjustment on the Clark Fork River.

Channel sinuosity will be calculated as the proportion of stream channel length to valley length. The stream channel length will be calculated from the longitudinal profile. The floodplain valley length will be determined by aerial imagery.

Channel slope will be calculated as the ratio of the difference in river elevation to the stream channel length. The change in elevation and channel lengths will be determined from the longitudinal profile.

4.2.4.3 Pool Density

Pools were identified in the field and survey points were collected at the point of maximum depth for each pool. Pool density was calculated as the frequency of pools per mile.

4.2.4.4 Residual Pool Depth

Residual pool depths were calculated for each pool as the difference between the maximum pool depth and the depth at each pool's hydraulic control (i.e., the pool tail crest; Lisle [1987]). The maximum pool depth and hydraulic control depth for each pool was measured manually.

4.2.4.5 Streambank Erosion and Channel Migration Rate

Streambank erosion and channel migration rates were not evaluated in Year 1. Lateral channel migration rate will be evaluated by comparing repeat longitudinal surveys. Streambank erosion rates will be evaluated by comparing repeat cross-sections.

4.2.4.6 Floodplain Connectivity

Floodplain connectivity was monitored by a field survey of the flood inundation area when streamflow was near the design bankfull streamflow level. When streamflow in the project area was at the design level a surveyor paced the perimeter of all standing surface water and tracked the area with a conventional GPS unit (accuracy ±5m). From this survey, GIS shapefile polygons were created and the total area inundated was calculated from those polygons. The inundated area was then compared to the entire Phase 1 area to determine the proportion of the floodplain inundated at the design streamflow level.

4.2.4.7 Floodplain Stability

Floodplain stability was monitored in conjunction with the flood inundation survey when the design bankfull streamflow was exceeded. In addition, following the spring runoff period, areas where secondary channels formed were reassessed to evaluate evidence channel formation including headcut development at points of secondary channel return to the main channel, or continuous rill development on the floodplain surface.

4.2.4.8 Secondary Channel Stability

Secondary channel stability was evaluated in conjunction with the floodplain connectivity assessment to identify as-built connectivity of engineered secondary channels. At each engineered secondary channel, the streamflow was estimated visually.

4.2.5 Data Analysis

For channel dimension monitoring metrics (i.e., cross-sectional area, bankfull width, mean bankfull depth, and width to depth ratio), and mean residual pool depth, all measurements were averaged throughout Phase 1 and the mean of those measurements was compared to the performance target. The Phase 1 flood inundation area and project area were calculated using GIS software.

4.3 RESULTS

4.3.1 Channel Cross-Sections

The mean for each channel dimension monitoring metric was within the performance target range in 2014 [Table 4-2]. Mean cross-sectional area in Phase 1 was 163 square feet (standard deviation [SD] = 72 square feet). Mean bankfull width in Phase 1 was 60 feet (SD = 22 feet). Mean bankfull depth was 2.7 feet (SD = 0.6 feet). Mean width to depth ratio was 23 (SD = 9).

Although the mean of each channel dimension metric was within the performance target range, multiple individual measurements for each metric were outside the target range [Table 4-2]. One cross-section (XS7) appeared to be an outlier with a cross-sectional area, bankfull width, and width to depth ratio of 3.0, 3.4, and 2.7 standard deviations above the mean for each metric, respectively [Table 4-2].

Table 4-2. Cross-section monitoring results for geomorphic monitoring in Phase 1 of the Clark Fork River Operable Unit, 2014.

Cross-section	Instream Feature Type	Bank Treatment (left)[16]	Bank Treatment (right)	Cross-Sectional Area (square feet)	Bankfull Width (feet)	Mean Bankfull Depth (feet)	Width/Depth Ratio
XS1	riffle	DVSL	DVSL	79	34.9	2.3	15.3
XS2	pool	BT	DVSL	243	69.6	3.5	20.0
XS3	pool	DVSL	PV	150	57.6	2.6	22.1
XS4	riffle	PV	BT	169	66.3	2.6	25.9
XS5	riffle	BT	PV	122	50.6	2.4	21.1
XS6	riffle	PV	DVSL	121	58.7	2.1	28.4
XS7	pool	BT	DVSL	380	133.8	2.8	47.1
XS8	pool	BT	PV	191	50.2	3.8	13.2
XS9	pool	BT	PV	128	54.3	2.4	22.9
XS10	pool	DVSL	BT	125	44.1	2.8	15.6
XS11	pool	DVSL	BT	221	68.2	3.2	21.1
XS12	riffle/run	PV	PV	107	47.6	2.2	21.2
XS13	pool	DVSL / BT	DVSL	180	51.0	3.5	14.5
XS14	riffle	DVSL	DVSL	111	67.7	1.6	41.5
XS15	pool	BT	DVSL	141	47.7	3.0	16.1
XS16	riffle	PV	PV	132	52.9	2.5	21.1
Performance Target Range				**119-179**	**44-66**	**2.2-3.2**	**18-27**
Mean				**163**	**60**	**2.7**	**23**
Standard Deviation				**72**	**22**	**0.6**	**9**

[16] Treatment abbreviations: single vegetated soil lift (SVSL), double vegetated soil lift (DVSL), brush trench (BT), and preserve vegetation (PV).

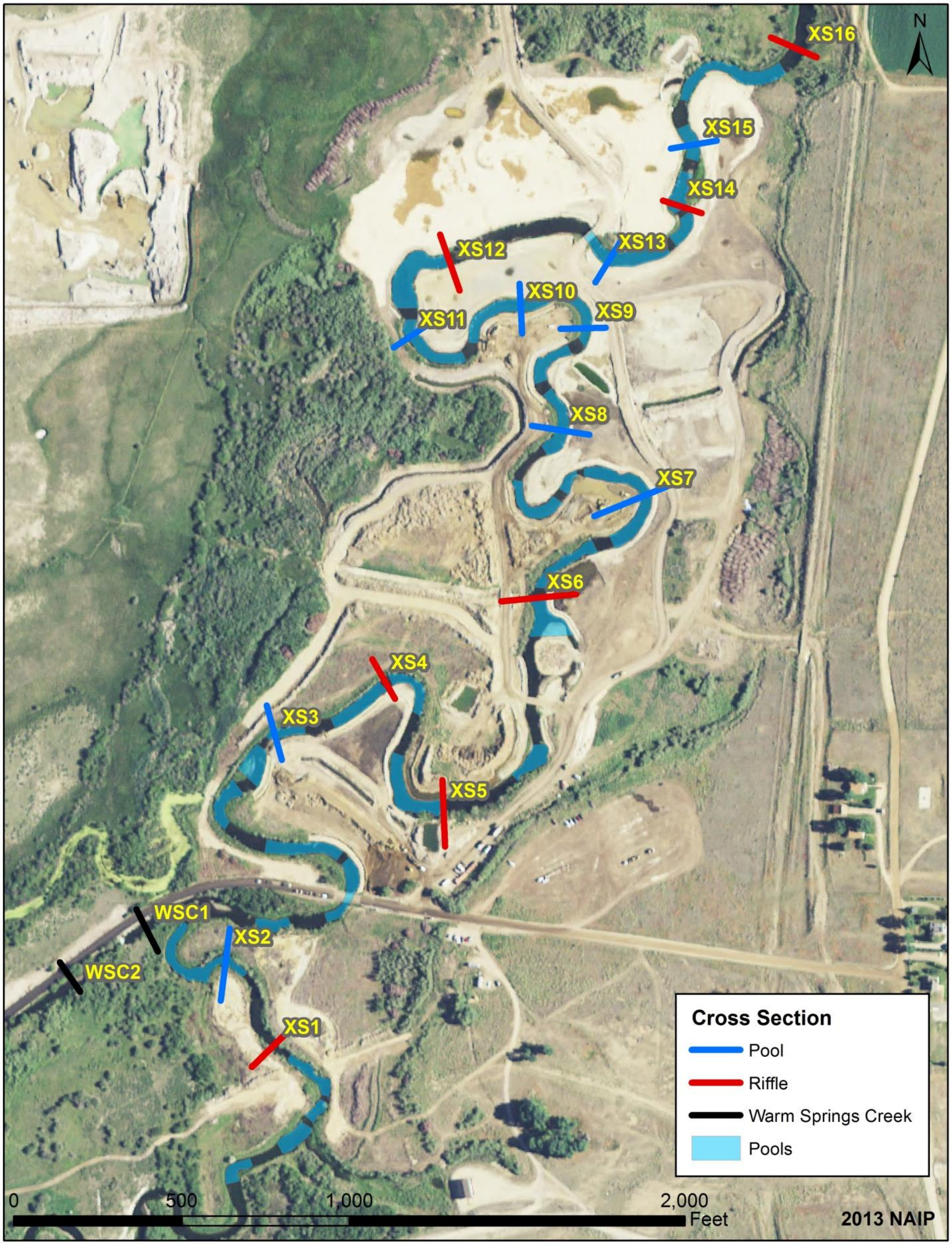

Figure 4-1. Channel cross-sections for geomorphic monitoring in Phase 1 of the Clark Fork River Operable Unit, 2014.

4.3.2 Slope and Sinuosity

Slope and sinuosity was not monitored in 2014. These metrics will be monitored in 2018 (Year 5).

4.3.3 Pool Density and Residual Pool Depth

In 2014, the channel length of the Clark Fork River in Phase 1 was 8,560 feet (1.62 miles) [Sacry et al., 2012] and 30 pools were identified in that river section [Figure 4-2]. Therefore, pool density in 2014 was 18.5 pools/mile (30 pools/1.62 miles). The performance target for pool density for Year 1 is at least 14.3 pools/mile. Therefore, the performance target for pool density was achieved in 2014.

Mean residual pool depth in Phase 1 was 3.3 feet (SD = 0.9 feet) which exceeded the Year 1 performance target of at least 2.4 feet [Table 4-3]. During the survey (August 20, 2014), streamflow at the nearest USGS gauge (USGS station number 12323800) was approximately 100 cfs. Maximum pool depths ranged from 3.0 feet to 6.7 feet and pool tail crest depths ranged from 0.8 feet to 2.6 feet. All of the identified pools appeared to be formed by lateral scour along the meandering river channel.

Figure 4-2. Pools identified in Phase 1 of the Clark Fork River Operable Unit, 2014.

Table 4-3. Residual pool depths in Phase 1 of the Clark Fork River Operable Unit, 2014.

Pool ID	Pool Tail Crest Depth (feet)	Maximum Pool Depth (feet)	Residual Pool Depth (feet)
14-1	1	3.5	2.5
14-2	1.5	3.7	2.2
14-3	1.3	3	1.7
14-4	1.2	3.9	2.7
14-5	1.8	4.6	2.8
14-6	1.3	4.4	3.1
14-7	2	6.7	4.7
14-8	1.3	4.4	3.1
14-9	1.3	5.6	4.3
14-10	2.2	4.6	2.4
14-11	1.3	4.9	3.6
14-12	1.5	3.9	2.4
14-13	2.6	5.6	3
14-14	1.3	4.8	3.5
14-15	1.3	5.4	4.1
14-16	0.8	3.5	2.7
14-17	1.5	5.1	3.6
14-18	1.2	6	4.8
14-19	2	4	2
14-20	2	4.5	2.5
14-21	1.1	4	2.9
14-22	1	5.8	4.8
14-23	1.7	4.7	3
14-24	1.3	4	2.7
14-25	1	5.9	4.9
14-26	1.6	4	2.4
14-27	1.7	5.8	4.1
14-28	2	5.5	3.5
14-29	1.5	5.4	3.9
14-30	1.5	5.2	3.7
Performance Target			**≥2.4**
Mean			**3.3**
Standard Deviation			**0.9**

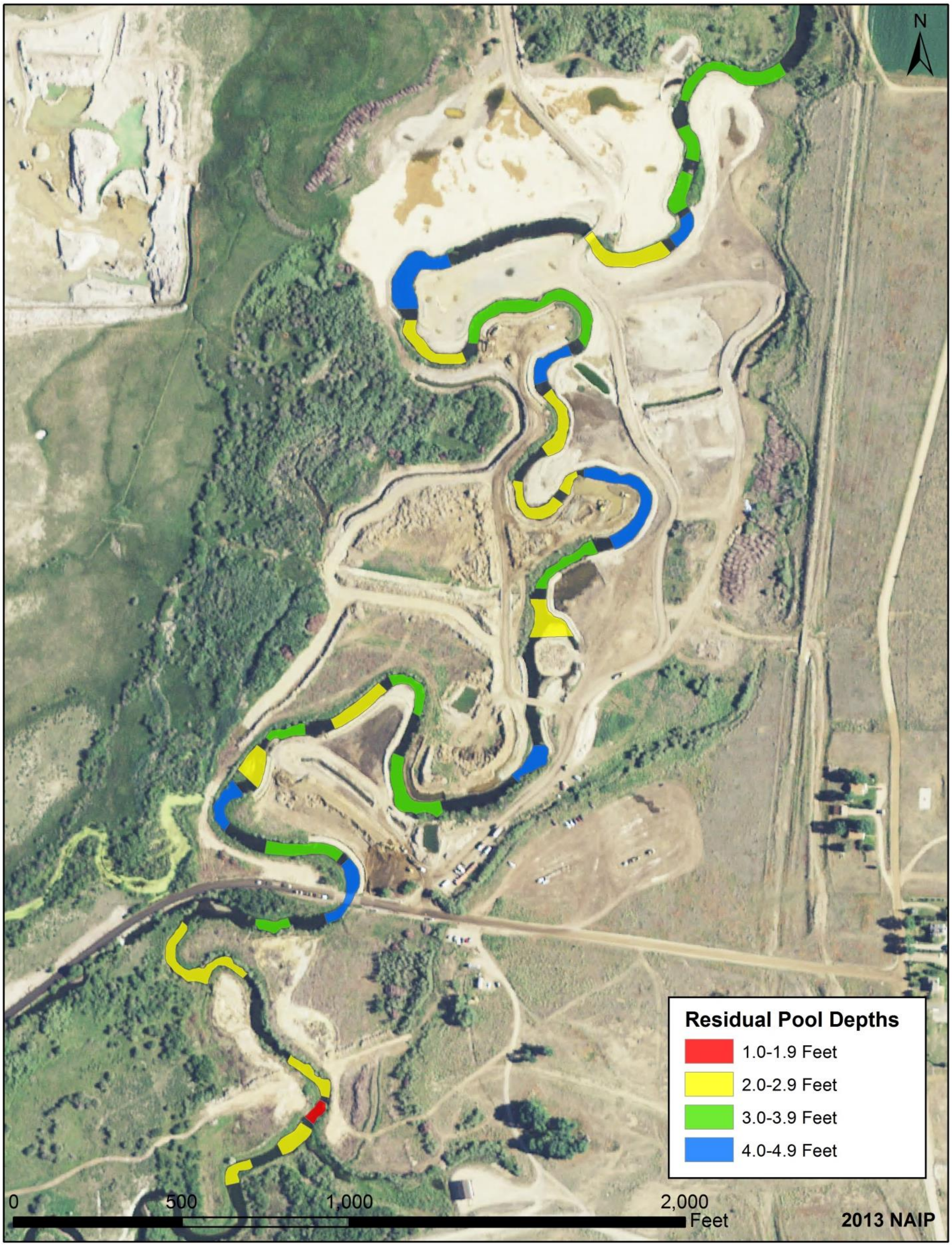

Figure 4-3. Pool depth in the Clark Fork River Operable Unit, 2014. Pool lengths are approximated.

4.3.4 Bank Erosion and Channel Migration Rate

Bank erosion and channel migration rates were not evaluated in Year 1 because no time had yet elapsed from which erosion and migration rates could be determined. The channel cross-sections and longitudinal profiles in Phase 1 will be re-surveyed in Years 5, 10, and 15 and those results will be compared to results obtained in 2014 to assess bank erosion rates and channel migration rates.

The locations of the channel cross-sections in 2013 relative to the streambank treatments are displayed in [Figure 4-4]. Of the 16 surveyed cross-sections, only one (XS16) does not include a treated streambank on either side of the channel [Figure 4-4]. All of the other cross-sections included a reconstructed streambank on at least one side of the channel and most include a reconstructed streambank on both sides of the channel [Figure 4-4].

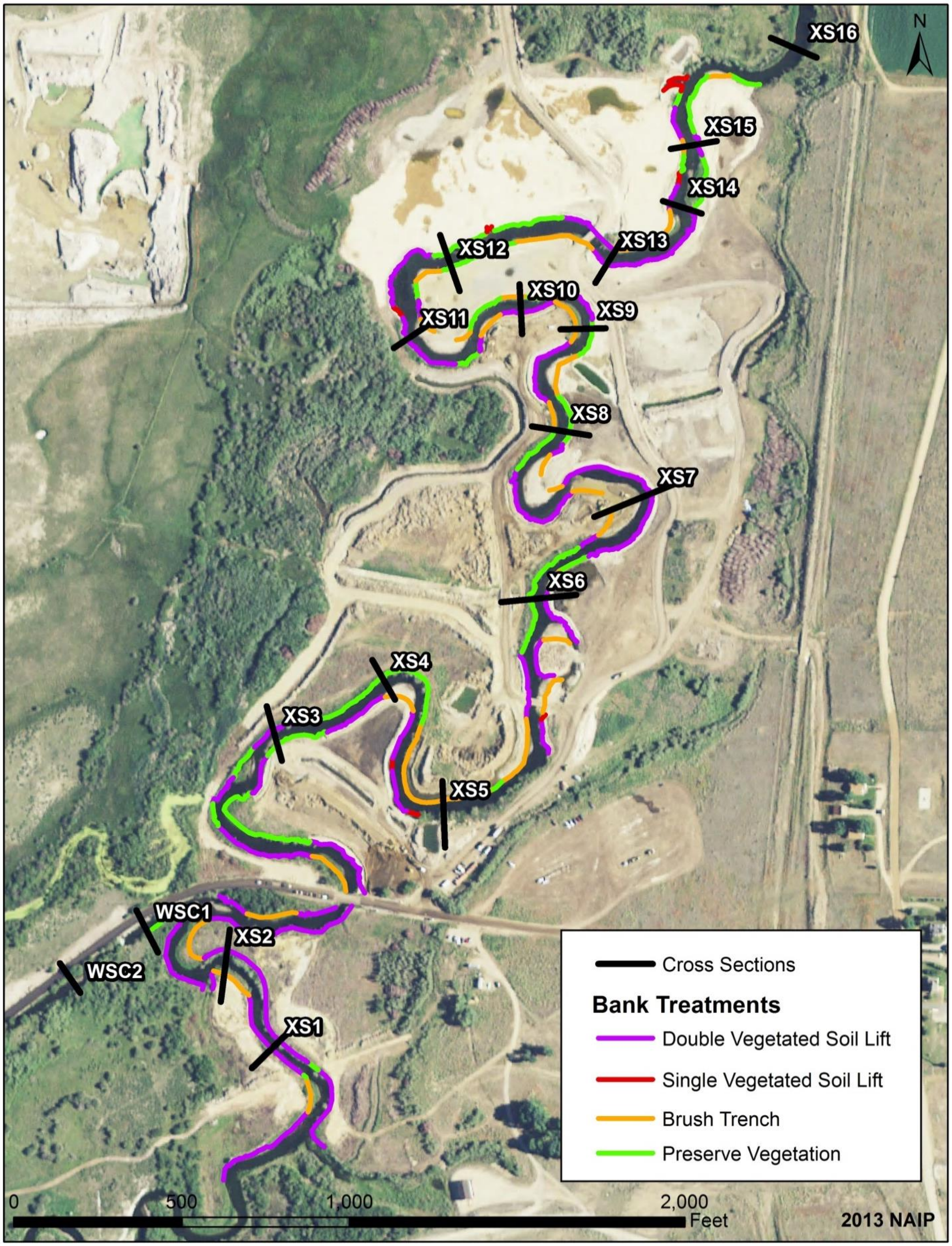

Figure 4-4. Streambank treatments and channel monitoring cross-sections in the Clark Fork River Operable Unit, 2014.

4.3.5 Floodplain Connectivity

In 2014, peak annual streamflow in the Clark Fork River near the Phase 1 project area [Figure 4-5] was 556 cfs (107% of the design bankfull streamflow) and occurred on May 27, 2014 [Figure 4-6]. The design bankfull streamflow for the river in Phase 1 is 522 cfs [Sacry et al., 2012]. Floodplain connectivity was assessed on May 28, 2014 from approximately 3:00 pm to 7:00 pm. During that period, mean streamflow at USGS 12323800 was 508 cfs, or 97.3% of the design bankfull streamflow. Based on the inundation survey [Figure 4-7], 51% of the floodplain area (32.1 acres inundated out of a total floodplain area of 63.2 acres) was inundated which exceeded the performance target range of 18-38% floodplain inundation at the design bankfull streamflow [Table 4-1].

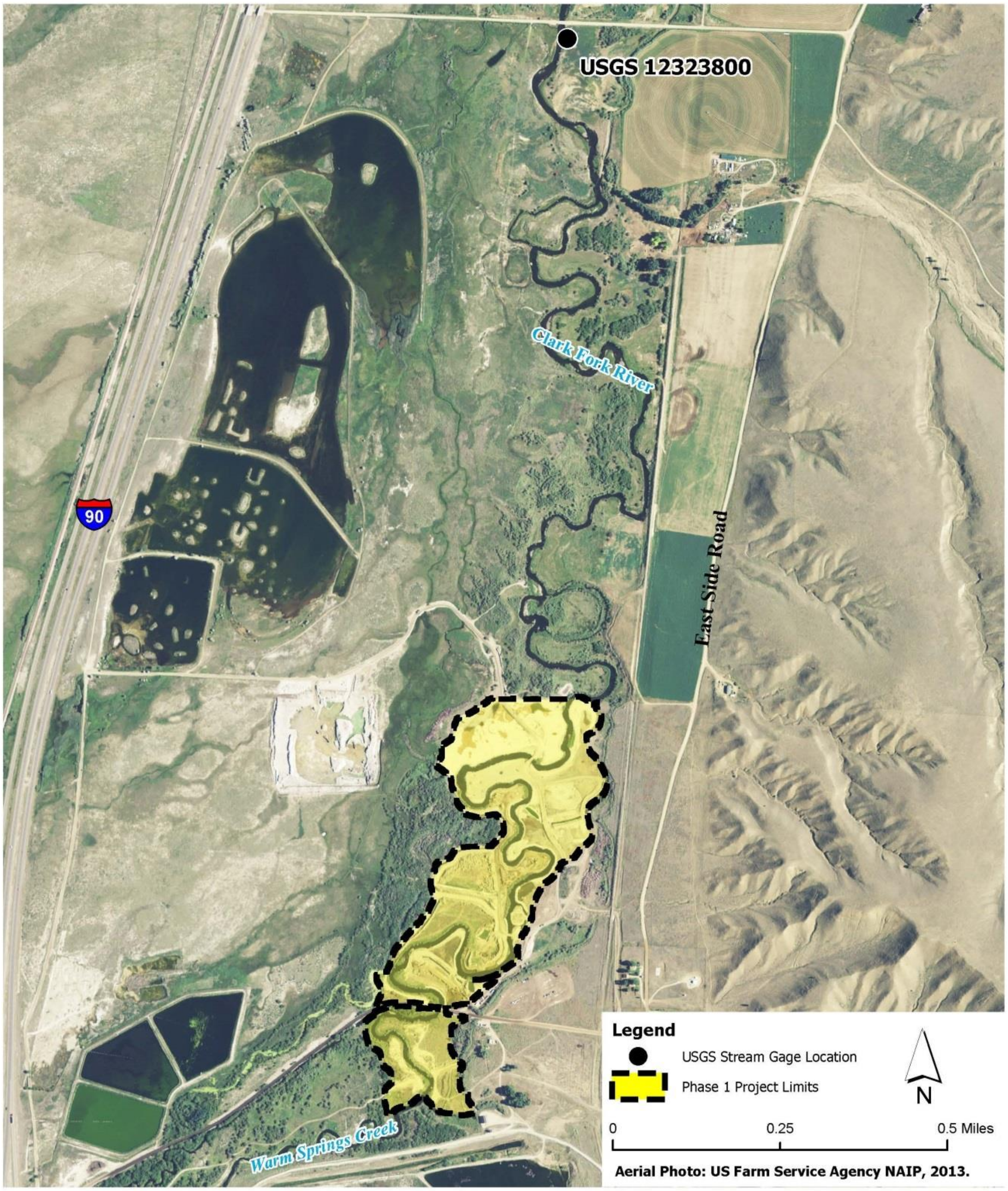

Figure 4-5. Location of nearest USGS streamflow gage (USGS 12323800) to Phase 1 project area in the Clark Fork River Operable Unit, 2014.

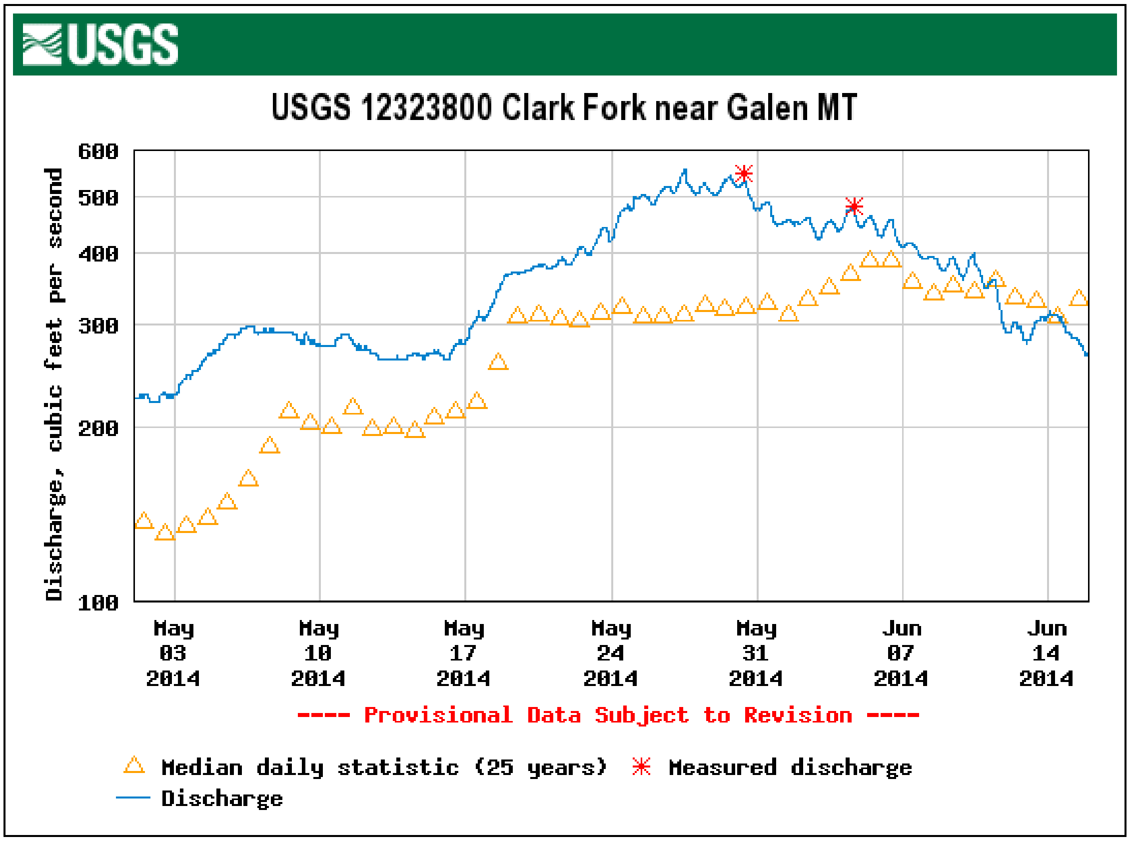

Figure 4-6. Streamflow in the Clark Fork River near the Phase 1 project site during the spring snowmelt runoff period of 2014 [Source: USGS, 2015b].

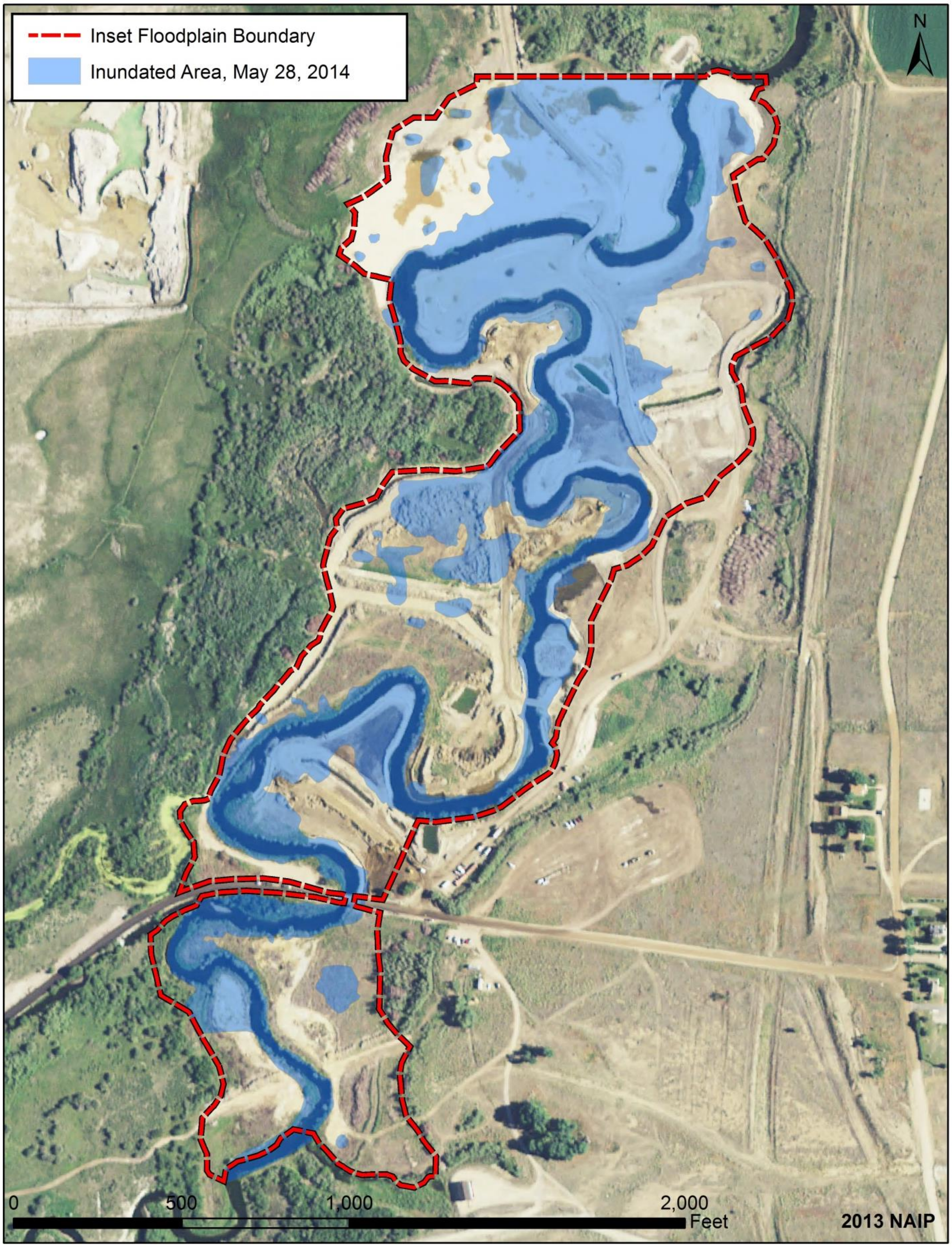

Figure 4-7. Inundated area of the Phase 1 floodplain of the Clark Fork River on May 28, 2014. Streamflow in the Clark Fork River at Galen (USGS 12323800) during the survey was 508 cfs compared to a bankfull design streamflow of 522 cfs.

4.3.6 Floodplain Stability

During the 2014 spring runoff event, two overflow channels developed on the floodplain. The approximate locations of these overflow channels ("Overflow Channel 1" and "Overflow Channel 2") are identified in Figure 4-8. The point where each overflow channel left the main river channel (the "inlet") occurred along the same double vegetated soil lift (DVSL) streambank treatment [Figure 4-8]. The inlet of Overflow Channel 1 formed near the boundary between the DVSL and the upstream preserve vegetation (PV) treatment [Figure 4-8; Figure 4-9] whereas the inlet of Overflow Channel 2 formed just downstream in the center of that same DVSL [Figure 4-8; Figure 4-10]. The point of return (or "outlet") of Overflow Channel 1 was in a DVSL treatment [Figure 4-8; Figure 4-11] and the outlet of Overflow Channel 2 was in a brush trench treatment [Figure 4-8; Figure 4-12].

Both overflow channels were identifiable as rill features on the floodplain following the runoff period. No headcutting was observed at outlet of either overflow channel during the field survey on August 20, 2014. Vegetation along the streambank appeared stable at the inlet and outlet of each overflow channel. A small sediment deposit was observed along the streambank and in the main channel at the outlet of Overflow Channel 1.

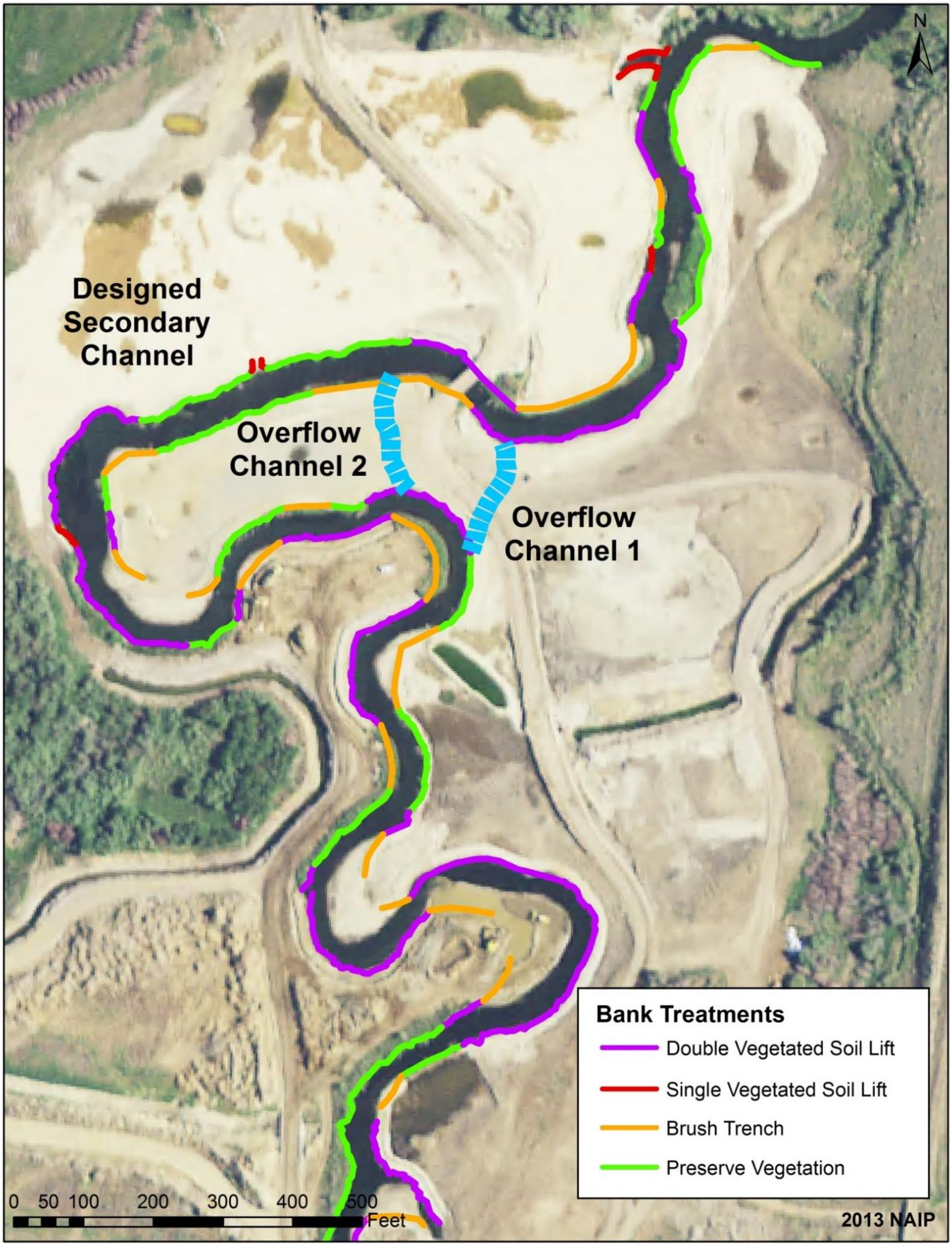

Figure 4-8. Overflow channels which developed in Phase 1 of the Clark Fork River Operable Unit in 2014 during the spring snowmelt runoff period.

Figure 4-9. View of Overflow Channel 1 inlet on August 20, 2014 (upper panel) and on May 28, 2014 (lower panel) in Phase 1 of the Clark Fork River Operable Unit. Mean daily streamflow at the Clark Fork River at Galen site [USGS, 2015b] was 100 cfs on August 20, 2014 and 508 cfs on May 28, 2014.

Figure 4-10. View of Overflow Channel 2 inlet (upper panel) and facing down the channel from the inlet (lower panel) in Phase 1 of the Clark Fork River Operable Unit on August 20, 2014. Mean daily streamflow at the Clark Fork River at Galen site [USGS, 2015b] was 100 cfs on August 20, 2014.

Figure 4-11. Views of Overflow Channel 1 facing up the channel from the outlet (upper panel) and at the outlet (lower panel) in Phase 1 of the Clark Fork River Operable Unit on August 20, 2014. Mean daily streamflow at the Clark Fork River at Galen site [USGS, 2015b] was 100 cfs on August 20, 2014.

Figure 4-12. View of Overflow Channel 2 facing up the channel from the outlet (upper panel) and at the outlet (lower panel) in Phase 1 of the Clark Fork River Operable Unit on August 20, 2014. Mean daily streamflow at the Clark Fork River at Galen site [USGS, 2015b] was 100 cfs on August 20, 2014.

4.3.7 Secondary Channel Stability

One secondary channel was included in the Phase 1 design [Figure 4-8]. The design for this secondary channel was to carry no more than 10% (i.e., ≤52 cfs) of the total streamflow of the mainstem channel at the design bankfull streamflow [Sacry et al., 2012]. During the floodplain inundation survey (May 28, 2014), when the Clark Fork River was approximately 508 cfs, streamflow in the designed secondary channel was visually estimated at less than 5 cfs. At that time the entire floodplain area surrounding the designed secondary channel was inundated by floodwater. The designed secondary channel had no surface water streamflow on May 21, 2014 or on August 20, 2014 [Figure 4-13]. On May 21, 2014 mean daily streamflow in the Clark Fork River was 384 cfs and on August 20, 2014 mean daily streamflow was 100 cfs. The streambank height at the inlet of the designed secondary channel was approximately 1.6 feet above the surface water elevation of the main channel on August 20, 2014 [Figure 4-14]. It appeared that any surface water carried by the secondary channel during periods of high streamflow was dissipated across the floodplain rather than carried in a focused channel back into the main channel [Figure 4-15]. This was reflected in an extensive inundated portion of the floodplain on the west side of the river channel at the downstream (north) end of the project area [Figure 4-7].

Figure 4-13. Views of designed secondary channel inlet in Phase 1 of the Clark Fork River Operable Unit on August 20, 2014. Mean daily streamflow at the Clark Fork River at Galen site [USGS, 2015b] was 100 cfs on August 20, 2014.

Figure 4-14. View of designed secondary channel elevation at inlet in Phase 1 of the Clark Fork River Operable Unit on August 20, 2014. Mean daily streamflow at the Clark Fork River at Galen site [USGS, 2015b] was 100 cfs on August 20, 2014.

Figure 4-15. View of designed secondary channel where the channel passes through browse protection fence (upper panel) and after passing through the fence (lower panel) in Phase 1 of the Clark Fork River Operable Unit on August 20, 2014. Mean daily streamflow at the Clark Fork River at Galen site [USGS, 2015b] was 100 cfs on August 20, 2014.

4.4 DISCUSSION

The results of geomorphic monitoring of Phase 1 in 2014 indicate that the project met some Year 1 performance targets but did not meet all of the targets. All monitoring metrics for channel dimension (i.e., cross-sectional area, bankfull width, mean bankfull depth, and width to depth ratio), pool density, and residual pool depth were within the specified target ranges. Additionally, the secondary channel stability performance target was met because the secondary channel did not carry more than 10% of the streamflow of the main channel when streamflows reached the design bankfull level. Performance targets that were not met included floodplain connectivity and floodplain stability. Performance targets for channel slope, sinuosity, bank erosion rate, and channel migration rate were not scheduled for monitoring in Year 1 (2014) but will be evaluated in Year 5 (2018).

Failure to meet the performance target for channel connectivity was the result of an over-connected river channel and floodplain, rather than the disconnected pre-project channel and floodplain. The proportion of the Phase 1 floodplain inundated when streamflows in the mainstem channel reached the design bankfull level was estimated at 51%, which exceeded the performance target range of 18% to 38%. However, there is some degree of uncertainty in the inundated area estimate due to practical survey constraints. For example, within areas considered completely inundated there were numerous “islands” of the floodplain that were un-inundated. The surveyor could not account for these small island areas within the standing water perimeter and inclusion of those areas as resulted in an overestimation of the inundated area. Additionally, at the time of the inundation survey streamflows in the project area were falling from a maximum level of 556 cfs the previous day. It seems likely that some of the inundated area was the result of remnant flooding from that time period.

The inundated area reflects high connectivity of the channel and floodplain. Over the long term this high degree of connectivity will likely promote vegetative growth, result in increased floodplain and streambank stability, and will presumably provide multiple ecological benefits. However, in the short term excessive connectivity will result in increased avulsion risk and contribute to reduced floodplain stability [Sacry et al., 2012]. The increased risk of avulsion was apparent as two overflow channels formed during the runoff period, resulting in failure to meet the floodplain stability performance target. Although the bankfull streamflows were achieved, maximum streamflows in 2014 reached only 107% of the design level indicating that the flood conditions were relatively mild. These overflow channels have the potential to capture the mainstem channel and therefore monitoring during subsequent years when streamflows approach or exceed the design bankfull streamflow may be necessary. Following monitoring in 2014, additional treatments were implemented to reduce avulsion risk in these overflow channels.

5.0 VEGETATION

5.1 INTRODUCTION

This report describes results of vegetation monitoring in 2014 for the revegetated streambanks and floodplain of Phase 1 in Reach A of the Clark Fork River Operable Unit (CFROU) in 2014. Data were collected for specific monitoring metrics to evaluate progress toward attainment of vegetation performance targets for the remedy and restoration of Phase 1. Major remediation of the floodplain of Phase 1 was completed in December 2013 [Bartkowiak et al., 2013]. In total over 330,000 cubic yards of floodplain waste material was removed and 189,000 cubic yards of rock and vegetative material was used to rebuild the floodplain [Bartkowiak et al., 2013]. Revegetation activities in Phase 1 began in fall of 2013 [Bartkowiak et al., 2013] and not all of these activities were complete in Phase 1 at the time monitoring occurred in August 2014. All streambank treatments were complete at the time of monitoring in August 2014. The majority of the woody shrub and tree plantings that were planned for Phase 1 were planted in the fall of 2013 and the majority of the shrub and herbaceous species seeding occurred in the spring and summer of 2014. Additional vegetation plantings and seeding occurred in the fall of 2014 in Phase 1 following the August monitoring period. Seeding success will be monitored in floodplain transect cover plots in 2015. Survival of woody plants that were planted after monitoring in August 2014 will be monitored in 2015.

5.2 METHODS

The protocol for monitoring vegetation in Phase 1 of Reach A of the CFROU was developed by Geum Environmental Consulting and Applied Geomorphology in consultation with MDEQ [Sacry et al., 2012]. Some alterations of the original monitoring protocol were recommended based on a site visit on May 28, 2014 [Sacry et al., 2014]. Alterations to the original protocol included the following, which are discussed in greater detail in a memo from Geum to MDEQ on July 29, 2014:

- The frequency of vegetation monitoring was reduced for most monitoring metrics. Planned monitoring in year 2 and 3 (post-planting) was discontinued. Performance targets for those years were also discontinued.
- Vegetation transect monitoring was not implemented in 2014. Transect monitoring will be conducted in Phase 1 in 2015.
- The density metric was eliminated.
- Streambank canopy cover was sampled every 50 feet rather than every 30 feet.
- The requirement for overall number of plants sampled in floodplain monitoring plots for woody plant survival and browse intensity were adjusted to reduce sampling effort.

5.2.1 Monitoring Locations

Vegetation monitoring occurred in Phase 1 of Reach A of the CFROU in 2014 [see Section 1.0]. Monitoring occurred in streambank cover monitoring plots in each vegetated soil lift treatment and floodplain plant survival monitoring plots within floodplain planting units.

5.2.1.1 Streambank Monitoring

All streambank treatment types were monitored. Types of streambank treatments included single vegetated soil lifts (SVSL) [Figure 5-1], double vegetated soil lifts (DVSL) [Figure 5-2], brush trenches [Figure 5-3], and preserve vegetation [Figure 5-4]. Streambank treatments were identified in the field by referring to the as-built design overview [Figure 5-6; Figure 5-7]. The origin (i.e., upstream end) and terminus (i.e., downstream end) of each streambank treatment was marked[17]. For vegetated soil lift treatments, additional markers were placed every 50 feet (following the river edge) from the treatment origin to mark the location of each cover plot[18]. Streambank distances were measured manually with a tape.

For each SVSL and DVSL streambank treatment, vegetation monitoring occurred in discrete 19.5 square foot plots selected based on a stratified sampling design. Monitoring plots were placed every 50 feet beginning at the upstream origin of each treatment [Figure 5-5]. Monitoring plots were rectangular (6.5x3.0 feet) and oriented parallel to the river edge, beginning at the boundary between the vegetated soil lift and the backfill [Figure 5-5]. For SVSL and DVSL treatments which were less than 50 feet in length, a single 6.5x3.0 foot plot was established at the mid-point of the treatment.

For each brush trench and preserved vegetation streambank treatment, vegetation was monitored throughout the length of the treatment.

[17] The origin and terminus of each streambank treatment was marked by placing a 36x5/8 inch steel reinforcing bar (rebar) stake approximately 24 inches below the soil surface. Each rebar stake was capped and marked with identifying information. Streambank survey stakes were placed approximately 18 inches behind the wetted edge of the river.

[18] The 50-foot survey markers for the vegetated soil lift treatment cover plots were marked with rebar stakes offset 6.5 feet behind the plot origin (boundary between the vegetated soil lift and the backfill), perpendicular to the river bank.

Figure 5-1. Single vegetated soil lift streambank treatment in Phase 1 of the Clark Fork River Operable Unit.

Figure 5-2. Double vegetated soil lift streambank treatment in Phase 1 of the Clark Fork River Operable Unit.

Figure 5-3. Brush trench streambank treatment in Phase 1 of the Clark Fork River Operable Unit.

Figure 5-4. Preserve vegetation streambank treatment in Phase 1 of the Clark Fork River Operable Unit.

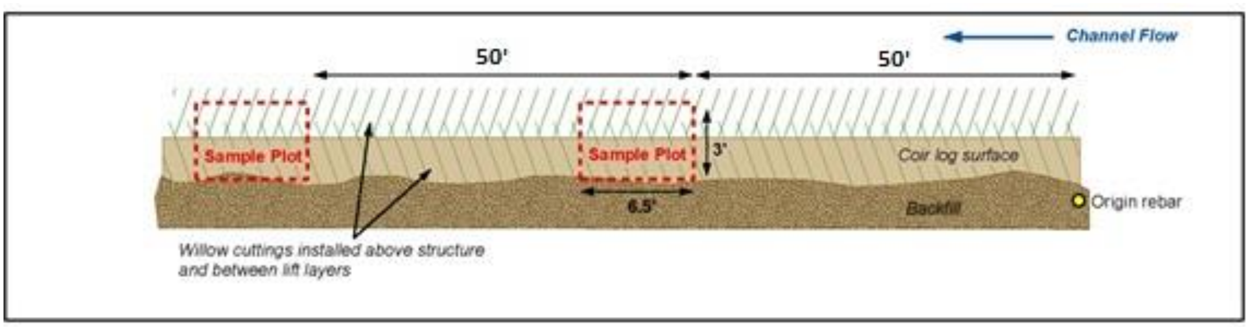

Figure 5-5. Streambank cover monitoring plot locations for single and double vegetated soil lift streambank treatments in Phase 1 of the Clark Fork River Operable Unit [Source: Sacry et al., 2012].

5.2.1.2 Floodplain Monitoring

Floodplain plant survival monitoring plots were selected using a stratified random sample design intended to include a minimum of 10% of the woody plantings in Phase 1 and characterize the range of vegetation cover types and browse treatments used in Phase 1 [Sacry 2014; Sacry et al., 2012; 2014]. Floodplain cover types comprised one sampling stratum and included "floodplain riparian shrub", "outer bank riparian shrub", and "riparian wetland" cover types. Browse treatment type comprise a potential second sampling stratum which was separated into either individual browse protectors or fenced exclosures. The characteristics of each planting unit were identified by referring to the as-built design overviews.

Planting units in which a survival monitoring plot was to be placed were specifically identified prior to completing field work to set up plots. In addition to the sampling strata described above, planting units from across the entire site were selected for monitoring and are well distributed across Phase I. In order to achieve the desired number of plants to be monitored for survival, a majority of the plots are located within planting units that had a high number of plants within them. Extremely small planting units with less than 15 plants were generally not selected. Once a planting unit was selected for monitoring, a rectangular monitoring plot was placed around a portion of that planting unit. All woody plants within each monitoring plot were surveyed to determine survival. The size and location of each monitoring plot within each selected planting unit was selected conveniently in order to include the minimum required number of woody plants to meet the objectives of the monitoring program (i.e., monitor 10% of all woody plants and monitor the range of floodplain vegetation cover types and browse treatments)[19].

5.2.2 Monitoring Schedule

The annual frequency of vegetation monitoring for Phase 1 of the CFROU varies by monitoring metric but all vegetation monitoring should occur during the growing season [Sacry et al., 2012]. The 2014 monitoring season was the first year of monitoring for Phase 1. Prior to data collection activities, a site visit occurred on May 28, 2014 to review conditions, monitoring protocols, and consider adaptations to the protocols based on recent conditions. The site visit included project managers from the Montana Department of Environmental Quality (MDEQ), members of the design team, and monitoring field staff. All vegetation field sampling occurred during the 2014 growing season in August 2014. Monitoring plots were installed from August 12-15, 2014, and plots were monitored from August 25-29, 2014. Field activities were conducted by a monitoring team of 4-5 people.

[19] Floodplain plant survival monitoring plot corners were marked with 36x5/8 inch steel reinforcing bar (rebar) stakes driven approximately 24 inches into the soil. Each rebar stake was capped and marked with identifying information. Prior to monitoring each floodplain plant survival monitoring plot, survey string was placed around the outside of the plot stakes to delineate plot boundaries.

5.2.3 Monitoring Parameters

5.2.3.1 Performance Targets

Data described in this report is intended to evaluate progress toward attainment of vegetation performance targets following remediation of Phase 1 in Reach A of the CFROU. In addition, results of this monitoring will inform adaptive management decisions for ongoing remediation and restoration actions in other Phases of the CFROU. This report describes conditions in Phase 1 during the summer of 2014, one year after remedial activities were completed, and evaluates progress toward attainment of the performance targets [Table 5-1]. The monitoring metrics used to evaluate the performance targets reflect desired project goals and were recommended by Sacry et al. [2012] for streambank and floodplain vegetation. Performance targets for noxious weeds and wetlands were specified in the CFROU ROD [USEPA, 2004].

Table 5-1. Performance targets for vegetation monitoring metrics in Phase 1 of the Clark Fork River Operable Unit following remediation [Source: Sacry et al., 2012].

Objective	Monitoring Metric	Year (post-remediation)				
		1	3	5	10	15
Streambanks	Woody plant canopy cover (%)			40	50	80
Floodplain	Woody plant survival (%)	80[20]				
Floodplain	Woody plant canopy cover (%)			30	50	
Floodplain	Total native cover (%)	20[21]		80	80	80
Noxious weeds[22]	Noxious weed cover (%)	<5[23]	<5	<5	<5	<5
Wetlands	Wetland area (acres)				0.47	
Wetlands	Functional effective wetland area (FEWA) score				2.3	

5.2.3.2 Other Factors

Natural recruitment of native vegetation will likely be an important component of the revegetation of Phase 1 [Sacry et al., 2012]. However, there is no performance target for natural recruitment of native vegetation in Phase 1 because multiple stochastic factors (e.g., proximity to seed sources, weather patterns, river hydrology), rather than management actions, are likely to influence natural recruitment [Sacry et al., 2012].

[20] In 2014, Year 1 woody plant survival was monitored in those floodplain planting units that had been completed as of the time of monitoring in August. Additional plantings will occur in floodplain planting units in the fall of 2014 and survival in those planting units will be monitored during the growing season in 2015.

[21] Will be monitored during the growing season of 2015.

[22] Noxious weeds include those listed by the state of Montana [MDA, 2015].

[23] Will be monitored during the growing season of 2015.

The intensity of vegetation browse by herbivorous animals is not a performance target but will likely influence attainment of all other vegetation performance targets [Sacry et al., 2012]. Browse intensity will therefore be monitored as a factor that may help explain why certain performance targets were, or were not, met.

5.2.4 Sample Collection and Analysis

5.2.4.1 Streambank Monitoring

Within each SVSL and DVSL streambank treatment, an overall assessment was made to describe the conditions of the streambank and treatment, identify potential maintenance needs, and identify any additional notable characteristics of that portion of the streambank or treatment. Surveyors took upstream and downstream photographs (one landscape and one portrait view) at the origin, terminus, and every 50 feet within each treatment[24]. Within each streambank cover monitoring plot of the SVSL and DVSL treatments, surveyors estimated woody plant canopy cover, measured the height of woody vegetation (minimum and maximum), identified the presence of all herbaceous and woody plant species, took photographs of the plot (one landscape view and one portrait view), and made note of any special characteristics of the plot. To estimate percent leaf cover a surveyor stood over the monitoring plot and visually estimated the proportion of the 19.5 square foot plot that was shaded by leaves from woody vegetation. Percent leaf cover was estimated to the nearest 10%. If the surveyor estimated the percent leaf cover was less than 10%, the surveyor estimated leaf cover to the nearest 1%. In estimating leaf cover, the surveyor disregarded cover from woody plant stems. All percent leaf cover estimates were made by the same surveyor to eliminate variation due to surveyor bias.

For each brush trench and preserve vegetation treatment, an overall assessment was made to describe overall treatment stability, the extent to which the treatment captured wood in the channel, shrub vigor, and any additional surveyor observations of the treatment. Shrub vigor was generally rated as low, moderate, or high based on the surveyors observations. Surveyors also took upstream and downstream photographs (one landscape and one portrait view) at the origin and terminus of each treatment.

5.2.4.2 Floodplain Monitoring

For each woody plant rooted within each floodplain plant survival monitoring plot, plant species, plant survival, browse intensity, and origin of the woody plant was determined. Plants which were rooted partially on the plot boundaries were considered within the plot if at least 50% of the plant's roots were assumed to be inside the plot. Each plant was marked after being counted to avoid being counted more than once.

Within each floodplain monitoring plot, all herbaceous and noxious species were identified. Additional notes were made for each monitoring plot such as the likely causes of plant

[24] All survey photographs were taken from a specific survey marker location with a tripod at a height of 4 feet.

mortality, potential needs for maintenance, potential water stress, and identification of possible insect infestations or diseases.

5.2.5 Data Analysis

The woody plant cover and maximum stem height estimates from each streambank cover monitoring plot was tabulated and the average (mean) value was calculated for all plots in Phase 1. To compare plant cover and maximum stem height between single and double vegetated soil lift streambank treatments, cover and maximum stem height were compared between each group with *t*-tests.

Survival in each floodplain plant survival monitoring plot was tabulated and the average value was calculated for all plots in Phase 1. Average woody plant survival among all floodplain monitoring plots was then compared to the Year 1 performance target [Table 5-1]. In addition, *t*-tests were used to compare survival among floodplain cover types.

5.3 RESULTS

5.3.1 Streambank Monitoring

In total, average percent cover of woody vegetation was estimated in 147 streambank cover monitoring plots distributed among 47 vegetated soil lift treatments. Streambank treatments are depicted in Figure 5-6 and Figure 5-7. Among all streambank cover monitoring plots, woody vegetation cover was 15.2% (standard deviation [SD] = 12.0%) [Table 5-2]. There was no evidence that average cover differed between single and double vegetated soil lift treatment types (*p*-value from two-tailed *t*-test = 0.8664; *t*-statistic = 0.1692) [Figure 5-8]. Among all streambank cover monitoring plots, average minimum willow height was 2.4 inches (SD = 1.1 inches) and average maximum height was 27.6 inches (SD = 10.3 inches). As with cover, there was also no evidence that the maximum willow height differed between single and double vegetated soil lift treatment types (*p*-value from two-tailed *t*-test = 0.4935; *t*-statistic = 0.6907).

For some of the streambank cover monitoring plots where percent cover was below 10% or where the majority of above ground stems were dead, the base of the willow cuttings were sprouting new stems approximately 1-3 feet behind the bioengineered bank. Figure 5-9 illustrates two extremes in cover; a streambank treatment with low canopy cover and little sprouting behind the bank and another with relatively high canopy cover and substantial sprouting behind the bank.

Streambank cover monitoring plots were not established along brush trench and preserve vegetation treatments. However, all treatments were photographed and general observations regarding treatment stability and the overall vigor of woody vegetation was noted. Of the 54 brush trench and preserve vegetation segments, 92% were rated as “moderate” to “high” for shrub vigor and overall treatment stability. Streambank treatments that were rated “low” for shrub vigor included:

- LB-S-11: a preserve vegetation treatment which was stable but comprised entirely of herbaceous vegetation [Figure 5-7];
- LB-N-22: a preserve vegetation treatment with bank erosion and comprised primarily of herbaceous vegetation including reed canary grass and sedges [Figure 5-7];
- RB-N-08: a brush trench treatment with above ground stems which were primarily dead but plants were re-sprouting from the base suggesting roots are taking hold and woody vigor will likely improve over time [Figure 5-6]; and
- RB-N-36: a brush trench treatment with above ground stems which were primarily dead but plants were re-sprouting from the base suggesting roots are taking hold and woody vigor will likely improve over time [Figure 5-7].

In addition to the brush trench treatments installed on or near the streambanks, additional brush trenches were installed 10 feet behind and oriented parallel to many of the DVSL and SVSL treatments. Photographs and general observations were made at each brush trench. Woody vigor was "moderate" to "high" at the majority of the trenches [Figure 5-10].

With regard to toe material scour and treatment undercutting, all bioengineered streambank treatments were determined to be stable during the August monitoring period, with nine treatments showing evidence of undercutting. Those treatments where undercutting was observed include: LBN-44, LBN-48, LBN-51, RBN-5, RBN-23, RBN-30, RBN-44, and RBN-47 [Figure 5-6; Figure 5-7]. At none of these locations was undercutting determined to be having an adverse effect on treatment integrity.

Three willow species were observed in the streambank cover monitoring plots [Table 5-3]: Booth willow, Drummond willow, and sandbar willow. Sandbar willow was observed in nearly all streambank cover monitoring plots (97.3%) and Booth willow was observed in the majority of the streambank cover monitoring plots (57.0%). Drummond willow was observed in a small proportion of the streambank cover monitoring plots (5.4%). The only other shrub identified was Wood's rose in one (0.7%) streambank cover monitoring plot. In addition to the shrubs, 19 forbs, grasses, or grass allies (i.e., "grass-like" plants such as sedges, rushes, bulrushes, cattail horsetail, or clubmoss) were observed [Table 5-3]. These species were observed in no more than 10.0% of the streambank cover monitoring plots. Of those species, three had been seeded (common yarrow, oak-leaf goosefoot, and alfalfa), ten naturally colonized (redtop, Common spikerush, willow-herb, field horsetail, field mint, curly dock, dandelion, common mullein, and American speedwell), and six were of unknown origin (mustard, sedge, true grasses in the *Poaceae* family, knotweed, dock, and clover).

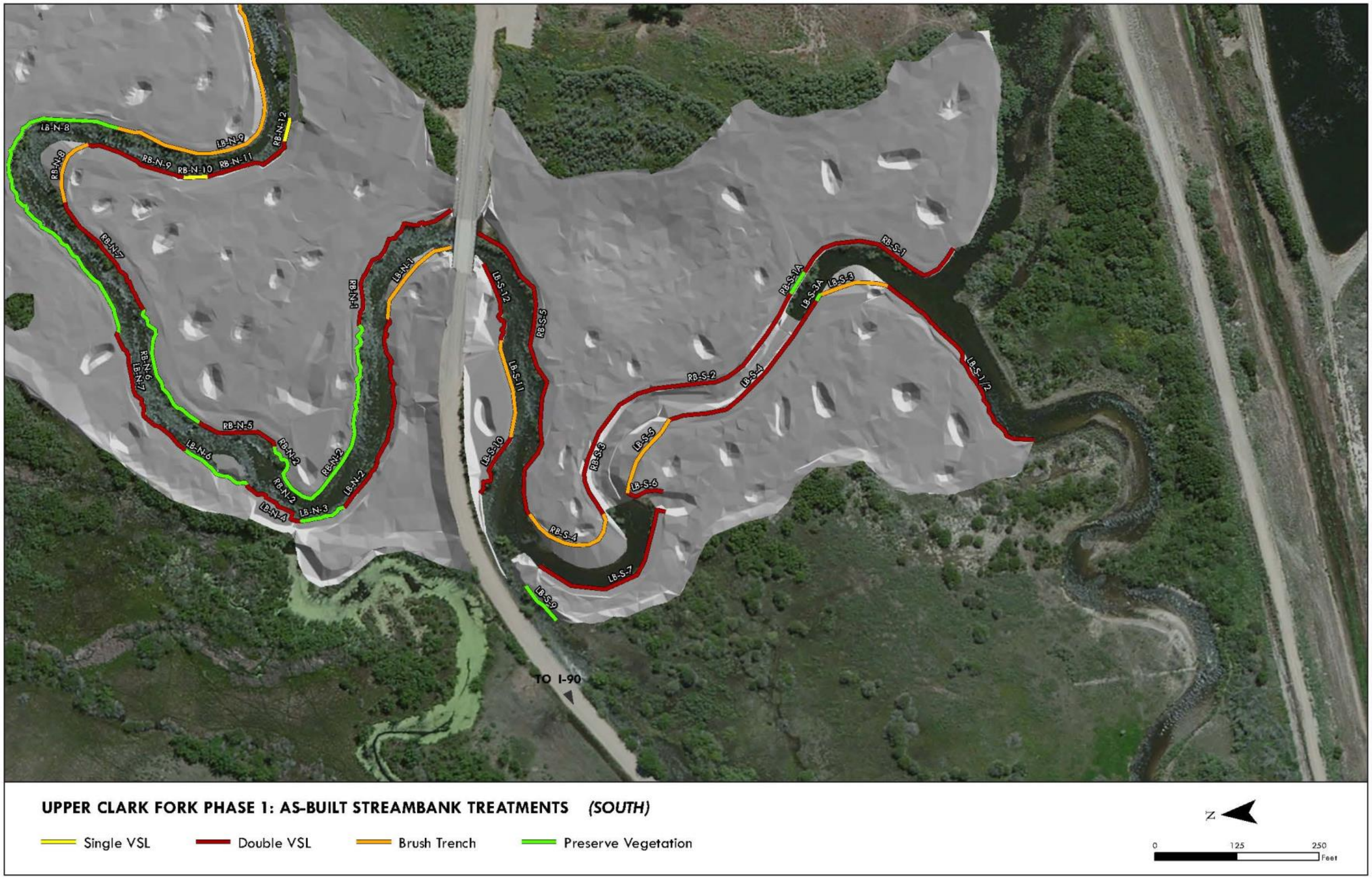

Figure 5-6. As-built streambank treatments at the south end of Phase 1 of the Clark Fork River Operable Unit, 2014 [Source: Sacry et al., 2014].

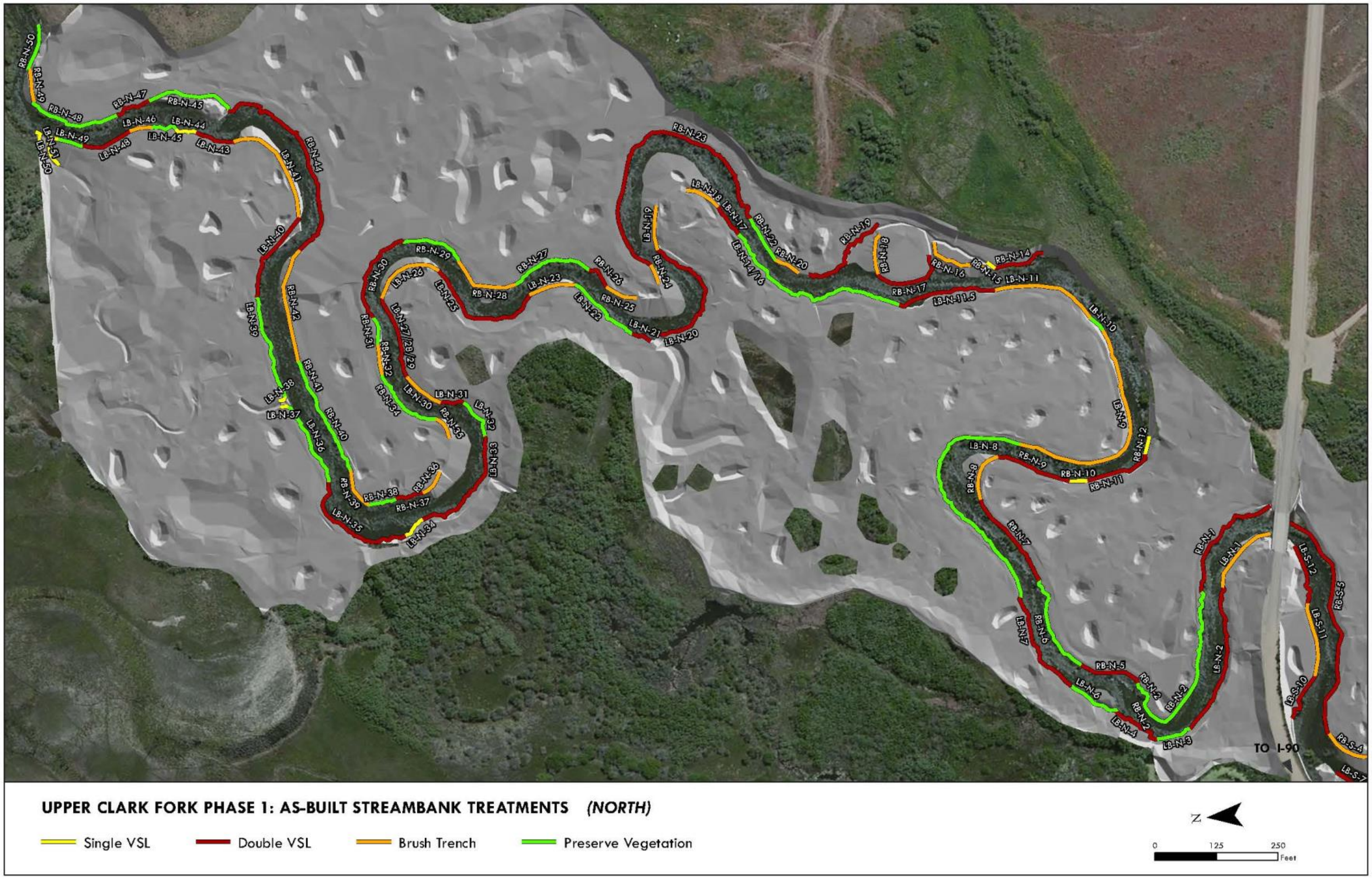

Figure 5-7. As-built streambank treatments at the north end of Phase 1 of the Clark Fork River Operable Unit, 2014 [Source: Sacry et al., 2014].

Table 5-2. Cover (%) and height (in) of woody vegetation in streambank cover monitoring plots in Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014.

Vegetated Soil Lift Type	Plot ID	Number of plots	Average cover of woody vegetation (%)	Average minimum height (in)	Average maximum height (in)
Double	LB-N-02	6	16	2	28
Double	LB-N-04	1	2	3	24
Double	LB-N-07	1	2	2	7
Double	LB-N-07A	2	3	0	36
Double	LB-N-11.5	3	20	2	28
Double	LB-N-17	1	30	2	31
Double	LB-N-20	5	38	2	37
Double	LB-N-21	1	30	3	24
Double	LB-N-25	5	14	3	35
Double	LB-N-27	3	27	3	36
Double	LB-N-31	1	3	2	22
Double	LB-N-33	5	28	3	40
Single	LB-N-34	1	10	4	32
Double	LB-N-35	5	12	3	32
Single	LB-N-37	1	8	2	37
Single	LB-N-38	1	10	2	9
Double	LB-N-43	1	2	2	13
Single	LB-N-44	1	1	4	16
Double	LB-N-48	2	40	1	45
Single	LB-N-50	1	20	2	32
Single	LB-N-51	0	0	0	0
Double	LB-S-01/02	6	15	2	23
Double	LB-S-04	6	15	1	17
Double	LB-S-06	1	30	1	22
Double	LB-S-07	5	11	1	17
Double	LB-S-10	2	15	2	31
Double	LB-S-12	2	10	1	23
Double	RB-N-01	5	14	3	20
Double	RB-N-05	2	6	3	26
Double	RB-N-07	4	17	3	42
Double	RB-N-09	3	13	3	35
Single	RB-N-10	1	5	5	33
Double	RB-N-11	2	25	2	37
Single	RB-N-12	1	60	4	55
Double	RB-N-14	2	25	3	27
Double	RB-N-17	3	8	1	27
Double	RB-N-19	4	15	2	34
Double	RB-N-23	12	13	3	30
Double	RB-N-26	1	5	2	15
Double	RB-N-30	4	12	5	33
Double	RB-N-37	1	2	2	15
Double	RB-N-44	8	11	3	35
Double	RB-N-47	1	5	3	30
Double	RB-S-01	5	13	2	28
Double	RB-S-02/03	10	22	2	27
Double	RB-S-05	9	18	2	26
Total		**147**	-	-	-
Average			**15.2**	**2.3**	**27.7**
Standard Deviation			**12.0**	**1.1**	**10.3**

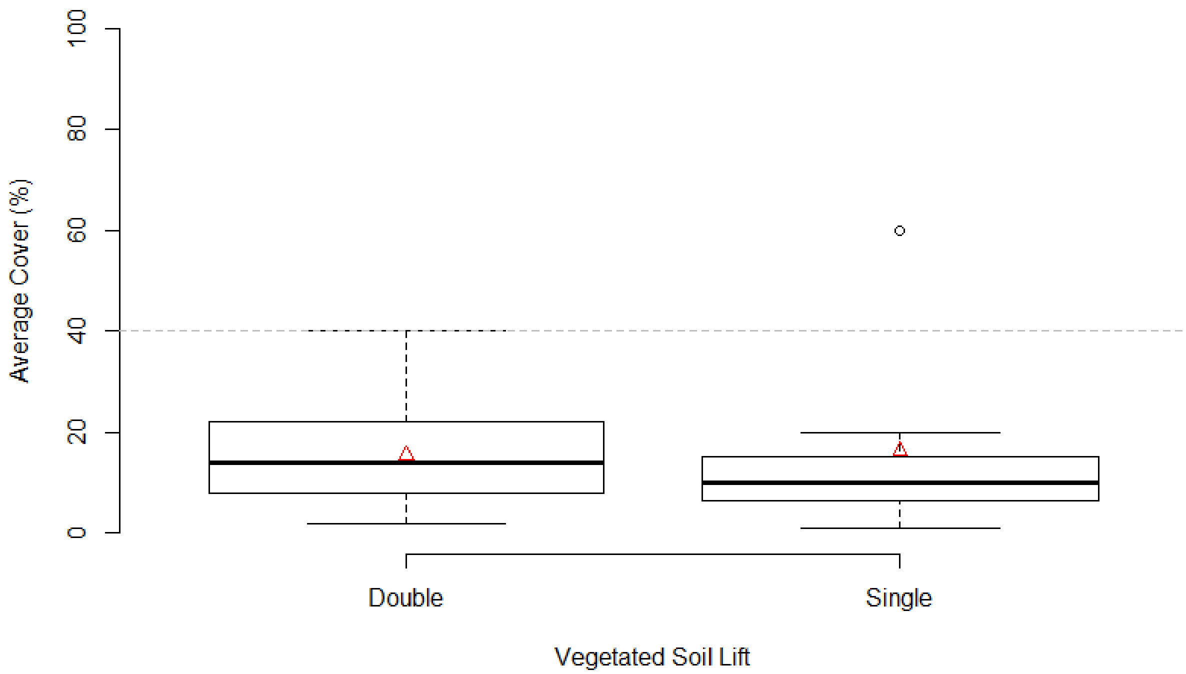

Figure 5-8. Cover (%) of woody vegetation in two types of vegetated soil lift treatments in Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014. Red triangles represent the group means. For reference, dashed line represents Year 5 performance target; however, monitoring in 2014 represents Year 1 conditions.

Figure 5-9. Example double vegetated soil lift streambank treatments with relatively low (2%; upper panel) and relatively high (40%; lower panel) woody canopy cover in Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014.

Figure 5-10. Example brush trench streambank treatment in Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014.

Table 5-3. Occurrence of plant species in streambank cover monitoring plots (*n* = 147) in Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014. Noxious species classifications from MDA [2015].

Common name	Taxonomic name	Species code	Origin	Status	Occurrence	
					Present	Proportion (%)
Forbs						
Common yarrow	*Achillea millefolium*	ACHMIL	Seeded	Native	1	0.7
Redtop	*Agropryon stolonifera*	AGRSTO	Colonized	Nonnative	6	4.1
Mustard	*Brassicaceae* family	BRAfam	Unknown	Nonnative	1	0.7
Oak-leaf goosefoot	*Chenopodium glaucum*	CHEGLA	Seeded	Native	6	4.1
Willow-herb	*Epilobium ciliatum*	EPICIL	Colonized	Native	6	4.1
Field horsetail	*Equisetum arvense*	EQUARV	Colonized	Native	15	10.2
Licorice root	*Glycyrrhiza lepidota*	GLYLEP	Colonized	Native	2	1.4
Alfalfa	*Medicago sativa*	MEDSAT	Seeded	Nonnative	7	4.8
Field mint	*Mentha arvensis*	MENARV	Colonized	Native	1	0.7
Knotweed complex	*Polygonum* species	POLspp	Colonized	Various; some species are noxious	4	2.7
Curly dock	*Rumex crispus*	RUMCRI	Colonized	Nonnative	3	2.0
Dock	*Rumex* species	RUMspp	Unknown	Unknown	1	0.7
Dandelion	*Taraxacum officinale*	TAROFF	Colonized	Nonnative	8	5.4
Clover	*Trifolium* species	TRIspp	Unknown	Unknown	3	2.0
Common mullein	*Verbascum thapsus*	VERTHA	Colonized	Nonnative	2	1.4
American speedwell	*Veronica americana*	VERAME	Colonized	Native	12	8.2
Grasses						
True grasses	*Poa* species	POAspp	Unknown	Unknown	11	7.4
Grass allies						
Sedge	*Carex* species	CARspp	Unknown	Native	1	0.7
Common spikerush	*Eleocharis palustris*	ELEPAL	Colonized	Native	11	7.4
Shrubs						
Wood's rose	*Rosa woodsii*	ROSWOO	Colonized	Native	1	0.7
Booth willow	*Salix boothii*	SALBOO	Planted	Native	84	57.0
Drummond willow	*Salix drummondiana*	SALDRU	Unknown	Native	8	5.4
Streamside willow	*Salix exigua*	SALEXI	Planted	Native	143	97.3

5.3.2 Floodplain Monitoring

In 2014, 32 floodplain plant survival monitoring plots were established and monitored within floodplain planting units [Figure 5-11; Figure 5-12]. In total 1,264 out of 10,245 (12.3%) containerized plants were monitored [Table 5-4]. Among all plants sampled in the floodplain plant survival monitoring plots, survival was 87.7% [Table 5-4] which exceeded the Year 1 performance target (80%) for floodplain plant survival in Phase 1 [Table 5-1]. Survival of all plant species was significantly different among cover types (p-value from two-sided chi-squared test <0.0001; chi-squared statistic = 88.985). When all plant species were pooled, survival was 72.1% in the floodplain riparian shrub cover type, 89.3% in the riparian wetland cover type, and 94.4% in the outer bank riparian shrub cover type [Table 5-5]. Several floodplain plant survival monitoring plots were noted to be inundated by floodwater at the time of monitoring during the late summer [Figure 5-13]. In the floodplain riparian shrub cover type, where survival of plants overall was at least 17.2% lower than in the other cover types, survival also differed significantly by species (p-value from two-sided chi-squared test <0.0001; chi-squared statistic = 70.358)[25]. Survival of birch was quite low (27.3%) in the floodplain riparian shrub cover type compared to all other species (red-oiser dogwood, Booth's willow, and sandbar willow) which each had ≥80.0% survival.

In the riparian wetland cover type survival also differed significantly by species (p-value from two-sided chi-squared test <0.0001; chi-squared statistic = 115.186). As in the floodplain riparian shrub cover type, birch survival was low (26.9%) compared to all other species (red-oiser dogwood, Booth's willow, and sandbar willow) which each had ≥83.3% survival.

In contrast, there was no evidence that survival differed by species in the outer bank riparian shrub cover type (p-value from two-sided chi-squared test 0.0812; chi-squared statistic = 11.243)[26]. In the outer bank riparian shrub cover type, survival of all plant species (speckled alder, birch, red-oiser dogwood, black cottonwood, quaking aspen, Booth's willow, and sandbar willow) was ≥83.3%.

Among the 32 floodplain survival monitoring plots, 37 forb species, 11 grass species, 5 grass allie species, and 9 shrub and plant species were observed [Table 5-6]. The ten most common forb species observed in these plots were common yarrow (75.0%), kochia (65.6%), oak-leaf goosefoot (59.4%), Rocky Mountain bee plant (43.8%), alfalfa (43.8%), foxtail barley (43.8%), field sowthistle (34.4%), tall tumbleweed mustard (31.3%), and small tumbleweed mustard (31.3%). Of those ten most common forb species, only four were known to be seeded: common yarrow, cudweed, oak-leaf goosefoot, and alfalfa. Of the grass species, tall wheatgrass (75%) and Canada bluegrass (75%) were the most common. Of the 11 grass species observed, at least eight were seeded. Of the six grass allie species, at least four were known to be seeded or planted and cattails were the most common (37.5%), although the origin of those cattails is unknown. All observed shrub and tree species were planted.

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[25] Speckled alder not included in this comparison due to inadequate sample size (n = 1).

[26] Four dead plants could not be identified to species and were not included in this comparison.

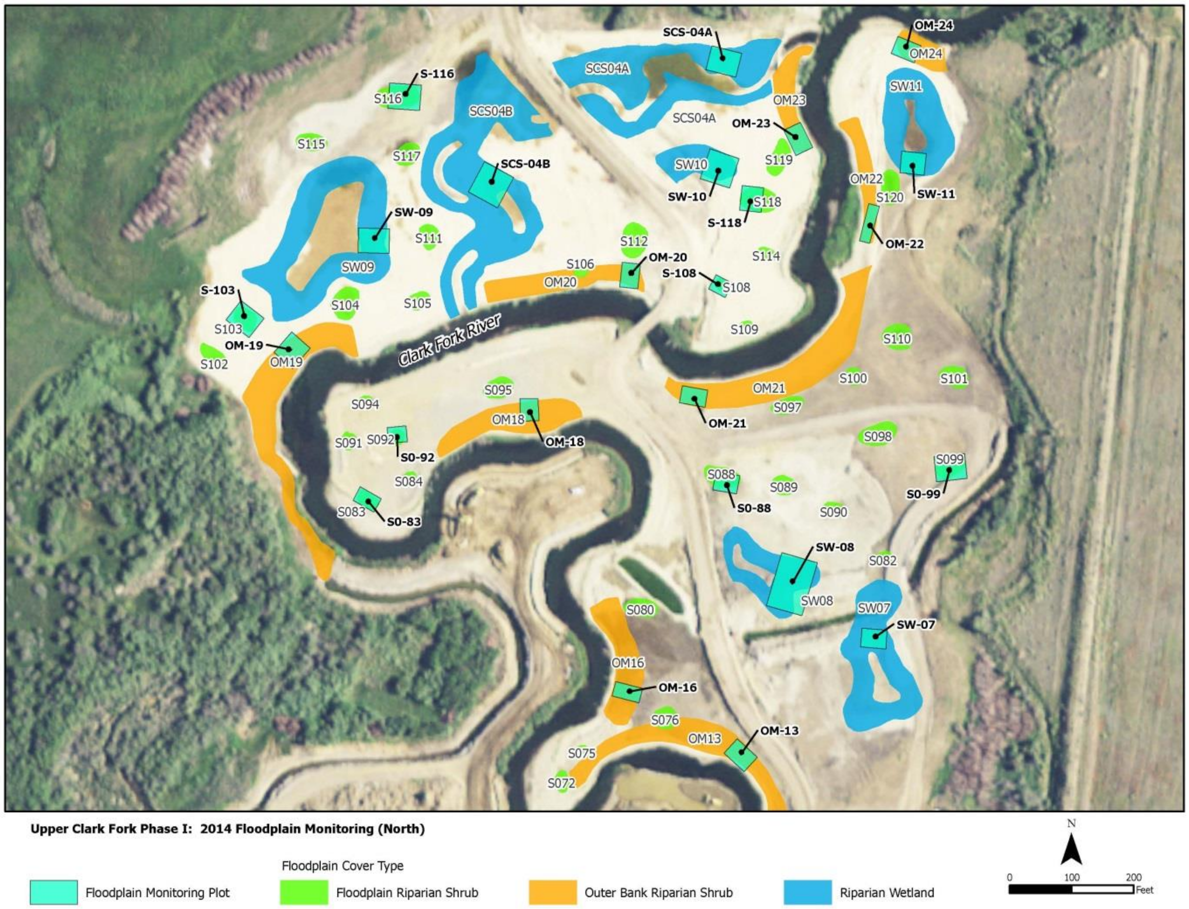

Figure 5-11. Floodplain plant survival monitoring plots in the northern half of Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014.

Figure 5-12. Floodplain plant survival monitoring plots in the southern half of Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014.

Table 5-4. Survival of planted shrubs and trees by planting unit in Phase 1, Reach A of the Clark Fork Operable Unit, 2014.

Floodplain cover type	Planting unit (Plot ID)	Number of plantings in planting unit	Number of sampled plants in planting unit		Planting unit survival (%)
			Alive	Total	
Floodplain Riparian Shrub	MC-02	1,400	45	58	78
	S-033	30	18	27	67
	S-036	30	24	28	86
	S-083	15	11	15	73
	S-088	50	16	31	52
	S-092	15	10	15	67
	S-099	30	20	29	69
	S-103	30	22	25	88
	S-108	10	10	10	100
	S-116	60	16	37	43
	S-118	40	23	23	100
Outer Bank Riparian Shrub	OM-06	400	51	51	100
	OM-10	370	38	41	93
	OM-12	367	38	39	97
	OM-13	1,047	57	58	98
	OM-16	343	43	43	100
	OM-18	395	35	35	100
	OM-19	457	39	42	93
	OM-20	297	45	51	88
	OM-21	755	49	50	98
	OM-22	235	43	43	100
	OM-23	137	22	25	88
	OM-24	173	49	57	86
Riparian Wetland	SCS-04A	752	56	58	97
	SCS-04B	470	40	40	100
	SW-02	200	36	58	62
	SW-04	430	40	40	100
	SW-07	420	37	50	74
	SW-08	110	41	45	91
	SW-09	580	51	52	98
	SW-10	140	45	46	98
	SW-11	457	39	42	93
Total		**10,245**	**1,109**	**1,264**	**87.7**

Table 5-5. Survival of planted shrubs and trees by cover type and species in Phase 1, Reach A of the Clark Fork Operable Unit, 2014.

Common name	Taxonomic name	Species code	Survival by cover type (live plants/total monitored)				Total (%)
			Floodplain riparian shrub	Outer bank riparian shrub	Riparian wetland	Total	
Speckled alder	*Alnus incana*	ALNINC	0/1	15/18	0/0	15/19	**78.9**
Birch	*Betula occidentalis*	BETOCC	15/55	12/12	7/26	34/93	**36.6**
Red-oiser dogwood	*Cornus sericea*	CORSER	8/10	8/8	15/18	31/36	**86.1**
Black cottonwood	*Populus balsamifera*	POPBAL	0/0	13/13	0/0	13/13	**100**
Quaking aspen	*Populus tremuloides*	POPTRE	0/0	17/17	0/0	17/17	**100**
Booth's willow	*Salix boothii*	SALBOO	50/56	80/81	26/27	156/164	**95.1**
Sandbar willow	*Salix exigua*	SALEXI	142/176	364/382	337/360	843/918	**91.8**
Unknown		UNK	0/0	0/4	0/0	0/4	**0**
Total			215/298	509/539	385/431	1,109/ 1,264	
Total (%)			**72.1**	**95.1**	**89.3**	**87.7**	

Figure 5-13. Inundated floodplain plant survival monitoring plot (S-116) in floodplain riparian shrub planting unit in Phase 1 of Reach A of the Clark Fork River Operable Unit, August 2014.

Table 5-6. Occurrence of plant species in floodplain survival monitoring plots in Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014. Noxious species classifications from MDA [2015].

Common name	Taxonomic name	Species code	Origin	Status	Occurrence by cover type				Total (%)
					Floodplain riparian shrub (n = 11)	Outer bank riparian shrub (n = 12)	Riparian wetland (n = 9)	Total (n = 32)	
Forbs									
Common yarrow	*Achillea millifolium*	ACHMIL	Seeded	Native	10	8	6	24	75.0
Redtop	*Agropryon stolonifera*	AGRSTO	Colonized	Nonnative	1	2	3	6	18.8
Pigweed	*Amaranthus* species	AMAspp	Colonized	Nonnative	0	1	0	1	3.1
Cudweed	*Artemisia ludoviciana*	ARTLUD	Seeded	Native	8	4	2	14	43.8
Tumbling saltweed	*Atriplex rosea*	ATRROS	Colonized	Nonnative	0	1	0	1	3.1
Mustard	*Brassicaceae family*	BRAfam	Unknown	Nonnative	0	1	0	1	3.1
Whitetop	*Cardaria draba*	CARDRA	Colonized	Noxious	0	0	2	2	6.3
Spotted knapweed	*Centaurea maculosa*	CENMAC	Colonized	Noxious	1	0	1	2	6.3
Goosefoot (blite)	*Chenopodium (capitatum)*	CHE(CAP)	Colonized	Native	0	0	1	1	3.1
Pitseed goosefoot	*Chenopodium berlandieri*	CHEBER	Colonized	Native	2	4	2	8	25.0
Oak-leaf goosefoot	*Chenopodium glaucum*	CHEGLA	Seeded	Native	8	5	6	19	59.4
Canada thistle	*Cirsium arvense*	CIRARV	Colonized	Noxious	0	1	1	2	6.3
Rocky Mountain bee plant	*Cleome serrulata*	CLESER	Seeded	Native	2	5	7	14	43.8
Willow-herb	*Epilobium ciliatum*	EPICIL	Colonized	Native	6	1	0	7	21.9
Leafy spurge	*Euphorbia esula*	EUPESU	Colonized	Noxious	2	0	1	3	9.4
Common sunflower	*Helianthus annuus*	HELANN	Seeded	Native	0	1	1	2	6.3
Foxtail barley	*Hordeum jubatum*	HORJUB	Unknown	Native	3	5	6	14	43.8
Kochia	*Kochia scoparia*	KOCSCO	Colonized	Nonnative	6	9	6	21	65.6
Black medick	*Medicago lupulina*	MEDLUP	Colonized	Nonnative	0	1	0	1	3.1
Alfalfa	*Medicago sativa*	MEDSAT	Seeded	Nonnative	7	5	2	14	43.8
Yellow monkeyflower	*Mimulus guttatus*	MIMGUT	Seeded	Native	0	1	0	1	3.1
Prostrate knotweed	*Polygonum aviculare*	POLAVI	Colonized	Nonnative	1	4	2	7	21.9
Spotted ladysthumb	*Polygonum persicaria*	POLPER	Colonized	Nonnative	0	1	1	2	6.3

Knotweed complex	*Polygonum species*	POLspp	Colonized	Various	0	0	1	1	3.1
Curly dock	*Rumex crispus*	RUMCRI	Colonized	Nonnative	0	2	0	2	6.3
Golden dock	*Rumex fueginus*	RUMMAR	Colonized	Native	1	1	0	2	6.3
Willow dock	*Rumex salicilfolius*	RUMSAL	Colonized	Native	0	0	1	1	3.1
Tall tumbleweed mustard	*Sisymbrium altissimum*	SISALT	Colonized	Nonnative	7	1	2	10	31.3
Small timbleweed mustard	*Sisymbrium loesii*	SISLOE	Colonized	Nonnative	6	1	3	10	31.3
Hoe nightshade	*Solanum sarachoides*	SOLSAC	Colonized	Nonnative	1	0	0	1	3.1
Cutleaf nightshade	*Solanum triflorum*	SOLTRI	Colonized	Native	1	0	1	2	6.3
Field sowthistle	*Sonchus arvensis*	SONARV	Colonized	Nonnative	6	2	3	11	34.4
Spiny sowthistle	*Sonchus asper*	SONASP	Colonized	Nonnative	1	0	0	1	3.1
Pursch seepweed	*Suaeda calceoliformis*	SUACAL	Colonized	Native	1	0	2	3	9.4
Field pennycress	*Thlaspi arvensis*	THLARV	Colonized	Nonnative	2	0	0	2	6.3
Common mullein	*Verbascum thapsus*	VERTHA	Colonized	Nonnative	1	0	0	1	3.1
American speedwell	*Veronica americana*	VERAME	Colonized	Native	0	2	0	2	6.3
Grasses									
Tall wheatgrass	*Agropyron intermedia*	AGRINT	Seeded	Native	7	10	7	24	75.0
Quackgrass	*Agropyron repens*	AGRREP	Colonized	Nonnative	6	6	2	14	43.8
Slender wheatgrass	*Agropyron trachycaulum*	AGRTRA	Seeded	Native	2	3	3	8	25.0
Bentgrass (rough)	*Agrostis (scabra)*	AGR(SCA)	Unknown	Native	0	1	0	1	3.1
American sloughgrass	*Beckmannia syzigachne*	BECSYZ	Seeded	Native	0	1	4	5	15.6
Tufted hairgass	*Deschampsia species*	DESspp	Seeded	Native	0	1	3	4	12.5
Canada wildrye	*Elymus canadensis*	ELYCAN	Seeded	Native	0	3	2	5	15.6
American mannagrass	*Glyceria grandis*	GLYGRA	Seeded	Native	0	2	0	2	6.3
Scratchgrass	*Muhlenbergia asperifolia*	MUHASP	Colonized	Native	0	1	0	1	3.1
Canada bluegrass	*Poa compressa*	POACOM	Seeded	Nonnative	6	11	7	24	75.0
Nuttall alkaligrass	*Puccinellia nuttalliana*	PUCNUT	Seeded	Native	0	0	1	1	3.1
Grass allies									
Nebraska sedge	*Carex nebrascensis*	CARNEB	Planted	Native	0	2	3	5	15.6
Woolly sedge	*Carex pellita*	CARPEL	Planted	Native	0	1	4	5	15.6
Sedge	*Carex* species	CARspp	Unknown	Native	0	1	1	2	6.3
Baltic rush	*Juncus balticus*	JUNBAL	Seeded	Native	0	3	1	4	12.5
Cattail	*Typha latifolia*	TYPLAT	Unknown	Native	0	6	6	12	37.5

Shrubs and trees									
Speckled alder	*Alnus incana*	ALNINC	Planted	Native	1	8	0	9	28.1
Birch	*Betula occidentalis*	BETOCC	Planted	Native	11	7	4	22	68.8
Red-oiser dogwood	*Cornus sericea*	CORSER	Planted	Native	6	5	7	18	56.3
Shrubby cinquefoil	*Dasiphora floribunda*	DASFLO	Planted	Unknown	6	3	2	11	34.4
Black cottonwood	*Populus balsamifera*	POPBAL	Planted	Native	0	7	0	7	21.9
Quaking aspen	*Populus tremuloides*	POPTRE	Planted	Native	0	9	0	9	28.1
Booth's willow	*Salix boothii*	SALBOO	Planted	Native	9	11	6	26	81.3
Sandbar willow	*Salix exigua*	SALEXI	Planted	Native	11	12	9	32	100.0
Yellow willow	*Salix lutea*	SALLUT	Planted	Unknown	0	9	7	16	50.0

5.3.3 Noxious Weeds

Quantitative data necessary to evaluate progress toward attainment of the noxious weed cover performance target [Table 5-1] were not collected in 2014 but will be collected in 2015. Although there was no standardized monitoring of noxious weed cover in 2015, during the course of monitoring streambank cover and floodplain survival noxious species were observed. No species observed in the streambank cover monitoring plots were listed by the state of Montana as a noxious weed [Table 5-3]. In the floodplain survival monitoring plots, four noxious species were observed: spotted knapweed, Canada thistle, leafy spurge, and whitetop [Table 5-6]. Spotted knapweed, Canada thistle, and whitetop were observed in 6.3% (2 of 32) of the floodplain survival monitoring plots and leafy spurge was observed in 9.4% (3 of 32) of the plots.

5.3.4 Browse Intensity

Browse intensity is not a monitoring metric with a performance target but is a covariate which may explain why specific monitoring metrics (e.g., percent cover of streambank woody vegetation) may achieve or fail to achieve a specific performance target. Browse on the planted containerized plants was rare and mild in the floodplain survival monitoring plots. Of the 1,264 plants monitored, 84% had no discernable browse and only 0.9% were browsed to a degree that was considered more than “mild” [Table 5-7]. Among all plants, survival was actually lower for plants with no browse (86.7%) compared to plants with at least some degree of browse (i.e., “mild” browse or greater; 93.1%) suggesting that where browse occurred it was mild and fencing was highly successful at limiting the frequency and severity of animal browse on the floodplain plantings. Frequency of having any degree of browse (i.e., “mild” or greater) differed among species (p-value from two-sided chi-squared test <0.0001; chi-squared statistic = 471.96). Only 3.4% of the sandbar willow and 5.3% of the speckled alder had any degree of browse whereas at least 58.8% of the red-oiser dogwood, black cottonwood, quaking aspen, and Booth’s willow had any degree of browse [Table 5-8]. Birch, which had low survival overall (36.6%), had a moderate degree of browse (36.6%).

Table 5-7. Browse intensity and plant survival in floodplain survival monitoring plots in Phase 1 of Reach A of the Clark Fork River Operable Unit, 2014.

Browse intensity[27]	Survival		Total
	Alive	Dead	
None	919	141	1,060
Mild	182	10	192
Low	7	0	7
Moderate	1	0	1
Heavy	0	4	4
Total	**1,109**	**155**	**1,264**

Table 5-8. Browse intensity by species in floodplain plant survival monitoring plots in Phase 1 of Reach A in the Clark Fork River Operable Unit, 2014.

Common name	Taxonomic name	Species code	Browse intensity[28]					Total
			None	Mild	Low	Moderate	Heavy	
Speckled alder	*Alnus incana*	ALNINC	18	1	0	0	0	19
Birch	*Betula occidentalis*	BETOCC	59	34	0	0	0	93
Red-oiser dogwood	*Cornus sericea*	CORSER	14	21	1	0	0	36
Black cottonwood	*Populus balsamifera*	POPBAL	4	9	0	0	0	13
Quaking aspen	*Populus tremuloides*	POPTRE	7	10	0	0	0	17
Booth's willow	*Salix boothii*	SALBOO	60	98	5	1	0	164
Sandbar willow	*Salix exigua*	SALEXI	886	31	1	0	0	918
Unknown		UNK	0	0	0	0	4	4
Total			**1,048**	**204**	**7**	**1**	**4**	**1,264**

[27] Browse intensity category definitions: mild = <50% of current year growth is browsed, low = >50% of current year growth is browsed, moderate = prior year growth was browsed, and heavy = extensive browse resulting in stunted plant growth.

[28] Browse intensity category definitions: mild = <50% of current year growth is browsed, low = >50% of current year growth is browsed, moderate = prior year growth was browsed, and heavy = extensive browse resulting in stunted plant growth.

5.4 DISCUSSION

Monitoring in Phase 1 of the CFROU in 2014 was primarily focused on two metrics: streambank woody canopy cover and floodplain woody plant survival. The only monitoring metric which was evaluated against a performance target in 2014 was floodplain plant survival. Other monitoring metrics with Year 1 performance targets (floodplain total native cover and noxious weed cover) will be monitored in 2015. Some floodplain plant survival monitoring plots will be monitored for plant survival in 2015 in planting units that had not yet been planted at the time of monitoring in 2014.

Based on the floodplain plant survival monitoring plots sampled in 2014, the performance target for woody vegetation survival was achieved. However, survival was significantly lower in floodplain riparian shrub cover types compared to other cover types in the floodplain and in the floodplain riparian shrub cover type, mean survival (72.1%) was lower than the performance target (80%). The floodplain riparian shrub cover type is primarily composed of floodplain swales. These swales were excavated relatively deep to intercept ground water which resulted in prolonged inundation, particularly where springs or wetlands were present adjacent to the constructed floodplain. Therefore, it appears that prolonged inundation in these swales may have been a primary cause of reduced plant survival in the floodplain riparian shrub cover type. In addition to lower survival of all plants in the floodplain riparian shrub cover type, birch survival was significantly lower than other plants overall (36.6%) and particularly so in the floodplain riparian shrub and riparian wetland cover types. Based on field observations, both insects and disease appeared to be proximate causes of mortality in floodplain plants. Browse apparently was not a factor which reduced survival of plants in the floodplain. Browse was rare and predominantly mild and there was apparently no negative association between browse and survival in 2014. However, because there were relatively few plants with more severe degrees of browse, the ability to associate survival with browse intensity was limited in 2014. Upon recent field surveys it appears that small mammal browse may become a factor in reducing vegetation cover and possibly survival in the floodplain.

There was no performance target for streambank plant canopy cover in Year 1 monitoring but by monitoring that metric in Year 1 and Year 5, the managers will be able to evaluate temporal trends. In Year 1, streambank cover was 15.2% and there was no difference in cover between single and double vegetated soil lifts. Willow sprouting behind a majority of the streambank treatments indicated strong root establishment even where measured canopy cover was low. It is anticipated that willow cuttings will continue to sucker into the streambank and floodplain, and canopy cover will increase over time.

Shrub vigor and overall treatment stability were rated as at least “moderate” in the majority (92%) of the preserve vegetation and brush trench streambank treatments. All streambank treatments were determined to be “stable” but nine demonstrated evidence of river undercutting. However, this undercutting did not appear to undermine treatment integrity at those sites and undercutting that does not jeopardize bank stability is often considered a desirable outcome for instream fish habitat.

The performance metric for noxious weeds is for less than 5% cover in all monitoring years. Although no quantitative data was collected in 2014 to assess noxious weed cover, noxious weed occurrence was monitored in the streambank cover monitoring plots and in the floodplain plant survival monitoring plots. No known noxious weeds were observed in the streambank cover monitoring plots. In the floodplain survival monitoring plots, four noxious species were observed: whitetop, spotted knapweed, Canada thistle, and leafy spurge. All of these were identified in <10% of the floodplain survival monitoring plots. Noxious weed cover will be monitored in the Phase 1 project area in 2015.

The total wetland area and functional effective wetland area performance goals will be evaluated five years after remediation was completed [USEPA, 2004]. Therefore, no monitoring of wetlands was conducted in 2014 and wetland monitoring will be conducted in Phase 1 in 2018.

Browse intensity was mild in 2014 and did not impede floodplain plant survival. Because browse was mild we did not evaluate if browse treatments (i.e., individual or collective) were related to browse intensity. However, these analyses may be conducted in the future if it appears that browse intensity is related to particular metrics or if there appear to be differences in the efficacy of particular browse treatments.

Finally, streamflows during the spring snowmelt period in 2014 slightly exceeded the bankfull design level (see Section 4.0) in Phase 1 and resulted in extensive inundation of the floodplain both spatially (see Section 4.0) and temporally. The lowered floodplain elevation in combination with these modest flood levels provided excellent conditions for plant survival in Phase 1 in 2014. Some floodplain plant survival monitoring plots remained wet in late August when monitoring occurred and soil moisture levels appeared to be high for that time of year (although soil moisture was not quantified). Floodwater redistributed wood that had been placed on the floodplain and brush trenches and streambank willow cuttings appeared to be effective at capturing and retaining that wood.

6.0 PERIPHYTON

6.1 INTRODUCTION

This chapter describes results of periphyton (benthic algae) monitoring within the CFROU in 2014. A total of twelve sites were sampled, including six sites on the Clark Fork River and Silver Bow Creek and six sites on tributary streams. Periphyton monitoring is one element of the Montana Department of Environmental Quality program for evaluating the influence of remediation on the ecology of the Clark Fork River.

Periphyton samples were analyzed for non-diatom (soft-bodied) algae, and diatom algae taxonomy and community structure. A suite of analytical metrics was applied to the diatom data to assess the degree of impairment from metals, nutrients, and sedimentation. These metrics included a stressor-specific tool developed for the Middle Rockies Ecoregion [Teply, 2010a; 2010b] and adopted by MDEQ as a periphyton standard operating procedure for determining the probability of sediment impairment [MDEQ, 2011]. In addition, a variety of diatom metrics developed for Montana mountain streams were used [Bahls et al., 1992; Bahls, 1993; Teply and Bahls, 2005] which are based on autecological preferences or requirements of freshwater diatoms [Lowe, 1974; Van Dam et al., 1994; Bahls, 2006].

Potential water quality or habitat stressors at each site, indicated by the taxonomic and functional composition of the algal flora, are described in a series of site-specific narratives.

6.2 METHODS

6.2.1 Sampling

In September 2014, the periphyton community was sampled at five sites on the Clark Fork River, and seven sites on tributary streams [Table 6-1]. Tributary sites were located in Mill and Willow Creeks (two sites), Warm Springs Creek, Lost Creek, Racetrack Creek, and the Little Blackfoot River. The twelve sites sampled in 2014 were the same as those sampled in 2013, with the exception of the Little Blackfoot River. The Little Blackfoot River site was moved from near the mouth (sampled in 2013 and prior years) upstream to the Beck Hill Road bridge crossing. Project staff collected periphyton samples on September 16-17, 2014. One composite periphyton sample was collected from multiple substrates and habitat types at each of the twelve monitoring sites. Periphyton samples were collected following the periphyton sampling standard operating procedure for flowing streams where a defined reach has not been established [MDEQ, 2011]. Periphyton samples were preserved in the field with Lugols IKI solution and were transported to the laboratory on ice.

Table 6-1. Periphyton sampling locations in the Clark Fork River Operable Unit, 2014.

Site ID	Site Location	Co-located USGS Streamflow Gauge	Location (GPS coordinates, NAD 83)	
			Latitude	Longitude
Mainstem Sites				
CFR-03A	Clark Fork River near Galen	12323800	46.20877	-112.76740
CFR-07D	Clark Fork River at Galen Road	none	46.23725	-112.75302
CFR-11F	Clark Fork River at Gemback Road	none	46.26520	-112.74430
CFR-27H	Clark Fork River at Deer Lodge	12324200	46.39796	-112.74283
CFR-116A	Clark Fork River at Turah	12334550	46.82646	-113.81424
Tributary Sites				
SS-25	Silver Bow Creek at Warms Springs	12323750	46.18123	-112.77917
MCWC-MWB	Mill-Willow Creek at Frontage Road	none	46.12649	-112.79876
MWB-SBC	Mill-Willow Bypass near mouth	none	46.17839	-112.78270
WSC-SBC	Warms Springs Creek near mouth	12323770	46.18041	-112.78592
LC-7.5	Lost Creek near mouth	12323850	46.21862	-112.77384
RTC-1.5	Racetrack Creek near mouth	none	46.28395	-112.74921
LBR-CFR	Little Blackfoot River at Beck Hill Road	none		

6.2.2 Laboratory Analysis

6.2.2.1 Non-Diatom Algae

To prepare samples for analysis of soft-bodied algae, raw periphyton samples were vigorously shaken in the original sample container to homogenize the sample. The contents were then emptied into a porcelain evaporating dish. A small, random subsample of the liquid fraction containing suspended algal material (approximately 3-5 drops) was dispensed onto a welled glass microscope slide using a disposable plastic dropper. Visible (i.e., macroscopic) soft-bodied algae were teased apart and subsampled in proportion to their estimated importance relative to the total volume of algal material in the sample, and this material was added to the liquid fraction on the slide. The assembled subsample was then covered with a 22x30 mm cover slip, and the completed wet mount was analyzed for soft-bodied algae using an Olympus BHT compound microscope as described below.

The cover slip was scanned at 100X following a set pattern in the approximate shape of an hourglass (upper and lower horizontal transects linked by diagonal transects); magnification was increased to 200X or 400X as necessary to resolve detail in smaller specimens. All soft-bodied algae were identified to genus. The relative abundance of each soft-bodied algal genus (and of all diatom genera collectively) was estimated for comparative purposes, according to the following system:

- rare (r): represented by a single occurrence in the subsample;
- occasional (o): represented by multiple occurrences, but infrequently observed;
- common (c): represented by multiple occurrences, regularly observed;
- frequent (f): present in nearly every field of view;
- abundant (a): multiple occurrences in every field of view;
- dominant (d): multiple occurrences in every field of view in abundances beyond practical limits of enumeration.

Soft-bodied genera (and the diatom component) also were ranked numerically according to their estimated contribution to the total algal biovolume present in each sample.

6.2.2.2 Diatom Algae

To prepare samples for diatom analysis, organic matter was oxidized and permanent fixed mounts of cleaned diatom material were prepared. Each raw periphyton sample was vigorously shaken in the original sample container to thoroughly homogenize the material, and a subsample of approximately 20 mL was poured into a 250 mL Pyrex beaker. Each beaker was treated with 30-50 mL of concentrated sulfuric acid (H2SO4), and a small quantity of 30% hydrogen peroxide (H2O2) and granulated potassium dichromate (K2Cr_2O_7) was added to each beaker. Samples were then covered with a Pyrex watch glass and gently heated to near-boiling for 1-2 hours to completely oxidize all organic matter in the sample. Samples were allowed to cool, and then were topped off with deionized water. The diatom material was allowed to settle for at least eight hours, and the clear supernatant decanted; this process was repeated at least five times to thoroughly flush all traces of oxidants from the diatom material.

Subsample volumes were adjusted to ensure manageable densities of diatom cells in suspension, and a small amount of each sample was dispersed onto clean 22-mm square glass cover slips. The cover slips were air dried, heated to 150 F, and affixed onto standard glass microscope slides with Naphrax mounting medium to create a permanent mount of diatom cells (frustules). To ensure a high quality mount for diatom identification and to make replicates available for archiving, at least two slide mounts were made from each sample; one of the replicates was selected from each sample batch for analysis. An Olympus BHT compound microscope with a SPlan oil immersion objective (1000X total magnification) was used for diatom identifications and counts. A proportional count of 800 diatom valves (400 frustules) was performed along a vertical transect line across the exact center of the fixed cover slip. The starting point on the top edge was determined with the aid of the microscope's stage micrometer and recorded, and all diatoms observed within a one-field-of-view width were identified and counted. Diatoms were identified to the lowest practical taxonomic level, generally to species.

6.2.3 Data Analysis

6.2.3.1 Non-Diatom Algae

Estimated relative abundance and biovolume of diatom algae at each site, with all taxa considered collectively under the division Bacillariophyta, are included for comparison with non-diatom algae. The number of “major” non-diatom genera present at each site (defined as those genera with estimated occurrence in a sample of at least “occasional”) are presented by algal Division in Table 6-2.

6.2.3.2 Diatom Bioassessment Indices

6.2.3.2.1 Sediment Increaser Taxa [Teply, 2010a; 2010b]

Diatom taxa counts were evaluated to determine the probability of sediment impairment using a list of recognized sediment increaser taxa for coldwater streams in the Middle Rockies Ecoregion [Teply, 2010a; 2010b]. Sediment increaser taxa have autecological preferences for sediment impaired habitats. The current impairment probability threshold for sediment impairment in Middle Rockies Ecoregion streams is 51%. Sites with a percent relative abundance of sediment increaser taxa >15.34 exceed the impairment probability threshold and are therefore classified as “sediment impaired”. The percent relative abundance values of sediment increaser taxa at CFROU monitoring sites are plotted in Figure 6-1.

6.2.3.2.2 Diatom Biocriteria for Montana Mountain Streams [Teply and Bahls, 2005]

Teply and Bahls [2005] proposed lists of diatom increaser taxa that indicate impairment in Montana mountain streams resulting from sediment, nutrients, metals, or non-specific causes. They developed equations to determine impairment probabilities based on the percent relative abundance of diatoms from each pollutant category that are present in a given sample. The increaser taxa criteria were based on empirical observations of ecological attributes of diatoms from Montana mountain ecoregions. The diatom increaser taxa identified in Teply and Bahls [2005] were not adopted as standard operating procedures (SOPs) by MDEQ because the likelihood for meeting performance criteria may be low, and the ability of these criteria to differentiate between specific causes of impairment may be low. For the sake of comparison, percent relative abundance values of metal and nutrient increaser taxa for each site are plotted in Figure 6-2 and Figure 6-3.

6.2.3.2.3 Diatom Association Metrics for Montana Mountain Streams [Bahls, 1993]

Bahls [1993] proposed a set of seven metrics to evaluate biological integrity in mountain streams in Montana [Appendix E]. These metrics are based on diatom associations in reference (i.e., relatively unimpaired) and impaired streams under a variety of impairment circumstances. Included are metrics indicative of impairment for sedimentation, nutrient enrichment, and metal contamination.

Of these metrics, the Pollution Index [Bahls, 1993] synthesizes the three pollution tolerance groups defined by Lange-Bertalot [1979] with diatom autecological profiles described by Lowe [1974], and unpublished Montana diatom data described later in Bahls [2006]. Diatom species were assigned to numerical categories 1 (“most-tolerant”), 2 (“less-tolerant”), or 3 (“sensitive”) for tolerance to nutrient enrichment, mineral salts, elevated temperatures, and metal toxicity.

A large number of diatom taxa are motile (i.e., capable of locomotion). The Siltation Index [Bahls, 1993] is calculated as the total percent abundance of motile diatom taxa which include species belonging to the genera Navicula, Nitzschia, Surirella and other closely related taxa.

Motility may be an adaptation to siltation, as a mechanism that allows individual diatom cells to avoid inundation by deposited sediment.

The Disturbance Index [Bahls, 1993] considers the percent abundance of the diatom Achnanthidium minutissimum, which is highly specialized in the post-disturbance recolonization of stream substrates. Elevated numbers may be indicative of recent environmental stress caused by elevated or highly variable streamflows, water velocities, and temperatures at a site.

Biocriteria evaluate the level of environmental stress or impairment, rate overall biological integrity, and evaluate any impairment to beneficial aquatic life uses. Values for the seven biological integrity metrics and the overall rating for each site summarized in Table 6-3.

6.2.3.2.4 Additional Diatom Association Metrics [Van Dam et al., 1994]

The percent relative abundance of diatoms representing a range of tolerance to inorganic nutrients (trophic state) is presented for each site in Figure 6-4. The percent relative abundance of diatoms with specific nitrogen metabolism processes, which determine the degree of organic nitrogen tolerance for those organisms, is presented for each site in Figure 6-5. The percent relative abundance of diatoms intolerant of hypoxia and elevated biological oxygen demand is presented for each site in Figure 6-6.

6.2.3.3 Ecological Interpretations

Narrative interpretations presented below infer the degree and potential causes of water quality impairment for each site. These interpretations are based on the taxonomic composition, autecological preferences, and functional organization of non-diatom and diatom components of the periphyton assemblage at each monitoring site

Varying tolerance to inorganic and organic nutrients has been established among non-diatom and diatom algae; some taxa are sensitive to nutrient enrichment, and other taxa are indifferent to, or tolerant of nutrient enrichment [Prescott, 1962; Wehr and Sheath, 2003; Bahls, 2006].

Many soft-bodied algae are sensitive to dissolved metals, particularly copper. Filamentous green algae (Chlorophyta) generally are more sensitive to copper than are colonial (i.e., mat-forming) blue-green algae (Cyanobacteria). Colonial blue-green algae (e.g., *Nostoc* and *Rivularia*) can tolerate metals due to a protective gelatinous mucilage (i.e., slime coating). However, some green algae (e.g., Cladophora, Mougeotia, Scenedesmus, Stigeoclonium and Ulothrix sp.) have demonstrated high tolerances to dissolved metals [Shaw, 1990].

Diatom assemblages may also indicate metal contamination. Diatom species that increase in abundance in response to heavy metals pollution were identified by Teply and Bahls [2005] and Stoermer and Smol [1999]. Elevated metals can cause teratological growth forms (i.e., abnormalities in cell walls) in diatoms [Falasco et al., 2009].

6.3 RESULTS

6.3.1 Non-Diatom Algae

A total of 30 genera of non-diatom algae representing five algal divisions were identified from the twelve CFROU sites monitored in 2014.

The number of "major" non-diatom algae genera (i.e., those with an estimated abundance ranking of "occasional" or greater) identified at each site monitored in 2014 are presented in Table 6-2. The complete list of non-diatom algae genera identified at each site in 2014, with their estimated relative abundance and biovolume rank, are presented in Appendix F.

At the seven tributary sites, from 8 to 17 genera of "major" non-diatom algae were identified in September 2014 [Table 6-2]. The fewest number of genera (8) occurred at Lost Creek (LC-7.5) and Racetrack Creek (RTC-1.5), while the greatest number (17) occurred at the Little Blackfoot River at Beck Hill Road (LBC-CFR-02). Silver Bow Creek (SS-25) had nine major non-diatom genera, while ten were present at Mill and Willow Creeks (MCWC-MWB), Mill-Willow Bypass (MWB-SBC) and Warm Springs Creek (WSC-SBC).

At the five mainstem Clark Fork River sites, from 6 to 10 genera of "major" non-diatom algae were identified in September 2014 [Table 6-2]. The fewest number of genera (6) occurred at Clark Fork River at Deer Lodge (CFR-27H), while the greatest number (10) occurred at three sites: Clark Fork River at Galen Road (CFR-07D), Clark Fork River at Gemback Road (CFR-11F), and the Clark Fork River at Turah (CFR-116A). The Clark Fork River near Galen (CFR-03A) had eight "major" non-diatom genera present in 2014.

At least one genus from each of the five algal divisions occurred as a "major" taxon at one or more of the monitoring sites in 2014 [Table 6-2]. Among all sites, Chlorophyta (green algae) and Cyanobacteria (blue-green algae) were most numerous, with far fewer genera of Xanthophyta (yellow-green algae), Rhodophyta (red algae), and Phaeophyta (brown algae) present. Chlorophyta outnumbered Cyanophyta at five of the seven tributary sites in 2014. However, Cyanophyta outnumbered Chlorophyta at all five mainstem sites. No more than four major genera belonging to divisions Rhodophyta, Xanthophyta, and/or Phaeophyta were present at any site. No genera belonging to divisions Rhodophyta, Xanthophyta, and/or Phaeophyta were found at six sites, including four of the five mainstem sites [Table 6-2]. A high diversity of non-diatom algae generally indicates nutrient rich water. Low diversity of non-diatom algae suggests impairment by toxic pollutants, although unimpaired, nutrient-poor waters may have naturally low algal diversity. Genera from all five algal divisions and the specific environmental conditions that they indicate are examined in Section 6.3.3.1.

Table 6-2. Number of major[29] non-diatom algae genera, by algal division, present at Clark Fork River Operable Unit monitoring sites, 2014.

Site ID	Site Location	Algal Division					
		Chlorophyta (Green Algae)	Cyanobacteria[30] (Blue-green Algae)	Rhodophyta (Red Algae)	Xanthophyta (Yellow-green Algae)	Phaeophyta (Brown Algae)	Total Major Genera
Mainstem Sites							
CFR-03A	Clark Fork River near Galen	2	6	0	0	0	8
CFR-07D	Clark Fork River at Galen Road	3	7	0	0	0	10
CFR-11F	Clark Fork River at Gemback Road	3	7	0	0	0	10
CFR-27H	Clark Fork River at Deer Lodge	2	4	0	0	0	6
CFR-116A	Clark Fork River at Turah	2	6	1	0	1	10
Tributary Sites							
SS-25	Silver Bow Creek at Warms Springs	5	4	0	0	0	9
MCWC-MWB	Mill-Willow Creek at Frontage Road	5	4	1	0	0	10
MWB-SBC	Mill-Willow Bypass near mouth	4	6	0	0	0	10
WSC-SBC	Warms Springs Creek near mouth	3	4	2	1	0	10
LC-7.5	Lost Creek near mouth	6	1	1	0	0	8
RTC-1.5	Racetrack Creek near mouth	4	2	1	1	0	8
LBR-CFR	Little Blackfoot River at Beck Hill Road	7	6	1	2	1	17

[29] "Major" includes all genera not rated as "rare". Definitions for "rare" genera in section 6.2.2.1.

[30] Formerly classified as Cyanophyta.

6.3.2 Diatom Bioassessment Indices

6.3.2.1 Diatom Increaser Taxa

The percent relative abundance and probability of impairment for diatom increaser taxa are plotted for sediment [Figure 6-1], metals [Figure 6-2], and nutrients [Figure 6-3] at the twelve sites monitored in 2014. Periphyton data for diatom algae are presented in Appendix G.

6.3.2.2 Sediment Increaser Taxa

Sediment increaser taxa [Figure 6-1] were most abundant at sites MCWC-MWB (Mill-Willow Creek at Frontage Road) and CFR-27H (Clark Fork River at Deer Lodge). The probability of impairment by sediment at MCWC-MWB and CFR-27H (93% for each) exceeded the impairment threshold (51%) for sediment increaser taxa. Five other sites had impairment probabilities exceeding the sediment impairment threshold: MWB-SBC (Mill-Willow Bypass near mouth; 77%), SS-25 (Silver Bow Creek at Warm Springs; 81%), site CFR-03A (Clark Fork River near Galen; 88%), site CFR-07D (Clark Fork River at Galen Road; 57%) and site CFR-11F (Clark Fork River at Gemback Road; 79%). The five remaining sites had sediment impairment probabilities which were less than the threshold; the probability of impairment by sediment among these sites ranged from 17-50% [Figure 6-1].

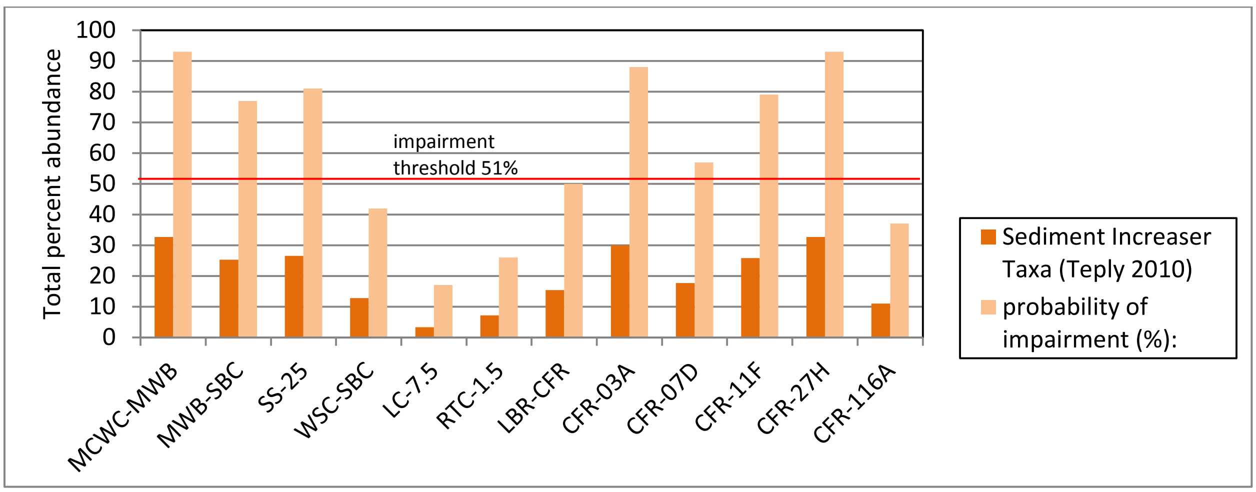

Figure 6-1. Total percent abundance and probability of impairment for diatom sediment increaser taxa bioassessment index [Teply, 2010a] at Clark Fork River Operable Unit sites in 2014.

6.3.2.3 Metals Increaser Taxa

Metals increaser taxa [Figure 6-2] were most abundant at CFR-116A (Clark Fork River at Turah) where the probability of impairment by heavy metals was 93%. Probability of metals impairment was 88% at CFR-07D (Clark Fork River at Galen Road). Sites CFR-11F (Clark Fork River at Gemback Road), SS-25 (Silver Bow Creek at Warm Springs), and CFR-03A (Clark Fork

River near Galen) had a probability of heavy metals impairment that exceeded 70% (range 74-76%). Sites WSC-SBC (Warm Springs Creek at Warm Springs), LC-7.5 (Lost Creek at Frontage Road) and CFR-27H (Clark Fork River at Deer Lodge) had probabilities of heavy metals impairment in excess of 40% (range 41-45%). The probability of impairment by heavy metals at site LBR-CFR (Little Blackfoot River near mouth), site RTC-1.5 (Racetrack Creek at Frontage Road), site MWB-SBC (Mill-Willow Bypass near mouth), and site MCWC-MWB (Mill-Willow Creek at Frontage Road was less than 33% [Figure 6-2]. No impairment threshold has been established for metals increaser taxa in the CFROU. This index is provided to allow for comparisons of the relative magnitude of impairment probabilities between sites.

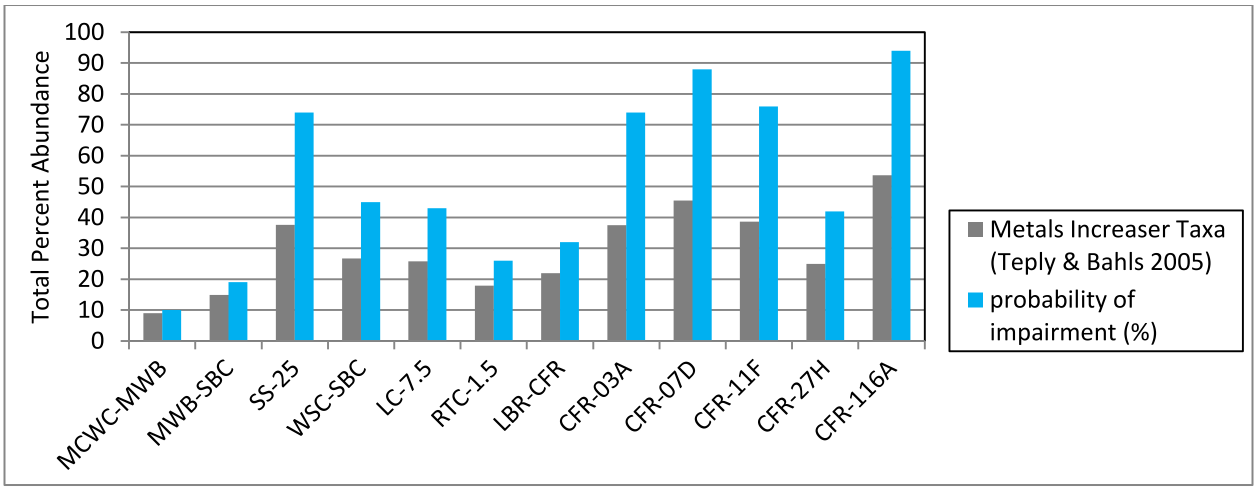

Figure 6-2. Total percent abundance and probability of impairment for diatom metals increaser taxa bioassessment index [Teply and Bahls, 2005] at Clark Fork River Operable Unit sites in 2014.

6.3.2.4 Nutrient Increaser Taxa

The highest probability of impairment by nutrients, based on nutrient increaser taxa relative abundances at the CFROU sites monitored in 2014 [Figure 6-3], was 98% at tributary site LBR-CFR (Little Blackfoot River near mouth). The probability of impairment by nutrients was 95% at mainstem site CFR-11F (Clark Fork River at Gemback Road) and 90% at sites SS-25 (Silver Bow Creek at Warm Springs) and CFR-03A (Clark Fork River near Galen). Site CFR-27H (Clark Fork River at Deer Lodge) had an impairment probability of 84%. Site CFR-116A (Clark Fork River at Turah) had an impairment probability of 76%. Site CFR-07D (Clark Fork River at Galen Road) had an impairment probability of 62%. Of tributary sites monitored in 2014, site LC-7.5 (Lost Creek at Frontage Road) had an 85% probability of impairment by nutrients, site MWB-SBC (Mill-Willow Bypass at mouth) had a 73% probability, and MCWC-MWB (Mill-Willow Creek at Frontage Road) had a 58% probability. Site WSC-SBC (Warm Springs Creek at Warm Springs) had a 22% probability of impairment, while the lowest probability of impairment by nutrients at all CFROU sites monitored in 2014 was 6% at site RTC-1.5 (Racetrack Creek at Frontage Road). No impairment threshold has been established for nutrient increaser taxa in the CFROU. This index is provided to allow for comparisons of the relative magnitude of impairment probabilities between sites.

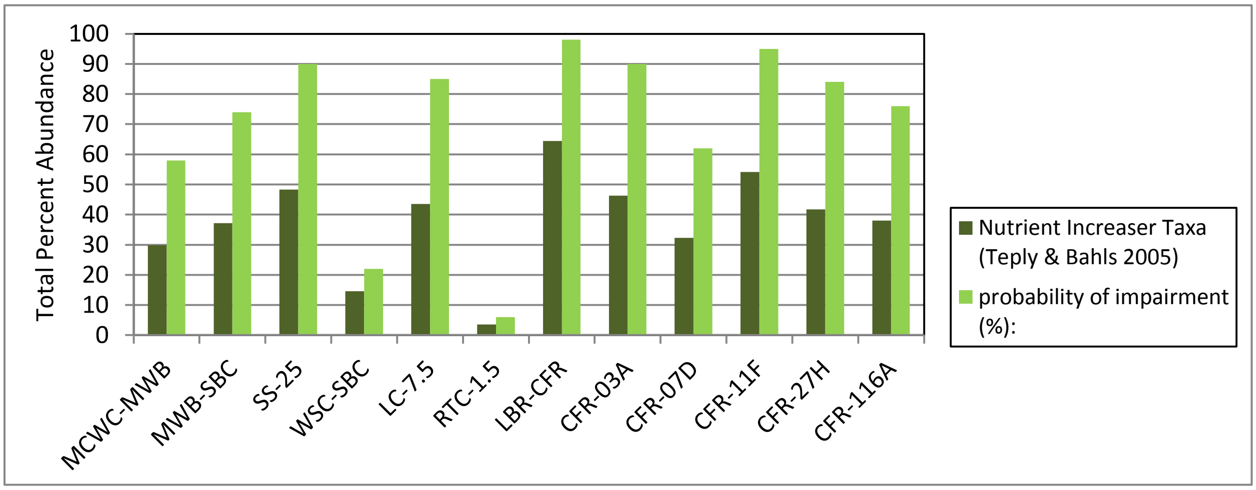

Figure 6-3. Total percent abundance and probability of impairment for diatom nutrient increaser taxa bioassessment index [Teply and Bahls, 2005] at Clark Fork River Operable Unit sites in 2014.

6.3.2.5 Diatom Association Metrics for Montana Mountain Streams

Metrics proposed by Bahls [1993] to evaluate biological integrity in Montana mountain streams were determined for the diatom associations present at each CFROU site monitored in 2014. Results are summarized in Table 6-3.

For the CFROU sites monitored in 2014, overall biological integrity was rated “good” at all but one site, which was rated “fair” for biological integrity [Table 6-3]. A biological integrity rating of “good” indicates minor impairment to aquatic life, while a rating of “fair” indicates moderate impairment. No sites monitored in 2014 received the highest biological integrity rating (“excellent”) or the lowest rating (“poor”).

At sites CFR-03A (Clark Fork River near Galen) and CFR-116A (Clark Fork River at Turah), the biological integrity was rated “good” rather than “excellent”, due only to a slightly to moderately elevated value for the siltation index. At site CFR-11F (Clark Fork River at Gemback Road) the biological integrity rating of “good” was due only to a slightly elevated percentage of abnormal cells. At sites MCWC-MWB (Mill and Willow Creeks at Frontage Road), site CFR-07D (Clark Fork River at Galen Road) and CFR-27H (Clark Fork River at Deer Lodge), biological integrity was rated “good” rather than “excellent” due to slightly to moderately elevated siltation index values along with a slightly elevated percentage of abnormal cells. At tributary sites WSC-SBC (Warm springs Creek near mouth), RTC-1.5 (Racetrack Creek at Frontage Road), and LBR-CFR (Little Blackfoot River near mouth), biological integrity was rated “good” due to slightly to moderately depressed Shannon diversity index values, along with slightly elevated values for percent dominant taxon, disturbance index, or both. At sites SS-25 (Silver Bow Creek at Warm Springs) and MWB-SBC (Mill-Willow Bypass near mouth), biological integrity was rated “good” due to slightly depressed for the pollution index and slightly elevated for the percentage of abnormal cells, along with a slightly elevated siltation index at the latter site [Figure 6-3].

Site LC-7.5 (Lost Creek at Frontage Road) was the lone site where biological integrity was rated “fair” due to an elevated percent abnormal cells. Otherwise biological integrity at LC-7.5 would have been rated “good” due to a moderately depressed Shannon diversity index value and a slightly elevated percent dominant taxon.

Table 6-3. Diatom association metrics and biological integrity[31] and impairment ratings[32] for Clark Fork River Operable Unit monitoring sites, 2014 (after Bahls [1993]).

Site ID	Site Location	Monitoring Site							
		Diatom Species Richness	Shannon Diversity Index	Pollution Index	Siltation Index	Disturbance Index	Dominant Taxon (%)	Abnormal Cells (%)	Biological Integrity
Mainstem Sites									
CFR-03A	Clark Fork River near Galen	59	3.29	2.62	33.25	3.63	13.5	0	Good
CFR-07D	Clark Fork River at Galen Road	66	3.17	2.62	26.88	1.88	20.75	0.63	Good
CFR-11F	Clark Fork River at Gemback Road	72	3.16	2.66	14.13	1.13	12.88	1.5	Good
CFR-27H	Clark Fork River at Deer Lodge	58	3	2.58	25.38	4	15.63	0.63	Good
CFR-116A	Clark Fork River at Turah	71	3.31	2.69	20.75	4.88	18.25	0	Good
Tributary Sites									
SS-25	Silver Bow Creek at Warms Springs	61	3.18	2.49	17.5	2.13	14.5	0.5	Good
MCWC-MWB	Mill-Willow Creek at Frontage Road	95	3.46	2.53	32.5	9.88	22.38	0.25	Good
MWB-SBC	Mill-Willow Bypass near mouth	75	3.37	2.44	26.63	4.88	19.75	0.25	Good
WSC-SBC	Warms Springs Creek near mouth	51	2.82	2.74	25.88	33	33	0	Good
LC-7.5	Lost Creek near mouth	55	2.53	2.56	6.88	16.5	28.88	**4.25**	**Fair**
RTC-1.5	Racetrack Creek near mouth	62	2.52	2.63	10.63	29.88	29.88	0	Good
LBR-CFR	Little Blackfoot River at Beck Hill Road	55	2.7	2.4	19.38	4.38	36.25	1.13	Good

[31] Biological integrity rating is based on numerical criteria for each diatom metric.

[32] Impairment rating codes: normal font = none, underline = minor, and **bold** = moderate.

6.3.2.6 Additional Diatom Association Metrics

For each of the sites monitored in 2014, three metrics based on ecological attributes of diatom associations are presented. The diatom trophic state metric is the total percent relative abundance of diatoms with different tolerance levels for inorganic nutrients (i.e., nitrogen and phosphorus) [Figure 6-4]. The nitrogen metabolism metric is the total percent relative abundance of diatoms exhibiting different tolerance levels for organic nitrogen compounds [Figure 6-5]. The oxygen demand metric is the total percent relative abundance of diatoms that require high levels of dissolved oxygen and are intolerant of elevated biological oxygen demand conditions [Figure 6-6].

The level of inorganic nitrogen and phosphorus enrichment, or trophic state of a water body, influences the algal community composition at a site. The response of many diatom taxa to inorganic nutrient enrichment (i.e., eutrophic conditions) is well known and provides the basis for the diatom trophic state categories presented in Figure 6-4. Nutrient tolerant diatom species do not necessarily require high nutrient levels. However, nutrient intolerant diatom species are at a competitive disadvantage in nutrient enriched conditions. As a result, nutrient intolerant species tend to be reduced in relative abundance or are absent under conditions of nutrient enrichment.

Figure 6-4 suggests water that was moderately enriched with inorganic nutrients (i.e., slightly to moderately eutrophic conditions) at all five Clark Fork River mainstem sites in 2014. At each of those sites, intolerant taxa abundance was very low, whereas tolerant taxa were very abundant. Similar but somewhat less pronounced results were observed at five of the six tributary sites. The primary exception was at site RTC-1.5 (Racetrack Creek at Frontage Road), where the percent abundance of intolerant taxa was significantly higher than that of tolerant taxa, and several-fold higher than at any other CFROU site in 2014, suggesting lower inorganic nutrient levels. At site WSC-SBC (Warm Spring Creek at Warm Springs), the percent abundance of diatom taxa indifferent to inorganic nutrients was similar to site RTC-1.5, but intolerant taxa were much less abundant [Figure 6-4].

Enrichment by organically-derived nitrogen compounds can influence the composition of the algal community. Diatoms exhibit a broad range of tolerance to organic nitrogen. Most diatoms are nitrogen autotrophs and are unable to utilize organic nitrogen, whereas some diatoms are metabolic specialists and are able to directly assimilate organic nitrogen in addition to, or as an alternative to, inorganic nitrogen (i.e., facultative nitrogen heterotrophs).

Nitrogen-autotrophic diatoms were dominant at all sites monitored in 2014 [Figure 6-5]. Nitrogen-autotrophic taxa with a higher tolerance to organic nitrogen were more abundant than less tolerant autotrophic forms at all sites, ranging from about 48% to 75% in relative abundance. Nitrogen-autotrophic taxa with lower organic nitrogen tolerance ranged in relative abundance from a low of about 4% at site MCWC-MWB (Mill and Willow Creek at Frontage Road) to a high of 36% at site CFR-116A (Clark Fork River at Turah). The percent abundance of nitrogen autotrophs with low organic nitrogen tolerance in the tributary stations ranged from about 4% to about 14% (mean 9.4%), and in the five mainstem Clark Fork River stations ranged from about 5% to 36% (mean 16.8%). These data indicate that diatom assemblages at CFROU sites in 2014, while showing tolerance to relatively high organic nitrogen concentrations, were predominantly autotrophic forms requiring inorganic nitrogen. While this suggests the possibility of organic nitrogen inputs to tributary and mainstem sites, it does not indicate that organic nitrogen had adverse impacts or toxic effects on the diatom assemblages.

The percent abundance of diatoms requiring oligosaprobous conditions (i.e., low levels of organic matter decomposition, high dissolved oxygen concentrations, and inorganic nitrogen only) and ß-mesosaprobous conditions (i.e., moderate levels of organic matter decomposition, high dissolved oxygen concentrations, and predominantly inorganic nitrogen) ranged from 42% to 81%, and exceeded 50% at 9 of 12 CFROU monitoring sites in 2014, including 4 of 7 tributary stations and all mainstem Clark Fork River stations [Figure 6-6]. Diatoms requiring dissolved oxygen saturation >75% were relatively dominant at all sites; percent abundance ranged from about 30% to 69% and exceeded 40% at all but three sites in 2014 [Figure 6-6]. These data suggest that no CFROU sites had impairments to diatom assemblages related to hypoxia or elevated biological oxygen demand resulting from decomposition of organic matter in 2014.

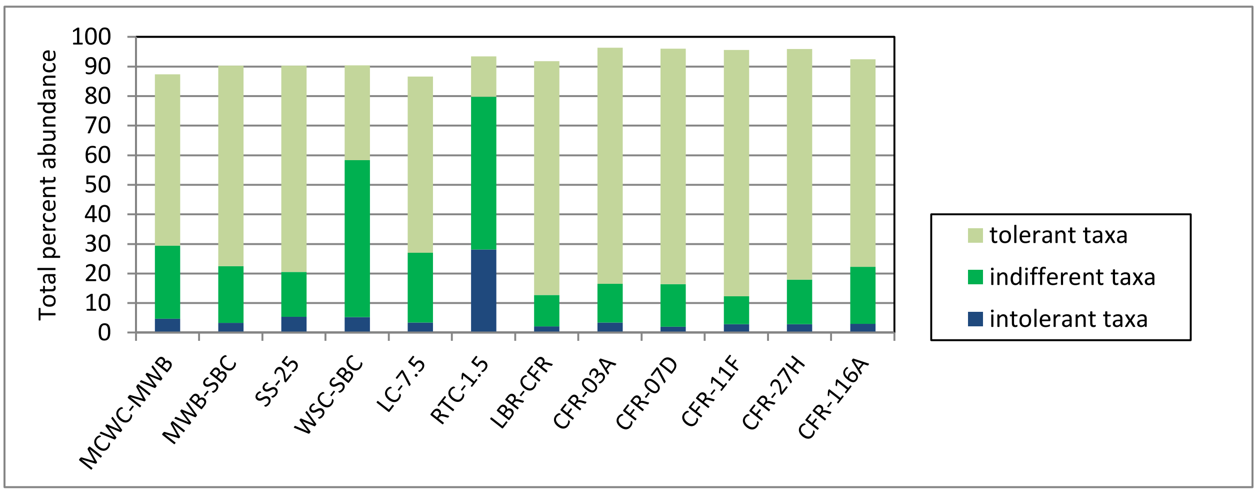

Figure 6-4. Variation in diatom trophic state tolerance among Clark Fork River Operable Unit monitoring sites, 2014; percent abundance of taxa tolerant to inorganic nutrients (after Van Dam et al., 1994).

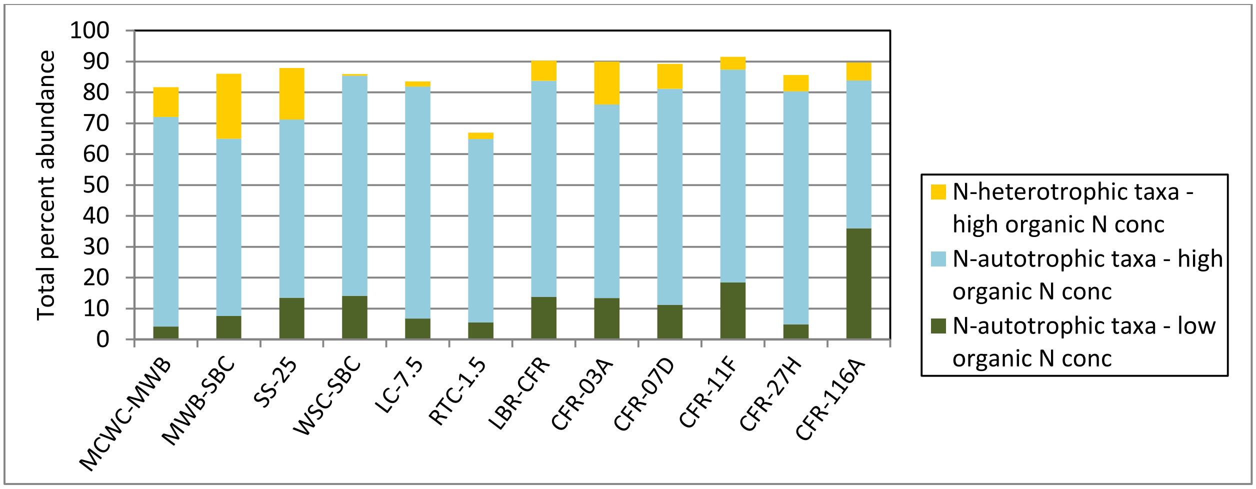

Figure 6-5. Variation in diatom nitrogen metabolism among Clark Fork River Operable Unit monitoring sites, 2014; percent abundance of taxa tolerant of organic nitrogen (after Van Dam et al., 1994).

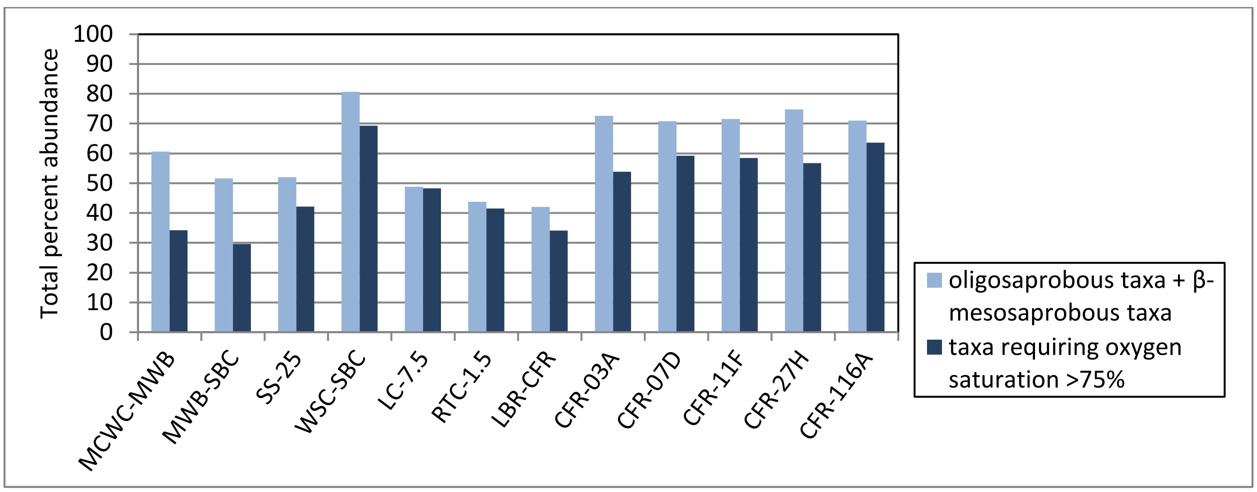

Figure 6-6. Variation in diatom oxygen demand among Clark Fork River Operable Unit monitoring sites, 2014; percent abundance of taxa intolerant to elevated biochemical oxygen demand (BOD) and hypoxia (after Van Dam et al., 1994).

6.3.3 Ecological Interpretations of Periphyton Assemblages

6.3.3.1 Non-Diatom Algae

From two to seven genera of Chlorophyta (green algae) were identified as "major" taxa at the CFROU monitoring sites in 2014 [Table 6-2]. Microscopic forms of Chlorophyta included filamentous genera (*Cladophora, Oedogonium, Spirogyra, Stigeoclonium,* and *Ulothrix),* colonial genera (*Scenedesmus),* and single-celled desmid genera (*Closterium* and *Cosmarium*). The genus *Chara,* a macroscopic filamentous form, was also observed. These algae are generally indicative of cool, moderately nutrient-rich water. Many of these species are relatively tolerant of elevated nutrients, acidity, metals, or combinations of those conditions. *Stigeoclonium,* and *Ulothrix* have been observed in streams with elevated zinc concentrations [Shaw, 1990]. *Scenedesmus* is known to tolerate elevated copper concentration, and *Cladophora* and *Ulothrix* are resistant to copper used in paint for watercraft and ship hulls [Shaw, 1990]. *Chara* occurs in streams that have high pH and elevated bicarbonate concentrations. *Cladophora* was a major taxon at all twelve sites in 2014, whereas *Oedogonium* was a major taxon at nine of twelve sites. Estimated biovolume for both *Cladophora* and *Oedogonium* ranked within the top four taxa identified (including diatom algae as a whole) at site SS-25 (Silver Bow Creek at Warm Springs) and at four mainstem Clark Fork River sites in 2014.

Of the Cyanobacteria (blue-green algae), the genus *Nostoc* was a "major" taxon at 10 of 12 monitoring sites in 2014, including four mainstem Clark Fork River sites, and ranked within the top four taxa in estimated biovolume at 9 of the 12 sites. *Nostoc* is generally indicative of cool, moderately nutrient-rich, relatively unpolluted water. Masses of *Nostoc* trichomes (i.e. filaments composed of individual cells) are encased in a tough colonial mucilage that is resistant to scour and desiccation. More importantly, *Nostoc* and several related Cyanobacteria genera (e.g. *Tolypothrix* and *Rivularia*) possess specialized cells called heterocytes that permit fixation of atmospheric nitrogen through enzyme reactions. This provides *Nostoc* with a competitive advantage over other non-diatom algae in water with low inorganic nitrogen concentrations. Additionally, several diatom species of the order Rhopalodiales (*Epithemia sorex, Epithemia turgid,* and *Rhopalodia gibba*) are known to harbor single-celled blue-green algae that can also fix nitrogen. All of these diatom taxa (and particularly *Epithemia sorex)* were present at several of the monitoring sites in 2014, and are the basis for the percent Rhopalodiales metric.

From one to seven "major" genera of Cyanobacteria, in addition to *Nostoc,* were identified at the twelve sites monitored in 2014. These included the filamentous genera *Dichothrix, Heteroleibleinia, Homoeothrix, Leptolyngbia, Microchaete, Phormidium and Tolypothrix.* All are microscopic benthic forms commonly identified in mountain ecoregion streams. *Dichothrix* is a largely cosmopolitan form that occurs attached to firm substrates in swiftly flowing water. *Tolypothrix* occurs in unpolluted freshwaters attached to stones, macrophytes or other algae, sometimes forming wooly mats or tufts. *Phormidium* is a cosmopolitan form which occurs within a relatively broad range of habitats and water quality conditions, and can form extensive macroscopic growths. *Heteroleibleinia, Homoeothrix* and *Leptolyngbia* commonly occur as epiphytes (i.e., plants that grow on other plants) on filamentous green algae (e.g., *Cladophora* or *Oedogonium*) in relatively unpolluted waters. The genus *Chamaesiphon* is a solitary or colonial Cyanobacteria that occurred as an epiphyte on filamentous green algae, often at densities that nearly covered the outer surfaces of the host alga. *Chamaesiphon* often is found on submerged substrates in cold water in mountain streams, and generally prefers low to moderate levels of nutrients and dissolved solids.

The filamentous alga *Audouinella,* a member of the division Rhodophyta (red algae), is a cosmopolitan form that prefers circumneutral (i.e., with a pH of around 7) to slightly alkaline water that is moderately low in nutrients and dissolved solids. *Audouinella* was identified as a major taxon at five of the twelve sites monitored in 2014, all of them on tributary streams to the Clark Fork River.

Tribonema and *Vaucheria* are filamentous genera of yellow-green algae (division Xanthophyta) that either together or singly were major taxa at several tributary sites in 2014. Often these taxa occur in cool, nutrient-poor water that is slightly acidic due to elevated levels of dissolved humic substances (e.g., tannins) associated with decaying vegetation and bog environments).

An uncommon filamentous brown alga *Heribaudiella* (division Phaeophyta) was found only at two sites in 2014. *Heribaudiella* is known to occur in cool water at higher current velocities, often with moderate levels of nutrients and alkalinity [Wehr and Sheath, 2003].

6.3.3.2 Diatom Algae

Diatom algae dominated the periphyton assemblage at all CFROU sites monitored in 2014, and were ranked first or second in estimated biovolume relative to non-diatom algae at five of twelve sites, and no lower than third at any of the sites. Over 175 species and varieties of diatoms were identified among the CFROU sites in 2014. Several diatoms were of particular interest because of specific autecological preferences and environmental requirements of those organisms.

Achnanthidium minutissimum is a specialist in recolonizing stream substrates that have been subjected to physical disturbance such as scour or impacted by dewatering. The percent relative abundance of *A. minutissimum* is the basis for the disturbance index [Bahls, 1993].

Cocconeis pediculus and C. placentula are cosmopolitan, attached forms that occur in very high densities as epiphytes on larger forms of filamentous algae, particularly the green algae *Cladophora* and *Oedogonium,* and are indicative of moderately nutrient-rich, slightly alkaline water.

Cymbella affinis is an attached, stalk-forming diatom that prefers alkaline water with moderately low levels of nitrogen and phosphorus and moderately high bicarbonate concentrations.

Diatoma moniliformis and *D. vulgaris* are non-motile chain forming diatoms that prefer cool, well oxygenated, moderately alkaline water with relatively low to moderate levels of nutrients.

Epithemia sorex, E. turgid and *Rhopalodia gibba* often harbor single-celled endosymbotic (i.e., internal to the cell wall) nitrogen fixing cyanobacteria, with an assumed benefit to both organisms in nitrogen limited waters. These taxa, considered collectively as the percent Rhopalodiales metric, suggest low levels of inorganic nitrogen relative to phosphorus in the water column.

Melosira varians is a non-motile, centric diatom that forms long ribbons of cells, often entangled with filamentous non-diatom algae. It is indifferent to nutrient concentrations but intolerant of elevated sediment and siltation.

Navicula caterva and *N. cryptotenella* are motile diatoms that prefer alkaline, moderately hard water with moderately low to moderate levels of nitrogen relative to phosphorus.

Nitrschia dissipata, N. fonticola and *N. paleacea* are highly motile forms that are adapted to elevated levels of deposited sediment and prefer cool, somewhat alkaline water with moderate levels of nitrogen and phosphorus.

Ulnaria ulna (formerly *Synedra ulna*) is a large attached form with a relatively low tolerance to deposited sediment that prefers alkaline water and variable levels nitrogen and phosphorus.

6.3.3.3 Site Specific Narratives

The narratives that follow are based on a review of collective results from analysis of data from individual sites, including the taxonomy and community structure of non-diatom and diatom algae and the suite of metrics derived from those data. Overall biological integrity and the degree of impairment of the aquatic biota are assessed for each monitoring site. The focus of each narrative is on water quality, specifically the influence of metals, nutrients, and sediment on diatom assemblages.

6.3.3.3.1 Mill Willow Creek at the Mill-Willow Bypass (MCWC-MWB)

Non-diatom algae were relatively diverse at site MCWC-MWB. Ten "major" genera representing three algal divisions were present [Table 6-2]. Five of these genera were green algae (order Chlorophyta), while four were blue-green algae (order Cyanobacteria). The filamentous blue-green Phormidium and the colonial blue-green *Nostoc* ranked first and second, respectively, in estimated biovolume, ahead of diatom algae. The single-celled green algae *Staurastrum* and *Closterium,* the filamentous green *Cladophora* and red alga (order Rhodophyta) *Audouinella* were also relatively important taxa at this site. These non-diatom algae indicated "good" water quality at site MCWC-MWB that was moderately nutrient-rich and likely nitrogen limited.

Diatom algae in the combined Mill and Willow Creeks had the highest species richness and Shannon diversity of the twelve sites monitored in 2014 [Table 6-3]. Dominant diatom taxa at site MCWC-MWB included *Cocconeis placentula, Achnanthidium minutissimum, Nitzschia dissipata* and *Navicula caterva,* which indicated cool, moderately nutrient-rich alkaline water. Diatom increaser taxa indicated a high probability of impairment by sediment [Figure 6-1], a low probability of impairment by metals [Figure 6-2], and a moderate probability of impairment by nutrients [Figure 6-3]. A majority of the diatom taxa present at site MCWC-MWB in 2014 were tolerant of elevated levels of inorganic nutrients [Figure 6-4] and organic nitrogen [Figure 6-5]. The percentage of diatoms requiring high levels of dissolved oxygen saturation was relatively low [Figure 6-6]. Overall biological integrity at site MCWC- MWB was rated as "good", with only minor impairment related to sediment and possible toxic effects indicated by abnormal diatom cell walls [Table 6-3].

6.3.3.3.2 Mill Willow Bypass near Mouth (MWB-SBC)

Non-diatom algae at site MWB-SBC were similar to those at the upstream site on Mill-Willow Creek [Table 6-2]. Ten "major" genera were divided between blue-green algae (six taxa) and green algae (four taxa). The filamentous blue-green *Phormidium* and the colonial blue-green *Nostoc* ranked second and third in estimated biovolume, behind diatom algae. The filamentous green algae *Stigeoclonium, Cladophora* and *Oedogonium* ranked fourth through sixth in estimated biovolume, respectively. Moderate enrichment by inorganic nutrients was indicated by the non-diatom algae. Limited inorganic nitrogen relative to phosphorus was suggested by the relative importance of nitrogen-fixing blue-green algae *Nostoc* and *Tolypothrix*.

Diatom species richness and Shannon diversity values decreased from those seen at the upstream site, but remained relatively high compared to all other CFROU sites in 2014 [Table 6-3]. Dominant diatoms at site MWB-SBC included *Cocconeis placentula, Melosira varians, Nitzschia paleacea* and *Diatoma moniliformis*. These diatom species indicated cool, alkaline water that was moderately rich in nutrients. Diatom increaser taxa indicated a moderately high probability of impairment by sediment [Figure 6-1] and nutrients [Figure 6-3], and a moderately low probability of impairment by metals [Figure 6-2]. A majority of diatoms at site MWB-SBC were tolerant of inorganic nutrients [Figure 6-4] and elevated organic nitrogen [Figure 6-5]. Diatoms requiring high dissolved oxygen levels comprised less than 30% of the taxa at site MWB-SBC, which was the lowest percentage for any CFROU site monitored in 2014. Overall biological integrity at site MWB-SBC was rated as “good”, with only minor impairments related to sediment and possible toxic effects indicated by abnormal diatom cell walls [Table 6-3].

6.3.3.3.3 Silver Bow Creek at Warm Springs (SS-25)

Nine “major” genera of non-diatom algae were identified at site SS-25 in 2014 [Table 6-2]. The flora was dominated by green algae (five taxa), with four filamentous genera (*Cladophora, Oedogonium, Stigeoclonium* and *Ulothrix*) and a single-celled desmid (*Cosmarium)* responsible for most of the non-diatom algal biovolume at site SS-25. Four genera of blue-green algae were present as “major” taxa at site SS-25, but none ranked higher than seventh in estimated biovolume. No other algal divisions were represented at site SS-25. The filamentous green algae present were indicative of water relatively rich in nutrients, particularly nitrogen, and are relatively tolerant of metals.

Diatoms ranked second in estimated biovolume at SS-25 [Table 6-2]. Diatom species richness and Shannon diversity values at site SS-25 were slightly depressed compared to the upstream site MWB-SBC [Table 6-3]. A very low disturbance index value at site SS-25 suggested relatively stable conditions and low levels of environmental stress, while a slightly depressed pollution index value and slightly elevated percent abnormal cells indicated likely metals toxicity [Table 6-3]. Several dominant diatom taxa at site SS-25, including *Cocconeis pediculus*, *C. placentula, Epithemia sorex, Melosira varians* and *Ulnaria ulna,* commonly occur as epiphytes or in association with filamentous algae and aquatic macrophytes in alkaline, nutrient-rich streams. Diatom increaser taxa indicated moderately high probabilities of impairment by metals [Figure 6-2], nutrients [Figure 6-3], and sediment [Figure 6-1] at site SS-25. Diatoms tolerant of elevated inorganic nutrients [Figure 6-4] and organic nitrogen [Figure 6-5] comprised relatively high percentages of taxa at site SS-25, and suggested eutrophic conditions in the reach below the Warm Springs Ponds. The percentage of diatoms requiring high dissolved oxygen levels at site SS-25 was comparable to upstream site MWB-SBC [Figure 6-6]. Biological integrity in 2014 at site SS-25 was rated as “good” with minor impairment of the biota due to toxic metals, indicated by the Pollution Index and abnormal diatom cells [Table 6-3].

6.3.3.3.4 Warm Springs Creek near Mouth (WSC-SBC)

Ten “major” genera of non-diatom algae were identified at site WSC-SBC in 2014 [Table 6-2]. Included within the top five non-diatom genera were the colonial blue-green *Nostoc,* the filamentous blue-green *Phormidium*, the filamentous green algae *Cladophora* and *Oedogonium,* the filamentous red alga *Audouinella,* and the filamentous yellow-green alga *Vaucheria*. All of these algae are indicative of cool, relatively unpolluted water with low to moderate levels of inorganic nutrients. The dominance of *Nostoc* suggests that inorganic nitrogen may have been the limiting nutrient relative to phosphorus at site WSC-SBC.

Diatom species richness at WSC-SBC was the lowest for any site in 2014, while Shannon diversity was slightly below the average for the CFROU sites monitored in 2014 [Table 6-3]. The disturbance index value suggested some environmental instability at WSC-SBC, with *Achnanthidium minutissimum* the dominant diatom taxon at 33% relative abundance. Diatom increaser taxa at WSC-SBC indicated moderately low probability of impairment by sediment [Figure 6-1] and metals [Figure 6-2], and a low probability of impairment by nutrients [Figure 6-3]. Most diatom taxa present at WSC-SBC were relatively intolerant of inorganic nutrients [Figure 6-4] and organic nitrogen [Figure 6-5], and required a high level of oxygen saturation [Figure 6-6]. Diatoms with a low tolerance of decomposing organic matter (i.e., biochemical oxygen demand) and requiring moderately high levels of dissolved oxygen saturation were present at site WSC-SBC in some of the highest percentages seen in 2014 [Figure 6-6]. Biological integrity at WSC-SBC was “good”, with minor impairment of the biota indicated by slightly elevated siltation index and disturbance index values, and a slightly depressed Shannon diversity [Table 6-3].

6.3.3.3.5 Clark Fork River near Galen (CFR-03A)

Eight “major” genera of non-diatom algae were identified at Clark Fork River headwaters site CFR-03A in 2014 [Table 6-2]. Six genera of blue-green algae (cyanobacteria) and two genera of green algae were present as major taxa at site CFR-03A; no other algal divisions were represented. Estimated biovolume was distributed relatively evenly between green and blue-green algae, with the cyanobacteria *Nostoc* and *Tolypothrix* and the green algae *Cladophora* and *Oedogonium* ranked as the top four non-diatom taxa. This suggests moderate nutrient enrichment, with somewhat limited levels of nitrogen relative to phosphorus at site CFR-03A. Several genera of cyanobacteria that are epiphytic on large filamentous green algae were also relatively important, including *Chamaesiphon, Leptolyngbya* and *Heteroleibleinia.*

Diatom algae ranked third in estimated biovolume at site CFR-03A. Diatom species richness and Shannon diversity at site CFR-03A were fairly comparable to those at tributary sites immediately upstream, and within the range of values for Clark Fork River sites downstream [Table 6-3]. Dominant diatom taxa included *Cocconeis pediculus, C. placentula* and *Epithemia* sorex, all forms epiphytic on filamentous algae, the non-motile *Diatoma vulgaris* and motile *Nitzschia paleacea*. All of these taxa suggest cool, alkaline water moderately rich in inorganic nutrients. Diatom increaser taxa at site CFR-03A indicated a moderately high probability of impairment by metals [Figure 6-2], and a high probability of impairment by sediment [Figure 6-1] and nutrients [Figure 6-3]. Most of the diatom taxa present were tolerant of elevated inorganic nitrogen [Figure 6-4] and organic nitrogen [Figure 6-5], and required a relatively high level of dissolved oxygen saturation [Figure 6-6]. Biological integrity at site CFR-03A was rated as “good”, with only minor impairment indicated by a slightly elevated value for siltation index [Table 6-3]. All other diatom metrics for Montana mountain streams indicated “excellent” biological integrity and an unimpaired biota at site CFR-03A in 2014 [Table 6-3]

6.3.3.3.6 Clark Fork River at Galen Road (CFR-07D)

Ten “major” genera of non-diatom algae were identified at site CFR-07D in 2014, with seven genera of blue-green algae and three genera of green algae present. No other algal divisions were represented as “major” taxa at site CFR-07D [Table 6-2]. The top two non-diatom taxa at site CFR-07D, by biovolume, were the filamentous green algae *Cladophora* and *Oedogonium* followed the colonial cyanobacteria *Nostoc* and the epiphytic cyanobacteria *Chamaesiphon, Leptolyngbya* and *Heteroleibleinia.* This assemblage was very similar to that seen at upstream site CFR-03A. Water moderately rich in inorganic nutrients, but possibly somewhat limited in nitrogen, is suggested by the dominant non-diatom algae at CFR-07D.

Diatom species richness was slightly higher, and Shannon diversity slightly lower, at site CFR-07D compared to upstream site CFR-03A [Table 6-3]. The diatom *Diatoma vulgaris* was strongly dominant at site CFR-07D, with a relative abundance of nearly 21%. *Diatoma moniliformis, Cocconeis placentula* and *Epithemia sorex* were also well represented, and together comprised 35% of diatom abundance. These taxa indicate cool, somewhat alkaline water with moderately high levels of inorganic nutrients. Diatom increaser taxa at site CFR-07D indicated a high probability of impairment by metals [Figure 6-2], and a moderately high probability of impairment by sediment [Figure 6-1] and nutrients [Figure 6-3]. Most of the diatom taxa present at site CFR-07D were tolerant of elevated inorganic nitrogen [Figure 6-4] and organic nitrogen [Figure 6-5], and required a relatively high level of dissolved oxygen saturation [Figure 6-6] similar to those at upstream site CFR-03A. Biological integrity at site CFR-07D was “good”, with only minor impairment related to sediment, and possible effects of toxic metals indicated by abnormal diatom cell walls [Table 6-3].

6.3.3.3.7 Lost Creek at Frontage Road (LC-7.5)

The site on Lost Creek was sampled at the Frontage Road crossing for the second year in a row. Eight “major” genera of non-diatom algae were present at LC-7.5, the fewest identified at any CFROU tributary site in 2014 [Table 6-2]. Six genera of green algae, one genus of blue-green algae, and one genus of red algae were “major” taxa at LC-7.5 [Table 6-2]. The filamentous green algae *Cladophora* and *Spirogyra* and the macroscopic green alga *Chara* ranked second through fourth in algal biovolume at LC-7.5, after the diatom assemblage. The red alga *Audouinella* and the blue-green *Chamaesiphon* were abundant and ranked fifth and sixth in algal biovolume at LC-7.5. These taxa indicated cool, high quality water moderately rich in nutrients. The occurrence of *Chara* only at site LC-7.5 is consistent with the alkaline nature of Lost Creek, presumably because of limestone geology in the Lost Creek watershed.

Diatom species richness and Shannon diversity values at LC-7.5 were the second lowest of any site in 2014 [Table 6-3]. *Diatoma moniliformis, Achnanthidium minutissimum* and *D. vulgaris* had the highest relative abundance values of the diatoms identified at site LC-7.5, together comprising over 61% of diatom abundance. These taxa prefer cool, well-oxygenated, alkaline water of moderate conductivity, with low to moderate inorganic nutrients. Four percent of *Diatoma moniliformis* frustules at site LC-7.5 had abnormal cell walls (i.e. teratological growth forms), while 0.25% of *D. vulgaris* frustules were abnormal. This response has been attributed to heavy metals. Diatom increaser taxa indicated a moderate probability of impairment by metals [Figure 6-2], a moderately high probability of impairment by nutrients [Figure 6-3], but a low probability of impairment by sediment [Figure 6-1] at site LC-7.5. A majority of diatoms present at site LC-7.5 were tolerant of inorganic nutrients [Figure 6-4] and organic nitrogen [Figure 6-5], and nearly 50% of diatom relative abundance was contributed by taxa that are intolerant of high biochemical oxygen demand and require high dissolved oxygen saturation [Figure 6-6]. Biological integrity at site LC-7.5 was rated as "fair", with moderate impairment indicated solely by the percent abnormal diatom cells [Table 6-3]. A biota with minor impairment and "good" biological integrity, or unimpaired with "excellent" biological integrity, was indicated by the remainder the diatom association metrics at site LC-7.5 [Table 6-3].

6.3.3.3.8 Clark Fork River at Gemback Road (CFR-11F)

Site CFR-11F was sampled for the second year in a row in 2014. Ten "major" genera of non-diatom algae were identified, with three genera of green algae and seven genera of blue-green algae present. No other algal divisions were represented by major taxa at site CFR-11F in 2014 [Table 6-2]. The filamentous green algae *Cladophora* and *Oedogonium* were ranked first and second in biovolume, with diatoms ranked third and the cyanobacteria *Nostoc* ranked fourth at site CFR-11F [Table 6-2]. The non-diatom algae assemblage at site CFR-11F was very similar to that observed at upstream sites CFR-03A and CFR-07D, again suggesting water moderately rich in inorganic nutrients but possibly somewhat limited by nitrogen.

The diatom *Epithemia sorex* was dominant at site CFR-11F with a percent abundance of nearly13%. This was twice that seen at site CFR-03A and CFR-07D. Other dominant diatom species at site CFR-11F included *Cocconeis pediculus, C. placentula* and *Diatoma moniliformis* together comprising nearly 35% of diatom abundance. All of these diatom species prefer water with low to moderate levels of inorganic nitrogen and phosphorus and moderate conductivity, and occur as epiphytes on, or in close association with, filamentous green algae. Diatom increaser taxa at site CFR-11F indicated relatively high probability of impairment by sediment [Figure 6-1], metals [Figure 6-2] and nutrients [Figure 6-3]. The percent abundance of diatoms tolerant of inorganic nutrients [Figure 6-4] and organic nitrogen [Figure 6-5] at site CFR-11F were comparable to upstream sites CFR-03A and CFR-07D. The percent abundance of diatoms at site CFR-11F requiring high dissolved oxygen saturation and intolerant to conditions of high biochemical oxygen demand was relatively high at over 70% [Figure 6-6]. Biological integrity at site CFR-11F was rated "good", with minor impairment indicated by only a slightly elevated value for percent abnormal diatom cells [Table 6-3]. The remainder of the diatom association metrics for site CFR-11F indicated "excellent" biological integrity with a unimpaired biota [Table 6-3].

6.3.3.3.9 Racetrack Creek at Frontage Road (RTC-1.5)

The site on Racetrack Creek was sampled at the Frontage Road crossing for the second year in a row. A relatively diverse assemblage of eight "major" non-diatom genera from four algal divisions was present at site RTC-1.5 in 2014 [Table 6-2]. The cyanobacterium *Phormidium,* a cosmopolitan taxon with relatively broad ecological tolerances, ranked first in estimated biovolume at RTC-1.5. The yellow-green alga *Vaucheria*, which is often found in somewhat acidic waters containing dissolved humic compounds, ranked third after diatoms. The filamentous green algae *Cladophora* and *Stigeoclonium* were ranked fourth and fifth, respectively, while the filamentous red alga *Audouinella* ranked sixth at site RTC-1.5. This diverse group of filamentous algae suggests cool, circumneutral, relatively unpolluted water with adequate levels of inorganic nitrogen relative to phosphorus.

The diatoms *Achnanthidium minutissimum* and *A. pyrenaicum* were dominant at site RTC-1.5 with about 30% and 24% relative abundance, respectively; *Encyonema minutum* and *E. silesiacum* accounted for about 13% and 4% relative abundance, respectively. All of these taxa prefer cool, low-conductivity water that is relatively low in nutrients. *Achnanthidium minutissimum* is well adapted to recolonizing recently disturbed substrates, and as such is the basis for the disturbance index. The dominance of *Achnanthidium minutissimum* at site RTC-1.5 suggests that physical factors such as high current velocities and substrate scour likely impacted the periphyton assemblage. Diatom increaser taxa indicated a very low probability of impairment by sediment [Figure 6-1], metals [Figure 6-2], or nutrients [Figure 6-3] at RTC-1.5. The diatom assemblage at site RTC-1.5 was relatively indifferent or intolerant of inorganic nitrogen [Figure 6-4], and somewhat tolerant of elevated organic nitrogen [Figure 6-5]. Over 40% of diatom species present at site RTC-1.5 required high levels of dissolved oxygen and were intolerant of conditions with elevated biochemical oxygen demand [Figure 6-6]. Overall biological integrity at site RTC-1.5 in 2014 was rated as "good", with minor impairment indicated by a slightly depressed Shannon diversity value, and slightly elevated values for percent dominant taxon and the disturbance index [Table 6-3].

6.3.3.3.10 Clark Fork River at Deer Lodge (CFR-27H)

Six "major" non-diatom genera were identified at site CFR-27H in 2014, with two genera of green algae and four genera of blue-green algae present. No other algal divisions were represented by major taxa at site CFR-27H [Table 6-2]. The non-diatom algae *Oedogonium, Cladophora* and *Nostoc* were the most numerous forms at site CFR-27H, which was similar to the three mainstem sites upstream of CFR-27H. Along with the diatom assemblage, they ranked as the top four taxa by estimated biovolume. *Cladophora* and *Oedogonium* indicate relatively high-quality water moderately rich in inorganic nutrients. The importance of *Nostoc* suggests that nitrogen may have been limited relative to available phosphorus at site CFR-27H, although the low percent abundance of the diatom *Epithemia sorex* did not support that conclusion.

Diatom species richness and Shannon diversity values at CFR-27H were the lowest found at any of the mainstem sites in 2014 [Table 6-3]. The dominant diatom taxa at site CFR-27H included *Cocconeis pediculus, Amphora pediculus* and *Diatoma moniliformis* with a total percent abundance between them of nearly 45%. All of these diatom species prefer water with low to moderate levels of inorganic nitrogen and phosphorus and moderate conductivity, and occur as epiphytes on, or in close association with, filamentous green algae. Diatom increaser taxa at site CFR-27H indicated the lowest probability of impairment by metals of any of the Clark Fork River mainstem sites in 2014 [Figure 6-2]. A relatively high probability of impairment by sediment [Figure 6-1] and nutrients [Figure 6-3] was indicated by diatom increaser taxa. The diatom assemblage as a whole was relatively tolerant of inorganic and organic nitrogen [Figure 6-4; Figure 6-5], and required a moderately high percent oxygen saturation [Figure 6-6]. Overall biological integrity at CFR-27H was "good", with slight impairment indicated by the siltation index and percent abnormal diatom cells [Table 6-3].

6.3.3.3.11 Little Blackfoot River at Beck Hill Road (LBR-CFR-02)

The site on the Little Blackfoot River was moved upstream approximately four miles to the Beck Hill Road crossing in 2014. A very diverse assemblage of 17 "major" genera of non-diatom algae representing five algal divisions was identified at LBR-CFR-02, including seven genera of green algae, six genera of blue-green algae, two genera of yellow-green algae, and one genus each of red algae and brown algae [Table 6-2]. The blue-green alga *Nostoc* was second in estimated abundance, behind only diatom algae, while the filamentous green algae *Cladophora* and *Oedogonium* ranked third and fifth, respectively. Other "major" filamentous forms at LBR-CFR-02 included the red alga *Audouinella,* the yellow-green algae *Vaucheria* and *Tribonema,* the blue-green algae *Tolypothrix, Heteroleibleinia* and *Leptolyngbya,* the brown alga *Heribaudiella* and the green algae *Spirogyra* and *Ulothrix*. The green algae *Closterium, Cosmarium* and *Staurastrum,* all single-celled desmids, also were "major" taxa in the lower Little Blackfoot River. This diverse non-diatom algae assemblage suggests relatively high quality, nutrient-rich water with little indication of impairment by toxic metals.

Diatom species richness and Shannon diversity at LBR-CFR-02 were near the low end of values for other tributary streams and Clark Fork River mainstem sites in 2014 [Table 6-3]. *Diatoma moniliformis* was the dominant diatom taxon at site LBR-CFR-02, with a relative abundance of over 36%; *Epithemia sorex* was the second most dominant diatom taxa with an abundance of about 10%. *Diatoma moniliformis* prefers cool, well-oxygenated, alkaline water of moderate conductivity, with low to moderate levels of inorganic nutrients. The importance of *Epithemia sorex,* along with the cyanobacteria *Nostoc,* suggests nitrogen was likely the limiting nutrient at site LBR-CFR-02, with inorganic phosphorus relatively abundant. Diatom increaser taxa at LBR-CFR-02 in 2014 indicated a moderately low probability of impairment by both sediment and metals [Figure 6-1; Figure 6-2], and a high probability of impairment by nutrients [Figure 6-3]. Most of the diatom taxa present at LBR-CFR-02 were tolerant of elevated inorganic nitrogen [Figure 6-4] and organic nitrogen [Figure 6-5], and required relatively high dissolved oxygen saturation [Figure 6-6]. Biological integrity at site LBR-CFR was "good", with minor impairment indicated by slightly depressed values for Shannon diversity index and pollution index, and slightly elevated values for percent dominant diatom taxon and percent abnormal cells [Table 6-3].

6.3.3.3.12 Clark Fork River at Turah (CFR-116A)

Ten "major" non-diatom genera were identified at site CFR-116A in 2014, including two genera of green algae, six genera of blue-green algae, and one genus each of red algae and brown algae [Table 6-2]. The filamentous green alga *Cladophora,* the filamentous red alga *Audouinella* and the colonial blue-green alga *Nostoc* were abundant, and were ranked second through fourth in estimated biovolume, respectively, after diatom algae. The filamentous blue-green algae *Dichothrix*, *Tolypothrix, Heteroleibleinia* and *Homoeothrix* and the epiphytic blue-green *Chamaesiphon* all ranked within the top ten in estimated biovolume. The common filamentous green alga *Ulothrix* and the uncommon filamentous brown alga *Heribaudiella* rounded out the ten "major" non-diatom taxa at site CFR-116A. The non-diatom algae assemblage at site CFR-116A was generally indicative of cool, nutrient-rich water, with moderate tolerance to toxic metals.

Diatom species richness was relatively high, and Shannon diversity was the third highest of the sites monitored in 2014 [Table 6-3]. *Epithemia sorex* was the dominant diatom species at site CFR-116A, with a relative abundance of about 18%, likely as an epiphyte on the green alga *Cladophora. Epithemia sorex* prefers slightly alkaline water with a relatively low level of organic nitrogen. *Cymbella affinis* was the only other diatom taxon to exceed 10% relative abundance at site CFR-116A. *Cymbella affinis* is a cosmopolitan, stalked form that prefers somewhat alkaline water with moderate nutrient levels. Diatom increaser taxa at CFR-116A indicated a low probability of impairment by sediment [Figure 6-1], a high probability of impairment by heavy metals [Figure 6-2], and a moderate probability of impairment by nutrients [Figure 6-3]. Most of the diatom taxa present at CFR-116A were tolerant of elevated inorganic nitrogen [Figure 6-4], but relatively intolerant of organic nitrogen [Figure 6-5], and required a high level of dissolved oxygen saturation [Figure 6-6]. Biological integrity at site CFR-116A was rated "good", with minor impairment indicated only by a slightly elevated value for siltation index [Table 6-3]. The remainder the diatom association metrics for site CFR-116A indicated "excellent" biological integrity with a largely unimpaired biota [Table 6-3].

7.0 MACROINVERTEBRATES[33]

7.1 INTRODUCTION

The Clark Fork River, a major tributary of the Columbia River, has been impacted by mining and mineral operations occurring in its headwaters at the confluence of Warm Springs and Silver Bow Creeks in Deer Lodge County, Montana. In the late 1800s and early 1900s these tributaries carried wastes to the Clark Fork from mining, milling and smelting operations in the Butte and Anaconda areas. Wastes included hazardous substances such as arsenic, cadmium, copper, lead and zinc that contaminate large areas of the Clark Fork floodplain, river sediments and surface water.

An investigation of the character and extent of the contamination on the Clark Fork River began in 1995 subsequent to the U.S. Environmental Protection Agency (USEPA) designation of a portion of the river from the Warm Springs ponds on Silver Bow Creek to upstream of Milltown Reservoir as a distinct operable unit of the Milltown Reservoir Superfund Site. These investigations showed that natural resources in and around the river were impacted by the release of hazardous substances prompting the development of an adaptive, comprehensive long-term monitoring plan for evaluating the success of restoration and remediation activities [DeArment et al., 2010]. The plan will be implemented over the next decade and includes monitoring techniques and remediation goals for surface water, ground water, instream sediment, vegetation and aquatic biota.

Stream benthic macroinvertebrates are major components of the aquatic biota present in the Clark Fork drainage and thus, play an important role in the comprehensive monitoring plan. The overall plan for macroinvertebrates "is a reduction of acute and chronic risks to aquatic life as measured by…. benthic macroinvertebrate community integrity…… An absence of impacts to macroinvertebrate organisms will be reflected by a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the regions" [Karr and Dudley, 1981]. Attainment of will be reflected by progressive increases in biological integrity [DeArment et al., 2010]. Specifically, the plan for the macroinvertebrate community is "to attain and maintain a 'nonimpaired' bioassessment rating (>80%) based in the metrics subset indicating metals pollution which was established by McGuire [DeArment et al., 2010]." Although metals pollution will be used as the primary benchmark for evaluation of the condition of the macroinvertebrate community relative to remediation measures, other metrics will also be used to evaluate overall community integrity.

This report describes the analysis of a subset of the benthic macroinvertebrate monitoring program, specifically the samples collected in the Clark Fork drainage in 2014. The benthic invertebrate fauna was analyzed using an index developed specifically for the Clark Fork

[33] Chapter 7 was prepared by Wease Bollman, Sean Sullivan, Jennifer Bowman, and Billie Kerans with Rhithron with minor editing and formatting by RESPEC.

drainage [McGuire, 2010]. This index has been applied over a long course of sampling dating from 1986. The index is divided into three parts: a general subset, an organic pollution subset and a metals subset. In addition, the taxonomic and functional composition of the benthic fauna was investigated to gain information about probable stressors to water quality and habitat integrity. This information is described in a series of site-specific narratives.

7.2 METHODS

7.2.1 Sampling

Benthic macroinvertebrates were sampled at three Clark Fork River headwater sites, four sites on the mainstem Clark Fork River, and three sites on tributaries of the Clark Fork River on August 7 and 8, 2014. Four sample replicates were collected at each site, using a Hess sampling device. Sites are described in Table 7-1. Samples were delivered to Rhithron Associates, Inc. for processing and identification.

Table 7-1. Macroinvertebrate sampling sites in the Clark Fork River basin, August 7-8, 2014.

Site description	Site ID.	Co-located USGS gauge	Latitude (NAD 83)	Longitude (NAD 83)
Mill-Willow Creek at Frontage Road	MCWC-MWB	NA	46.12649	-112.79876
Warm Springs Creek near mouth	WSC-SBC	12323770	46.18041	-112.78592
Silver Bow Creek at Warm Springs	SS-25	12323750	46.18123	-112.77917
Clark Fork near Galen	CFR-03A	12323800	46.20877	-112.76740
Clark Fork at Galen Road	CFR-07D	12323800	46.20877	-112.76740
Clark Fork at Gemback Road	CFR-11F	NA	46.26520	-112.74430
Clark Fork at Turah	CFR-116A	12334550	46.49340	-113.48480
Lost Creek near mouth	LC-7.5	12323850	46.21862	-112.77384
Racetrack Creek near mouth	RTC-1.5	NA	46.28395	-112.74921
Little Blackfoot River near Garrison	LBR-CFR	12324590	46.51964	-112.79312

7.2.2 Laboratory Analysis

Samples were completely picked of organisms, following procedures consistent with previous Clark Fork River biomonitoring projects [McGuire, 2010; Bollman, 2010]. Similar to the most recent studies [Bollman and Sullivan, 2013; Bollman et al., 2014], densities of abundant taxa were not estimated, but actual counts were obtained for all organisms. Caton trays [Caton, 1991] were used to distribute the samples for sorting. Each individual sample was thoroughly mixed in its jar(s), poured out and evenly spread into the Caton tray. Grids were systematically selected, and grid contents were examined under stereoscopic microscopes using 10x-30x magnification (Leica S6E and Leica EZ4 stereoscopic dissecting microscopes). All invertebrates were sorted from the substrate, and placed in 95% ethanol for subsequent identification.

Organisms were individually examined by certified taxonomists, using 10x–80x stereoscopic dissecting scopes (Leica S8E) and identified to the lowest practical level consistent with previous Clark Fork River biomonitoring projects [McGuire, 2010], using appropriate published taxonomic references and keys. Midges and worms were carefully morphotyped using 10x–80x stereoscopic dissecting microscopes (Leica S8E) and representative specimens were slide mounted and examined at 200x–1000x magnification under compound microscopes (Olympus BX 51 with Hoffman Contrast and Leica DM1000). Slide mounted organisms were archived at the Rhithron laboratory.

Identification, counts, life stages, and information about the condition of specimens were recorded. Organisms that could not be identified to the taxonomic targets because of immaturity, poor condition, or lack of complete current regionally applicable published keys were left at appropriate taxonomic levels that were coarser than target levels. To obtain accuracy in richness measures, these organisms were designated as "not unique" if other specimens from the same group could be taken to target levels. Organisms designated as "unique" were those that could be definitively distinguished from other organisms in the sample. Identified organisms were preserved in 95% ethanol in labeled vials, and archived at the Rhithron laboratory.

7.2.3 Quality Assurance Systems

Quality control procedures for macroinvertebrate sample processing involved checking sorting efficiency on two randomly selected quality control samples. These checks were conducted by trained quality assurance technicians who microscopically re-examined 100% of sorted substrate from each quality control sample. Sorting efficiency was evaluated by applying the following calculation:

$$SE = \frac{n_1}{n_1 + n_2} \times 100$$

where: SE is the sorting efficiency, expressed as a percentage, n_1 is the total number of specimens in the first sort, and n_2 is the total number of specimens in the second sort.

Quality control procedures for taxonomic determinations of invertebrates involved checking accuracy, precision and enumeration. Two samples were randomly selected and all organisms re-identified and counted by an independent taxonomist. Taxa lists and enumerations were compared by calculating a Bray-Curtis similarity statistic [Bray and Curtis, 1957] for each selected sample. The percent taxonomic disagreement (PTD) and percent difference in enumeration (PDE) were also calculated [Stribling et al., 2003].

7.2.4 Data Analysis

Taxa lists and counts for each sample were constructed. Standard metric calculations were made using customized database software. McGuire's indices are ".....specifically designed to evaluate water quality in the Clark Fork River Basin" [McGuire, 2010]. The indices comprise 11 metrics. Two subsets of three metrics each are scored and summed separately to obtain values for organic/nutrient impairment and for metals impairment. Individual metrics and the expected response of each to environmental stress are described in the project sampling and analysis plan [Naughton et al., 2014].

7.2.5 Ecological Interpretations: Approach

We use narrative interpretations of taxonomic and functional composition of invertebrate assemblages to reveal the probable stressors in the Clark Fork River Operable Unit. Often canonical procedures are used for stressor identification; however, the substantial data required for such procedures (e.g., surveys of habitat, historical and current data related to water quality, land use, point and non-point source influences, soils, hydrology, geology) were not readily available for this study. Instead our narrative interpretations are based on demonstrated associations between assemblage components and habitat and water quality variables gleaned from the published literature, the writer's own research (especially Bollman [1998]) and professional judgment, and the research (especially Wisseman [1996]) and professional judgment of other expert sources.

We use attributes of invertebrate taxa that are well substantiated in diverse literature and that are generally accepted by regional aquatic ecologists as evidence of water quality and instream and reach-scale habitat conditions. The approach to this analysis uses some assemblage attributes that are interpreted as evidence of water quality and other attributes that are interpreted as evidence of habitat integrity. To arrive at impairment classifications, attributes are considered individually, so information is maximized by not relying on a single cumulative score, which may mask stress on the biota. Such an approach also minimizes the possibility of using inappropriate assessment strategies when the biota at a site is atypical of "characteristic" sites in a region. Replicate samples were electronically combined into composited samples for this analysis. Below we describe the invertebrate attributes that were used and their relationships to water quality and habitat conditions.

Mayfly taxa richness, the Hilsenhoff Biotic Index (HBI) value [Hilsenhoff, 1987], the richness and abundance of hemoglobin-bearing taxa and the richness of sensitive taxa are often used as indicators of water quality. Mayfly taxa richness has been demonstrated to be significantly correlated with chemical measures of dissolved oxygen, pH, and conductivity (e.g., Bollman [1998], Fore et al. [1996], Wisseman [1996]). The HBI has a long history of use and validation [Cairns and Pratt, 1993; Smith and Tran, 2010; Johnson and Ringler, 2014]. In Montana foothills, the HBI was demonstrated to be significantly associated with conductivity, pH, water temperature, sediment deposition, and the presence of filamentous algae [Bollman, 1998]. Nutrient enrichment in Montana streams often results in large crops of filamentous algae [Watson, 1988]. Thus in these samples, when macroinvertebrates associated or dependent on filamentous algae (e.g., LeSage and Harrison [1980], Anderson [1976]) are abundant, the presence of filamentous algae and nutrient enrichment are also suspected. Sensitive taxa exhibit intolerance to a wide range of stressors (e.g., Hellawell [1986], Wisseman [1996], Friedrich [1990], Barbour et al. [1999]), including nutrient enrichment, acidification, thermal stress, sediment deposition, habitat disruption, and others. These taxa are expected to be present in predictable numbers in functioning montane and foothills streams (e.g., Bollman

[1998]). Although the abundance of invertebrates in Hess samples can be highly variable, reflecting the patchy and dynamic areal distribution of the benthos in stony-bottomed streams, McGuire's thresholds for environmental perturbation [McGuire, 2010] are cited as evidence of enrichment or impairment.

The richness and abundance of cold stenotherm taxa [Clark, 1997] and calculation of the temperature preference of the macroinvertebrate assemblage [Brandt, 2001] can predict the thermal characteristics of the sampled site. Hemoglobin-bearing taxa are also indicators of warm water temperatures [Walshe, 1947], since dissolved oxygen is directly associated with water temperature; oxygen concentrations can also vary with the degree of nutrient enrichment. Increased temperatures and high nutrient concentrations can, alone or in concert, create conditions favorable to hypoxic sediments, habitats preferred by hemoglobin-bearers.

The absence of invertebrate groups known to be sensitive to metals and the Metals Tolerance Index [Bukantis, 1998] are considered signals of possible metals contamination. Metals sensitivity for some groups, especially the heptageniid mayflies, is well-known (e.g., Kiffney and Clements [1994]; Clements [1999]; [2004]; Montz et al. [2010]; Iwasaki et al. [2013]). In the present approach, the absence of these groups in environs where they are typically expected to occur is considered a signal of possible metals contamination, but only when combined with a measure of overall assemblage tolerance of metals. The Metals Tolerance Index ranks taxa according to their sensitivity to metals. Weighting taxa by their abundance in a sample, assemblage tolerance is estimated by averaging the tolerance of all sampled individuals.

Characteristics of the macroinvertebrate assemblages can also reveal the condition of instream and streamside habitats. Stress from sediment is evaluated by caddisfly richness and by "clinger" richness [Kleindl, 1995; Bollman, 1998; Karr and Chu, 1999; Wagenhoff et al., 2012; Leitner et al., 2015]. A newer tool, the Fine Sediment Biotic Index (FSBI) [Relyea et al., 2012] shows promise when applied to the montane and foothills regions. This index and its interpretation are modified in this report, based on the author's professional judgment, to more effectively characterize the Clark Fork River and tributaries in the sampled reaches.

The functional characteristics of macroinvertebrate assemblages are based on the morphology and behaviors associated with feeding, and are interpreted in terms of the River Continuum Concept [Vannote et al., 1980] in the narratives. Alterations from predicted patterns in montane and foothills streams may be interpreted as evidence of water quality or habitat disruption. For example, shredders and the microbes they depend on are sensitive to modifications of the riparian zone [Plafkin et al., 1989].

7.3 RESULTS

7.3.1 Bioassessment

Analytical macroinvertebrate data are presented in Appendix H. Mean bioassessment scores and their associated impairment classifications are given in Table 7-2. Raw scores for each macroinvertebrate replicate sample are given in Appendix I. Quality control and quality assurance results are reported in Appendix J.

7.3.1.1 Overall Biointegrity Index

Mean scores for McGuire's overall biointegrity index [Table 7-2] indicate unimpaired biological integrity at the headwaters site on Mill-Willow Creek (MCWC-MWB) and at the tributary site Lost Creek at Frontage Road (LC-7.5). All other studied sites are classified as slightly impaired using this index. There was little variation in overall biological integrity scores among sample replicates. The mean coefficient of variation (CV) among replicates for this index (scores as percent of maximum score) was 2.38%. Mean, maximum and minimum scores, with 95% confidence intervals are graphed in Figure 7-1.

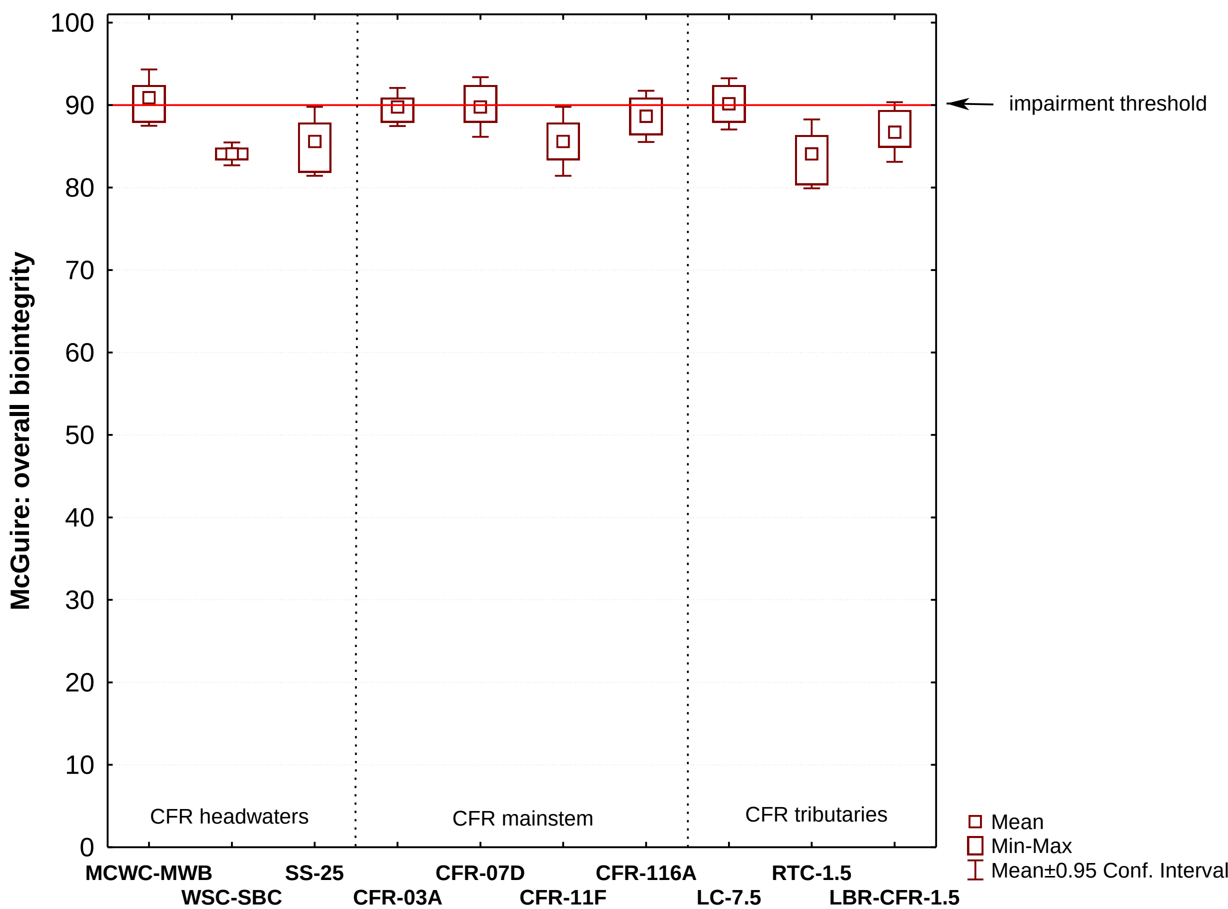

Figure 7-1. Variability among replicates: mean scores, maximum and minimum scores, and 95% confidence intervals for McGuire's overall biointegrity index. Clark Fork River basin, August 7-8, 2014.

7.3.1.2 Metals Subset

Mean scores for McGuire's metals index [Table 7-2] indicate unimpaired conditions at five sites. Slight metals impairment was indicated at: Silver Bow Creek at Warm Springs (SS-25), Clark Fork at Gemback Road (CFR-11F), and Little Blackfoot River near Garrison (LBR-CFR). Moderate impairment due to metals was indicated at Warm Springs Creek near mouth (WSC-SBC) and Racetrack Creek at Frontage Road (RTC-1.5). The mean CV among replicates for the metals subset index score (scores as percent of maximum score) was 8.18%, suggesting greater variability in these scores compared to the overall biointegrity scores. Mean, maximum and minimum scores, with 95% confidence intervals are graphed in Figure 7-2.

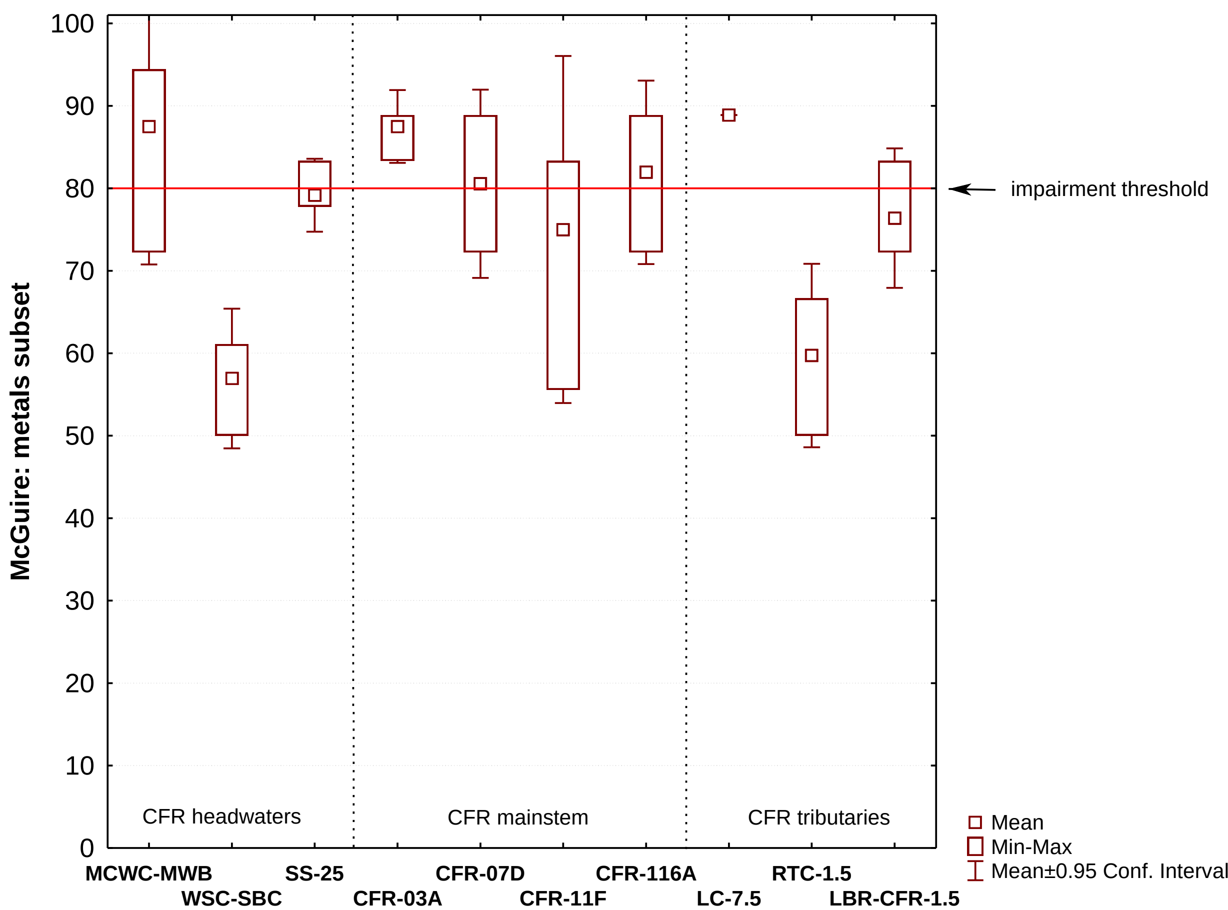

Figure 7-2. Variability among replicates: mean scores, maximum and minimum scores, and 95% confidence intervals for McGuire's metals pollution metric subset. Clark Fork River basin, August 7-8, 2014.

7.3.1.3 Organic and Nutrient Subset

Mean scores for McGuire's organic and nutrient index [Table 7-2] indicate unimpaired conditions at all sites. The mean CV among replicates for the organic and nutrient subset index score (scores as percent of maximum score) was 5.17%, indicating moderate variation in these scores. Mean, maximum and minimum scores, with 95% confidence intervals are graphed in Figure 7-3.

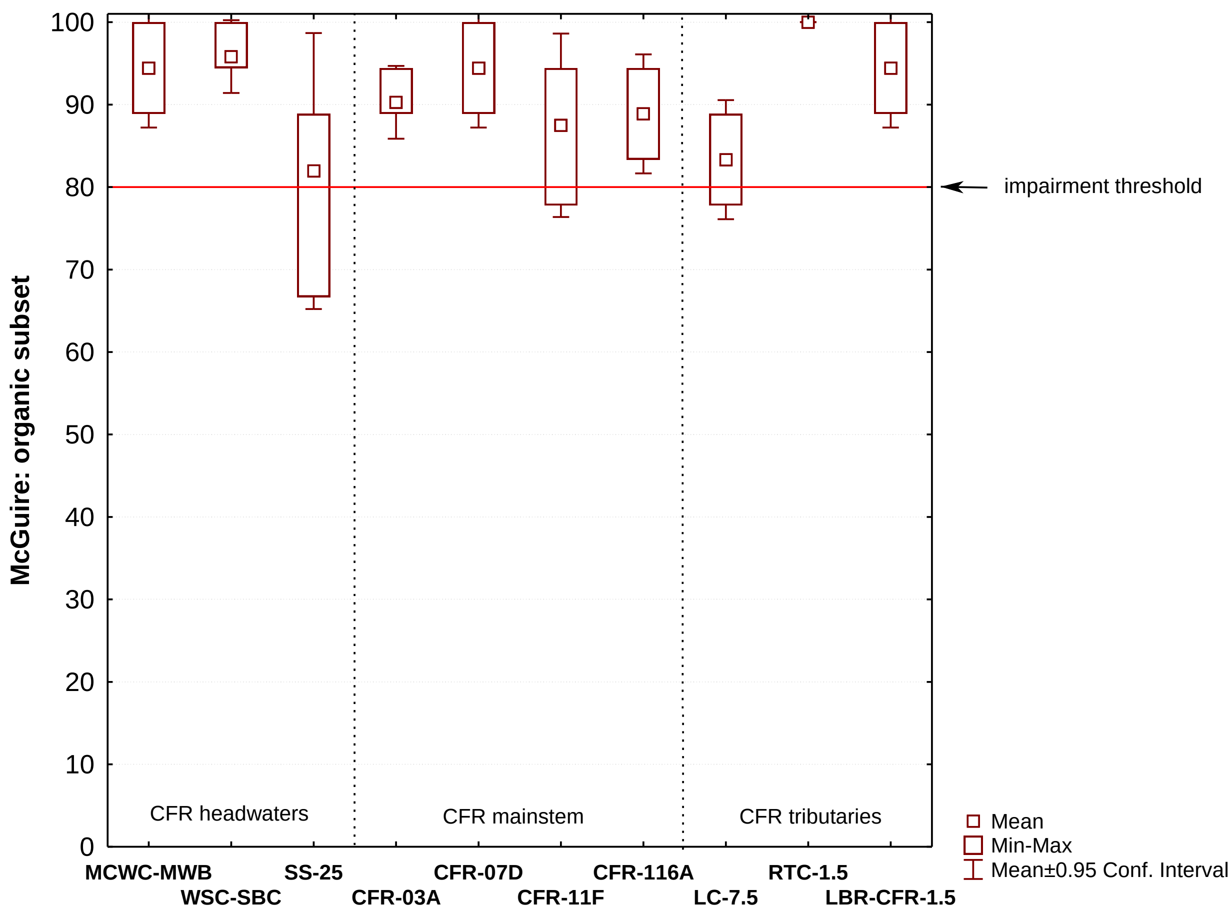

Figure 7-3. Variability among replicates: mean scores, maximum and minimum scores, and 95% confidence intervals for McGuire's organic/nutrient pollution metric subset. Clark Fork River basin, August 7-8, 2014.

Table 7-2. Mean macroinvertebrate bioassessment scores and impairment classifications: McGuire's indices for general biointegrity, nutrient/organic impairment, and metals impairment. Scores are mean values over four replicate samples, and are expressed as the percent of maximum score. Clark Fork River basin, August 7-8, 2014.

Site name	Site identifier	McGuire biointegrity metrics [McGuire, 2010]		McGuire metals-sensitive subset [McGuire, 2010]		McGuire organic/nutrient-sensitive subset [McGuire, 2010]	
		score	impairment class	score	impairment class	score	impairment class
Mill -Willow Creek at Frontage Road	MCWC-MWB	90.9	none	87.5	none	94.4	none
Warm Springs Creek near mouth	WSC-SBC	84.1	slight	56.9	moderate	95.8	none
Silver Bow Creek at Warm Springs	SS-25	85.6	slight	79.2	slight	81.9	none
Clark Fork near Galen at Perkins Lane	CFR-03A	89.8	slight	87.5	none	90.3	none
Clark Fork at Galen Road	CFR-07D	89.8	slight	80.6	none	94.4	none
Clark Fork at Gemback Road	CFR-11F	85.6	slight	75.0	slight	87.5	none
Clark Fork at Turah	CFR-116A	88.6	slight	81.9	none	88.9	none
Lost Creek at Frontage Road	LC-7.5	90.2	none	88.9	none	83.3	none
Racetrack Creek at Frontage Road	RTC-1.5	84.1	slight	59.7	moderate	100.0	none
Little Blackfoot River near mouth near Garrison	LBR-CFR	86.7	slight	76.4	slight	94.4	none

7.3.2 Ecological Interpretation of Aquatic Invertebrate Assemblages

7.3.2.1 Mill-Willow Creek at Frontage Road (MCWC-MWB)

Metric indicators of water quality suggested good conditions at this site: Mayfly taxa richness (11) was high, and the HBI value (3.40) was within expectations for a low-order valley stream, indicating a moderately sensitive invertebrate assemblage. The dominant taxon was the caddisfly *Brachycentrus occidentalis*, accounting for 38% of sampled organisms. The abundance of this filter-feeder suggests that suspended organic particulates were an important energy source in the reach: *B. occidentalis* is typical of dam-outflow environments. Notably, the Metals Tolerance Index (MTI) value (3.91) exceeded the HBI value, suggesting metals contamination. However, heptageniid mayflies (*Ecdyonurus criddlei*) were common in the sample. It seems likely that metals contamination was not a major influence on the composition of the benthic fauna. The thermal preference of the assemblage was estimated at 15.7 C.

The benthic fauna did not appear to be stressed by sediment deposition. Thirteen caddisfly taxa and 29 "clinger" taxa were counted. The FSBI value (5.28) indicated a sediment-sensitive assemblage. High overall taxa richness (59) suggests diverse and intact instream habitats. The presence of eight semivoltine taxa indicates that the fauna was not substantially influenced by catastrophic dewatering, thermal extremes, or severe sediment pulses. Filter-feeders, especially *Brachycentrus occidentalis*, and the midge *Rheotanytarsus* sp., dominated the functional composition of the assemblage. All other expected groups were also present.

7.3.2.2 Warm Springs Creek near mouth (WSC-SBC)

Collections at this site were relatively depauperate, the number of organisms in Hess sample replicates ranged from 147 to 244. Low numbers of organisms may be due to very poor water quality, habitat disruption or limitations, sampling error, or a combination of those factors.

Five mayfly taxa were counted, which is somewhat fewer than expected. Nearly all (96.7%) of mayflies in the replicates were baetids (*Acentrella insignificans*, *Baetis tricaudatus* complex, *Diphetor hageni*), among the more tolerant taxa in this insect order. The HBI value (4.04) suggested a mildly tolerant invertebrate assemblage. Similar to the data of 2013, the MTI value (4.66) was higher than the HBI value, and metals-sensitive taxa such as heptageniid mayflies and *Lepidostom*a sp. were uncommon. Based on these findings, metals contamination cannot be ruled out here. The thermal preference calculated for the fauna was 14.8 C.

It seems likely that sediment deposition did not appreciably limit colonization of stony substrates, since 12 caddisfly taxa and 23 "clinger" taxa were collected. The FSBI value (4.84) indicated a sediment-sensitive assemblage. Overall taxa richness (41) was somewhat lower than expected: instream habitats may have been monotonous or disrupted. Semivoltine taxa (8) were well-represented, indicating that dewatering or thermal stress did not interrupt long life cycles. All functional groups were present, but shredders were notably rare, suggesting limited riparian inputs of organic material, or hydrologic conditions that did not favor retention of such material.

7.3.2.3 Silver Bow Creek at Warm Springs (SS-25)

Mayfly taxa richness (5) was lower than expected, and the HBI value (4.99) was higher than expected for a low-order valley stream. These findings suggest that the invertebrate assemblage may be stressed by impaired water quality. Nearly half of the sampled organisms were taxa tolerant to nutrient pollution: these included amphipods (*Hyalella* sp.), isopods (*Caecidotea* sp.), and leeches (*Helobdella stagnalis*). Hemoglobin-bearing midges (*Cryptochironomus* sp., *Microtendipe*s sp., *Polypedilum* sp., and *Pseudochironomus* sp.) further suggest that hypoxic conditions may be present. Abundant hydroptilid caddisflies (*Hydroptila* sp. and *Ochrotrichia* sp.) suggest the presence of filamentous algae. Large crops of filamentous algae may be associated with nutrient enrichment. In addition, warm water temperatures are suggested by large numbers of the caddisfly *Cheumatopsyche* sp. and the mayfly *Tricorythodes* sp. The thermal preference of the assemblage was calculated at 16.3 C. No heptageniid mayflies were present in the sample, but the MTI value (4.59) was lower than the HBI value. There is no definitive evidence of metals contamination.

Thirteen caddisfly taxa and 20 “clinger” taxa were counted in the composited samples. It seems likely that stony substrate habitats were not excessively compromised by deposited sediment. The FSBI value (3.19) indicated a moderately sediment-tolerant assemblage. High overall taxa richness (61) may be related to diverse and intact instream habitats. Catastrophic dewatering, thermal stress, or sediment pulses seem unlikely, since the site supported at least 5 semivoltine taxa. Filterers, especially among the hydropsychid caddisflies (*Ceratopsyche cockerelli*, *Cheumatopsyche* spp., *Hydropsyche occidentalis*), blackflies (*Simulium* sp.), and the midges (*Microtendipes* spp.) dominated the functional mix. This suggests that fine organic particles in suspension were an important energy source, and may be evidence of nutrient enrichment. All other expected feeding groups were present, although shredders were notably scarce. A poor showing of shredders suggests that large organic material such as leaves and woody debris from riparian inputs may have been limited, or that hydrologic conditions did not favor retention of such material.

7.3.2.4 Clark Fork near Galen (CFR-03A)

Similar to the samples collected in 2013, the midge *Cricotopus* (*Nostococladius*) sp. dominated collections taken at this site in 2014, accounting for 26% of the sampled fauna. The relatively high tolerance value (6) assigned to this midge may overestimate its tolerance, and resulted in an HBI value of 4.68, higher than expected for a low- to mid-order stream in the Valley and Foothill ecoregion. Mayfly taxa richness (7) was within expectations. It seems likely that nutrient pollution did not substantially influence the macroinvertebrate assemblage here. Nitrogen was likely a limiting nutrient, since abundant *C.* (*Nostococladius*) sp. suggests a large crop of the blue-green alga *Nostoc* sp. The MTI value (4.50) was lower than the HBI value, but metals-sensitive taxa such as heptageniid mayflies and the caddisfly *Lepidostoma* sp. were poorly represented. Based on these data, there is no definitive evidence of metals contamination. The thermal preference of the fauna was calculated at 15.9 C.

At least 24 "clinger" taxa and 15 caddisfly taxa were supported at this site, suggesting that stony substrates were largely free of deposited sediment. The FSBI value (4.19) indicated a moderately sediment-sensitive fauna. Overall taxa richness (58) was moderately high and may have been related to intact and diverse instream habitats. The dominance of *C*. (*Nostococladius*) sp. suggests that the benthic substrate may have been composed primarily of *Nostoc* sp. colonies. Seven semivoltine taxa were counted in samples, and several of these taxa were abundant. Catastrophes such as dewatering, scouring sediment pulses, or thermal extremes were probably not influential here. Shredders, especially *C*. (*Nostococladius*) sp. were abundant, but this midge does not respond to riparian inputs of large organic material: this type of material may have been limited in the reach. Filter-feeders, collectors, and scrapers were also abundant.

7.3.2.5 Clark Fork at Galen Road (CFR-07D)

Mayfly taxa richness (6) was moderate in samples collected at this site, and the HBI value (4.32) was somewhat higher than expected for a mid-order valley stream. The midge *Cricotopus* (*Nostococladius*) sp. was common, and its overestimated tolerance value (6) influenced the HBI calculation. It seems likely that nutrient pollution, if present, was mild at this site. Metals contamination, however, cannot be ruled out: the MTI value (4.41) was higher than the HBI value. In addition, common metals-sensitive taxa were rare here: no heptageniid mayflies were counted, and the caddisfly *Lepidostoma* sp. was represented by a single specimen. The thermal preference of the benthic fauna was calculated at 16.1 C.

Sediment deposition probably did not influence this assemblage to an appreciable extent: the site supported no fewer than 11 caddisfly taxa and 21 "clinger" taxa. The FSBI value (4.05) indicated a moderately sediment-sensitive assemblage. Overall taxa richness (50) was somewhat lower than expected, suggesting limited instream habitats. Dewatering or thermal extremes probably did not influence the composition of the benthic fauna, since seven semivoltine taxa were counted in samples. Filterers, especially the caddisflies *Ceratopsyche cockerelli* and *Brachycentrus occidentalis*, dominated the functional composition, suggesting that suspended fine organic material was a major energy source in the reach. All other feeding groups were present, but shredders indicative of riparian inputs were not common.

7.3.2.6 Clark Fork at Gemback Road (CFR-11F)

Although mayfly taxa richness (10) was high, the HBI value (4.34) indicated a relatively tolerant benthic fauna at this site. Hydroptilid caddisflies (*Hydroptila* sp.) and midges in the genus *Orthocladius* spp. were common in the samples: these taxa are typically associated with filamentous algae, large crops of which may suggest nutrient enrichment. Cool to warmwater temperatures may have also been influential here, since several warmwater preferring taxa were present, including the caddisflies *Helicopsyche* sp. and *Oecetis* sp., and the mayfly *Tricorythodes* sp. The thermal preference of the entire assemblage was calculated at 16.8 C.

Eleven caddisfly taxa were collected, but "clinger" richness was slightly lower than expected, suggesting mild influence of sediment deposition. The FSBI value (4.04), however, indicated a moderately sediment-sensitive assemblage. Lower than expected taxa richness (45) may be related to monotonous or disrupted instream habitats. Semivoltine taxa were well represented: six such taxa were counted in samples. Catastrophic dewatering or thermal extremes did not appear to be influential. Filterers, especially among the hydropsychid caddisflies (*Ceratopsyche cockerelli*, *Cheumatopsyche* sp., and *Hydropsyche occidentalis*), dominated the functional mix, suggesting abundant fine organic particulates in suspension. Some nutrient enrichment may be indicated. Although all other feeding groups were represented, shredders were notably uncommon. Riparian inputs of large organic material such as leaves and woody debris may have been limited in the reach.

7.3.2.7 Clark Fork at Turah (CFR-116A)

At least 12 unique mayfly taxa were supported at this site. The HBI value (4.47) indicated a mildly tolerant assemblage, which seems appropriate for a higher-order riverine system in the Valley and Foothill ecoregion. Although taxa typically associated with filamentous algae (*Hydroptila* sp., *Cricotopus* spp., *Orthocladius* spp.) were present, nutrient enrichment was probably mild. This assemblage yielded the highest thermal preference (17.4 C) of any site in this study. Cool to warmwater taxa, such as *Asioplax edmunsdi*, *Tricorythodes* sp., immature gomphid dragonflies, and the aquatic larvae of moths (*Petrophila* sp.) were common in samples collected here.

The site supported at least nine caddisfly taxa and 22 “clinger” taxa, suggesting that colonization of stony substrates was not inhibited by deposited sediment. The FSBI value (4.53) indicated a sediment sensitive assemblage. Overall taxa richness (53) was high, suggesting diverse instream habitats. Eight semivoltine taxa were counted in samples: catastrophic dewatering or thermal stress probably did not influence the biota in this reach. Filterers, especially among the hydropsychid caddisflies (*Hydropsyche occidentalis*, *Cheumatopsyche* sp., and *Ceratopsyche cockerelli*), dominated the functional mix. Gatherers were also abundant. This pattern is sometimes interpreted as evidence of nutrient enrichment. Shredders associated with leafy and woody debris from riparian sources were more common here than at other Clark Fork River sites in this study.

7.3.2.8 Lost Creek at Frontage Road (LC-7.5)

Although seven mayfly taxa were collected at this site, the high HBI value (5.41) indicated a tolerant invertebrate assemblage. Impaired water quality seems to be indicated. Tolerant taxa were abundant: these included large numbers of the amphipods *Hyalella* sp. and *Gammarus* sp., snails (*Gyraulus* sp., *Physella* sp.), leeches (*Helobdella stagnalis*, *Glossiphonia complanata*), hydroptilid caddisflies (*Hydroptila* sp.) and other tolerant caddisflies (*Helicopsyche* sp., *Oecetis* sp.). Some of these taxa are associated with filamentous algae, large crops of which may be an indication of nutrient enrichment. There was no discernible evidence of metals contamination. The thermal preference of the invertebrate fauna was calculated at 16.9 C.

The site supported at least 12 caddisfly taxa, but there were fewer “clinger” taxa (18) than expected. These findings suggest that sediment deposition may have compromised stony substrate habitats. However, the FSBI value calculated for the assemblage was 4.25, indicating a moderately sediment-sensitive fauna. Overall taxa richness (57) was high, suggesting diverse instream habitats. Six semivoltine taxa were counted in samples: catastrophic dewatering or thermal extremes probably did not influence the biota in this reach. All expected functional groups were present: gatherers and filterers were the most common organisms. This pattern is sometimes interpreted as evidence for nutrient enrichment.

7.3.2.9 Racetrack Creek at Frontage Road (RTC-1.5)

High mayfly taxa richness (12) and low HBI value (3.04) suggest that nutrient enrichment was not influential here. The benthic fauna included several moderately sensitive taxa, including the mayflies *Ameletus* sp. and *Rhithrogena* sp., as well as the caddisfly *Agapetus* sp. Of concern is the high MTI value (5.16), which exceeded the HBI value. A few specimens of metals-sensitive taxa (*Ecdyonurus criddlei*, *Rhithrogena* sp., *Lepidostoma* sp.) were present; abundance of these taxa was so limited that metals contamination cannot be ruled out at this site. The most abundant taxon, the midge *Pagastia* sp., accounted for 24% of sampled organisms, and is considered to be tolerant of metals contamination. The thermal preference of the assemblage was calculated at 14.6 C.

Eight caddisfly taxa and 21 "clinger" taxa were collected, suggesting that sediment deposition did not appreciably limit colonization of stony substrates. The hyporheic stonefly *Paraperla* sp. was present, indicating that interstitial spaces were not compromised by sediment or embedded substrates. The FSBI value (4.80) indicated a sediment-sensitive fauna. Overall taxa richness (54) was high, even though invertebrate abundance was lower than expected. Replicate sample sizes ranged from 201 to 444 organisms: only 1,182 specimens were present in the four replicate samples collected here. Three of the six semivoltine taxa counted in samples were pioneering taxa (dytiscid and haliplid beetles) with more mobility than other benthic invertebrates. Still, it seems unlikely that the site was influenced by catastrophic dewatering, thermal extremes or scouring sediment pulses. Gatherers overwhelmed the functional composition of the assemblage, filterers were rare, and other feeding groups were uncommon. This pattern represents a likely disturbance of the expected functional condition, which may be related to either water quality problems, habitat disruption, or both.

7.3.2.10 Little Blackfoot River at Beck Hill Road (LBR-CFR)

Nine mayfly taxa were counted in samples collected at this site, but the elevated HBI value (4.60) suggests a moderately tolerant assemblage. The HBI value is at least partly influenced by abundant *Cricotopus* (*Nostococladius*) sp., which has a tolerance value assignment that seems to underestimate its sensitivity. But large numbers of the midges *Eukiefferiella* spp. and *Tvetenia* spp. suggest that filamentous algae may be common in the reach. Large crops of filamentous algae may be associated with nutrient enrichment. Hemoglobin-bearing taxa, including the midge *Polypedilum* sp., were common, supporting a hypothesis of nutrient pollution. The MTI value (4.32) was lower than the HBI value, and heptageniid mayflies (*Ecdyonurus criddlei*) were present, as was the metals-sensitive caddisfly *Lepidostoma* sp. It seems likely that the site was not contaminated by metals pollution. The thermal preference of the benthic fauna was estimated at 15.7 C.

Twelve caddisfly taxa were collected at this site, and samples yielded 28 “clinger” taxa. Sediment deposition probably did not substantially limit colonization of stony substrate habitats here. The FSBI value (5.41) indicated a sediment-sensitive fauna. Overall taxa richness (62) was high, suggesting diverse and intact instream habitats. Nine semivoltine taxa were counted: year-round surface flow and absence of events that would interrupt long life cycles are indicated. All expected functional groups were represented. The functional composition was dominated by gatherers and filterers, a pattern which is sometimes interpreted as evidence of impaired water quality.

7.4 CONCLUSIONS

Among Clark Fork River headwaters and tributary sites, five sites had metals pollution subset scores below 80% including Warm Springs Creek near mouth (WSC-SBC) with a mean score of 56.9%, Silver Bow Creek at Warm Springs (SS-25) with a mean score 79.2%, the Clark Fork River site at Gemback Road (CFR-11F) with a mean score of 75.0%, Racetrack Creek at Frontage Road (RTC-1.5) with a mean score of 59.7%, and the Little Blackfoot River near Garrison (LBR-CFR) with a mean score of 76.4%.

On the basis of the taxonomic composition of the macroinvertebrate fauna and the performance of the MTI, the influence of metals contamination was a possible stressor at two headwaters sites: Warm Springs Creek near mouth (WSC-SBC) and Silver Bow Creek at Warm Springs (SS-25). Metals contamination could not be ruled out at the mainstem Clark Fork River sites near Galen at Perkins Lane (CFR-03A) and at Galen Road (CFR-7D), and at the tributary site on Racetrack Creek (RTC-1.5). Table 7-3 summarizes the probable stressors suggested by the taxonomic and functional composition of macroinvertebrate assemblages at each site.

Table 7-3. Clark Fork River basin sites and probable stressors as suggested by the composition of macroinvertebrate assemblages. Clark Fork River basin, August 7-8, 2014.

Site name	Site ID	Low abundance	Nutrient and/or organic pollution	Metals	Sediment deposition	Thermal extremes	Habitat instability
Mill -Willow Creek at Frontage Road	MCWC-MWB						
Warm Springs Creek near mouth	WSC-SBC	+	+	+			
Silver Bow Creek at Warm Springs	SS-25		+				
Clark Fork near Galen at Perkins Lane	CFR-03A						
Clark Fork at Galen Road	CFR-07D			+			
Clark Fork at Gemback Road	CFR-11F		?		?		
Clark Fork at Turah	CFR-116A						
Lost Creek at Frontage Road	LC-7.5		+		?		
Racetrack Creek at Frontage Road	RTC-1.5	+		?			
Little Blackfoot River near mouth near Garrison	LBR-CFR		?				

+ Composition of the assemblage suggests stress.

? Evidence from the assemblage was contradictory or inconclusive.

8.0 FISH[34]

8.1 INTRODUCTION

Metal mining and milling operations began in Silver Bow Creek and the Upper Clark Fork River (UCFR) Basin as early as the 1860s. These operations expanded as the focus of mining shifted from gold to copper in the 1880s. Over the next century, an estimated 100 million tons of copper mine waste were deposited in the UCFR and the adjacent floodplain [Andrews, 1987]. Waste products from these mining operations contain high concentrations of metals that are known to be hazardous to fish [Wood, 2012]. These metals, especially copper, have been linked to increased mortality of adult and juvenile trout in the UCFR [Schreck et al., 2012; Mayfield, 2013; Richards et al., 2013].

Metals such as copper and zinc have been shown to enter fish tissues through multiple pathways including diet and the uptake of water through the gills [Marr et al., 1995a, 1995b; Woodward et al., 1995a]. Concentrations of these substances in fish tissues are a function of ambient metal concentration and duration of exposure to contaminated water [Marr et al. 1996; Gundogdu and Erdem, 2008]. Copper is transferred from the water into fish tissue though sodium (Na^+) and copper-specific uptake mechanisms [Wood, 2012]. Water-borne metals not only accumulate metals in fish tissue, but also can directly damage gill epithelium and inhibit olfaction [Wood, 2012]. Aquatic invertebrates are a large part of trout diets, and contaminants within these diet items are integrated into fish tissue when consumed. Several studies have demonstrated metal accumulation in fishes fed invertebrates from the UFCR [Farag et al, 1994; Woodward et al., 1995a; Louma et al., 2008]. Aquatic invertebrates typically represent the largest source by which copper enters fish in the Clark Fork River. Regardless of the pathway into fish, metal exposure causes a variety of negative effects. Potential effects include cell damage [Farag et al., 1994; Woodward et al., 1995a], reduced growth [Marr et al.1996], behavioral changes [Woodward et al., 1995b; Hansen et al., 1999], and mortality [Farag et al., 2003].

In addition to heavy metal contamination, high water temperatures are often cited as a factor that negatively affects fish populations in the UCFR Basin. Elevated water temperatures can cause stress and can worsen effects of other stressors and diseases [Wahli et al., 2002; Hari et al., 2006; Jonsson and Jonsson, 2009]. High water temperatures also increase susceptibility to metals exposure through increased respiration [Sorensen, 1991]. The upper thermal limit for Brown Trout is 19.0°C, above which growth rate approaches zero [Elliot, 1994]. During the summer months, temperatures routinely exceed 19°C in some reaches of the UCFR. For example, water temperatures in the Clark Fork River near Deer Lodge exceeded 20°C for 31-56 days annually between 2001 and 2004 [Naughton, 2015]. These high water temperatures may make trout in the UCFR more likely to succumb to toxic effects of heavy metal contamination.

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[34] Chapter 8 was prepared by Nathan Cook, Pat Saffel, Brad Liermann, Jason Lindstrom, and Trevor Selch of Montana Fish, Wildlife, and Parks with minor editing and formatting by RESPEC.

Effects on trout of various concentrations of water borne heavy metals have been well studied (e.g., Dixon and Sprague [1981]; Marr et al. [1995a]; Hansen et al. [2002]). However, metal concentrations and toxicities vary depending on flows and water chemistry, which makes getting an adequate representation of river contamination through water sampling difficult. Thus, using whole body metal tissue burdens have become an important tool in monitoring contamination and ongoing remediation in the UCFR. Other than a study conducted by Montana Fish, Wildlife and Parks (MFWP) in 2013 [Leon et al., 2014], no studies have related fish survival directly to the concentration of heavy metals within fish tissue. More understanding of the relationship between tissue burdens and fish survival is needed.

In 2014, MFWP received funding from Montana Department of Environmental Quality (MDEQ) to complete a caged fish study similar to those conducted by Leon et al. [2014] and Richards et al. [2013] and Schreck et al. [2012] as well as to collect fish population information on the mainstem Clark Fork River. The goals of this project are to document current levels of metals contamination in the Upper Clark Fork River, assess potential impacts these metals have on fishes, and collect baseline fish population monitoring data for future assessment of remediation efforts.

8.1.1 Objectives

1. Document status and trends of fish populations in the upper Clark Fork River.
2. Identify water quality factors affecting the growth, condition, and mortality of young trout.
3. Determine survival rates of age 0 Brown Trout in the upper Clark Fork River at nine sites (from Warm Springs Ponds to Bearmouth, Montana), two tributary streams, and one handling control site.
4. Draw comparisons between tissue burdens of: 1) tributary and mainstem sites, 2) sites upstream and downstream of the construction area in Warm Springs, Montana, and 3) fish collected in different months of the year.
5. Explore possible trends between data collected in previous years and the current year.
6. Provide information to remediation project managers that will aid in the planning and implementation of cleanup efforts.

8.2 METHODS

8.2.1 Population Monitoring

Mark-recapture population estimates were calculated for the following sample reaches of the Upper Clark Fork River in 2014: Bearmouth, Flint Creek Mouth, Phosphate, Williams-Tavenner, Below Sager Lane, and pH Shack. Field methods were conducted in the same manner as Lindstrom (2011). During the month of April, fish were collected with the use of a 14 ft long aluminum drift boat with a mounted electrofishing unit and two front boom anodes and one netter. The system was powered by a 5,000-watt generator and current was modified with a Coffelt VVP-15 or Smith-Root VVP-15B rectifying unit. Estimates were made using two mark passes and two recapture passes of which recapture passes were completed roughly one week later. All captured trout were identified to species, weighed (g) and measured (mm), and given a small fin clip unique to the sampling section and day. Resulting data were analyzed by sample reach and species and summarized by the population estimate (if available; standardized to number of fish per mile), 95% confidence interval with upper and lower bounds, capture efficiencies, number of fish handled, mean length, length range, and percent of species composition. Population estimates were generated using the Chapman modification [Chapman, 1951] of the Petersen method provided in MFWP's Fisheries Information System database. Estimates and capture efficiencies were calculated for trout species that had a minimum of 4 marked fish that were recaptured [B. Liermann, MFWP, personal communication, 2014). Due to low numbers and/or poor capture efficiency of smaller size classes, only estimates for fish greater than 175 mm (~7 in) in length were reported.

Estimates from previous years (2008-2013) included in this report are part of the long-term dataset required for this study. A Chapman modification of the Petersen method, as described above, was used to generate estimates in the Fisheries Information System for data from 2011-2014, two sample reaches from 2010 (Bearmouth and Flint Creek Mouth), and two sample reaches from 2009 (Bearmouth and Flint Creek Mouth). Estimates from 2008, remaining sample reaches in 2009 (pH Shack, Below Sager Lane, Williams-Tavenner, and Phosphate), and remaining sample reaches in 2010 (pH Shack, Below Sager Lane, Williams-Tavenner, and Phosphate) were generated using a Chapman estimator for the Peterson method provided in Montana Fish, Wildlife and Park's Fisheries Analysis Plus (FA+) software package, and are presented here as originally reported in Lindstrom [2011]. Both programs produce identical population estimates, but confidence intervals around the estimates are calculated differently, with FA+ assuming sample data is normally distributed and the Fisheries Information System assuming sample data is binomially distributed (see Ogle [2013] for details).

When sampling for these population estimates, only trout and char (members of Salmo, Oncorhynchus, and Salvelinus genera) are netted. Thus, other species present in the Clark Fork River are not captured, enumerated, weighed, or measured during population estimate sampling events. Because remediation in the Upper Clark Fork River has the potential to affect all fish species present, two reaches were sampled in which all fish were netted, weighed, and measured. These reaches were one mile long and were located upstream of the town of Deer Lodge ("Above Deer Lodge") and upstream from the Jens Road Bridge ("Jens"). One electrofishing pass was conducted at each sampling reach using methods similar to those listed above. Resulting data were analyzed by sample reach and species and summarized by catch per unit effort (fish per mile or river and fish per minute of electrofishing), mean length, length range, and percent of species composition.

8.2.2 Cage Construction

Thirty-six wooden cages were constructed in winter 2011, prior to the first year of the Upper Clark Fork caged fish study. The cages resembled those used to hold Rainbow Trout in the Middle Clark Fork River, but were 34% larger to accommodate the Brown Trout used in this study [Figure 8-1]. The internal volume of the cages was 0.75 ft^3 (actual volume of water available). Knotless nylon seine material (1/16 inch bar mesh) was used for the netting on the sides and bottom of the cages. Cages were also fitted with floats to provide buoyancy.

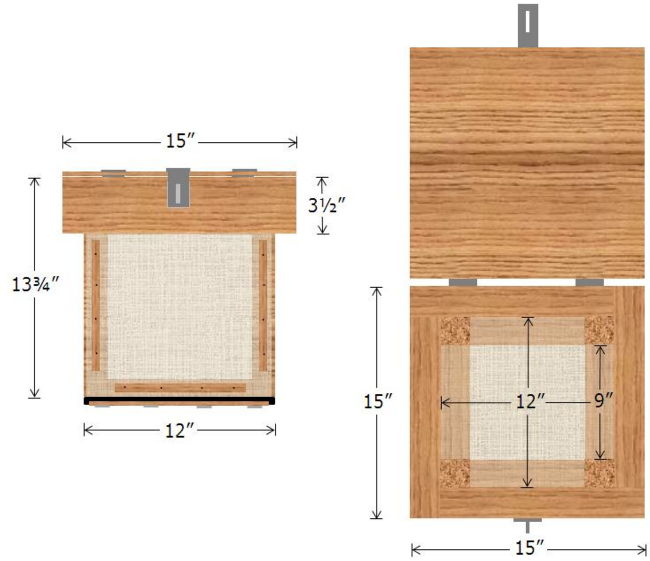


Figure 8-1. Dimensions of the cages constructed for the study.

8.2.3 Study Sites

Cages were deployed at twelve locations in the Upper Clark Fork River Drainage in late March 2014 [Figure 8-2]. Sites were numbered from 1 to 12 starting at the Pond 2 Outlet and progressing downstream in the drainage. Nine treatment sites were located at the following locations:

1. Pond 2 Outlet at Warm Springs, Montana (Pond 2)
2. Silver Bow Creek at Warm Springs, Montana (Silver Bow)
3. Warm Springs Creek near the mouth (Warm Springs)
4. Clark Fork River at Perkins Lane Bridge (Perkins Lane)
5. Clark Fork River at Galen Road Bridge (Galen)
6. Clark Fork River upstream of Racetrack Creek confluence (Racetrack)
7. Clark Fork River at Deer Lodge, Montana (Deer Lodge)
8. Clark Fork River upstream of the Little Blackfoot River (U/S Lil Black)
11. Clark Fork River near the Bearmouth FAS (Bearmouth)

Two control sites were located on tributaries:

9. Lower Little Blackfoot River (Lil Black)
10. Flint Creek (Flint)

One handling control site was located in a spring-fed channel.

12. Clinton, Montana (Spring)

The Clinton Spring handling control served as a reference to establish baseline mortality rates. The Clinton site was used to determine if handling during cage checks (e.g., cleaning and relocating) or stress from initial fish delivery to the cages negatively impacted survival, independent of water quality. All sites except Pond 2, Galen, Racetrack, and Spring were located near U.S. Geological Survey (USGS) gauging stations equipped to measure discharge four times per hour.

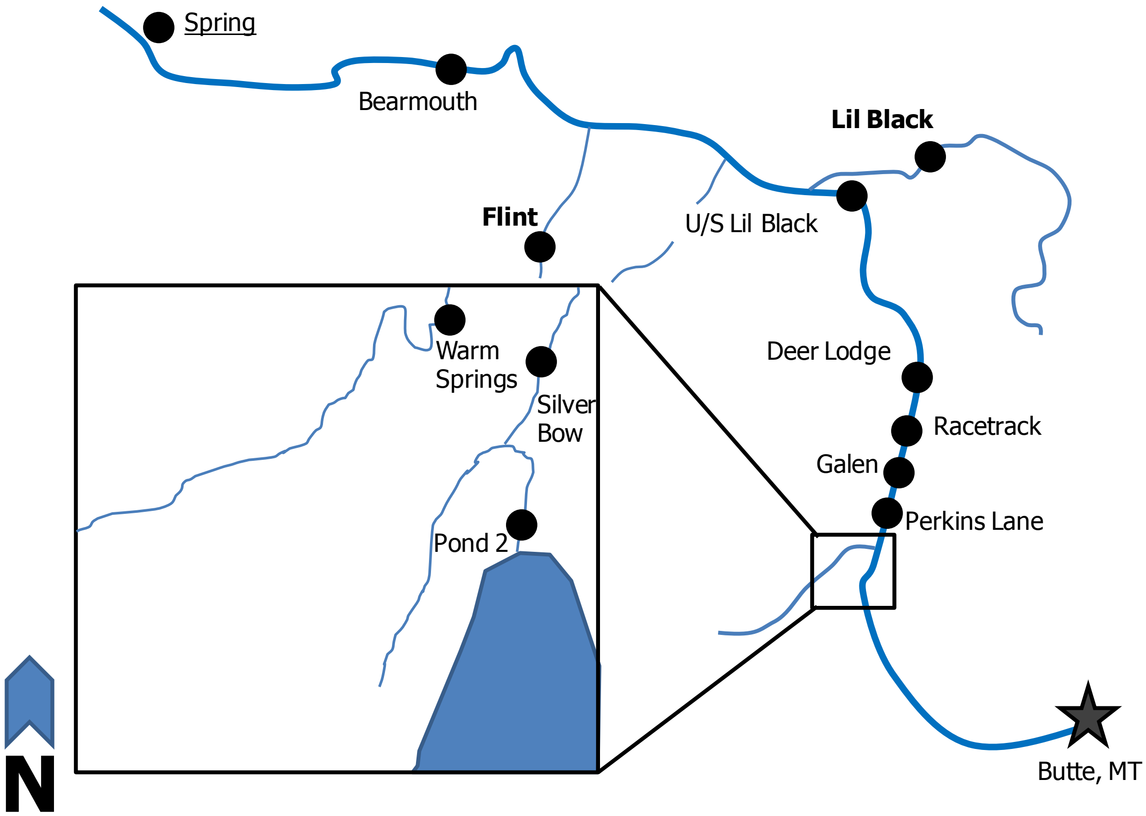


Figure 8-2. Distribution of the twelve study sites in the Upper Clark Fork River drainage. Tributary control sites are shown in bold and the handling control is underlined

8.2.4 Cage Deployment

Within each site exact locations of the cages were dependent on the availability of low velocity habitats with access to refuge during periods of high runoff. Cages were positioned in velocities less than 0.75 ft/s. Three cages were deployed at each site. Cages were secured with sections of reinforcing bar (rebar) driven into the substrate, as well as sash weights and tether lines [Figure 8-3]. The sash weights provided additional anchoring during rising water levels, and tether ropes insured the cages were not completely lost should a flood event occur. Temperature loggers (HOBO ® U22 Pro v2) were attached to the rebar securing the cages in the channel and the units were most often set 6-12 inches above the substrate. The loggers were programmed to take a measurement once every half hour.

Two cages served as treatment cages (i.e., one replicate) and the third held fish for replacement of individuals in the treatment cages and live fish collection. The study began with 25 Brown Trout per cage and these densities were maintained in the treatment cages as long as possible by replacing them with individuals from the replacement cage. However, high fish mortality during 2014 led to the third cage at most sites becoming empty of fish before the field season was completed. This required that fish from the treatment cages (cages one and two) be used for live fish collections and resulted in fewer than 25 fish in most treatment cages at most sites.

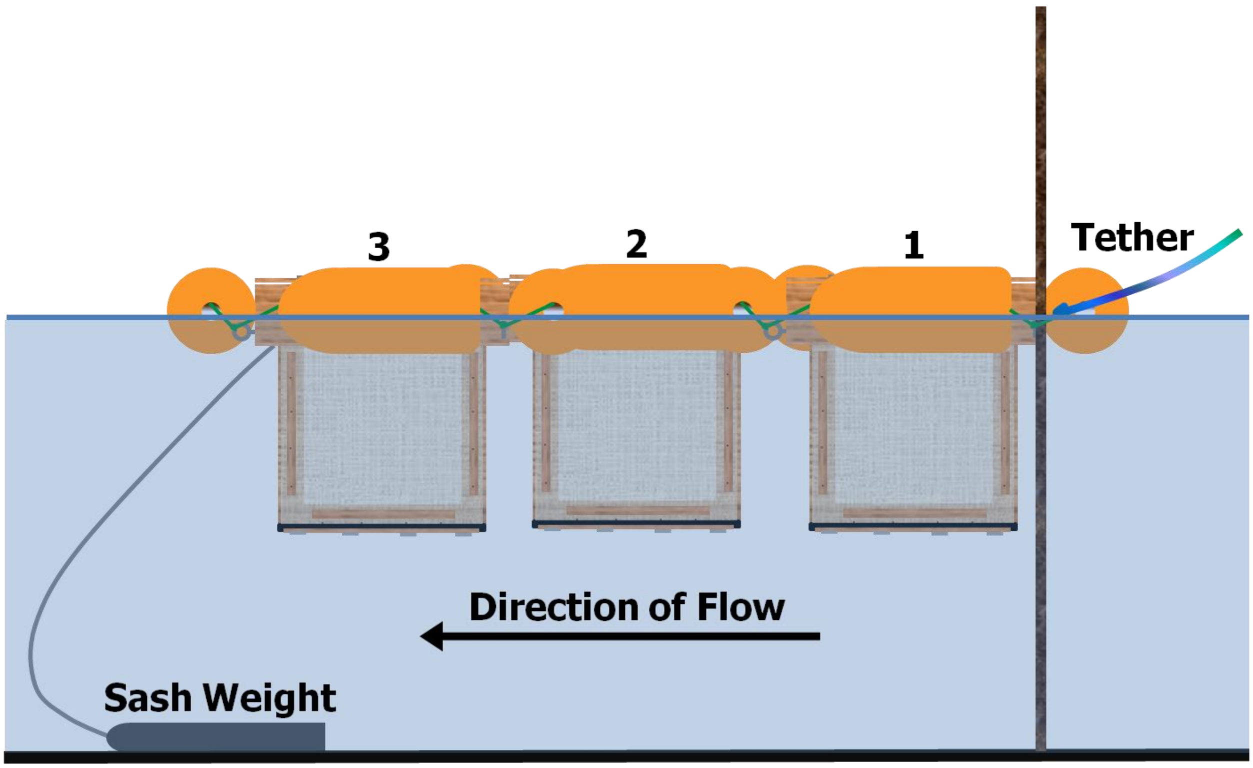


Figure 8-3. Representation of cage deployment (arrangement of cages differed by site, and cages often drifted together).

Brown trout were selected for this study given their dominance in the Upper Clark Fork River. Due to low densities of young trout in the upper river, fingerling study specimens were obtained from a state hatchery. In late March approximately 900 fingerling Brown Trout were obtained from Big Springs Hatchery in Lewistown, Montana. The trout were transported from the hatchery via an aerated cooler.

At each site trout were anesthetized with clove oil, measured for total length (mm), weighed to the nearest 0.1 g and divided into one of the three cages. Lengths of fingerlings ranged from 56-95 mm (mean = 75 mm) and weights ranged from 1.9-9.8 g (mean = 4.1 g). Fingerlings were feed-trained on pellet feed prior to leaving the hatchery. Prior to being anesthetized, fish were acclimated to the water temperature at each site with the addition of onsite water. Water temperature in the coolers was 6.7 °C before stocking. Water temperatures at the first six sites stocked ranged from 5.0 °C to 5.6 °C.

8.2.5 Mortality Monitoring

Beginning the last week of March, trout mortality was monitored twice per week. At each visit the trout in each cage were fed one tablespoon of Bio Oregon BioClark's Starter #1 pellet feed (pellet size 0.6 mm). It should be noted that both the size and brand of feed was different in 2014 than previous years. For example, in the first three months of the 2013 study, trout were fed 1.0 mm sinking feed (Silver Cup Extruded Salmon). During the remaining months of 2013, trout were fed slightly larger No. 3 sinking feed (Silver Cup Crumbled Salmon/Trout).

Cages were repositioned to seams and eddies as needed to maintain water velocities near 0.75 ft/s around the cages. Velocities around the cages were measured periodically to ensure they were near to 0.75 ft/s. The exterior of the cages were brushed clean as needed to provide for exchange of water between the cage and the site.

At each visit mortalities were removed from the cages and weighed and measured. In previous years, mortalities removed from the treatment cages (cages 1 and 2) were replaced with live individuals from the replacement cage (cage 3). However, the rapid depletion of fish caused by high mortality and live fish sampling meant that most sites ran out of replacement fish at some point during the 2014 study. As a result, most treatment cages could not be maintained at 25 fish. All mortalities were held in a freezer at the Region 2 MFWP headquarters after collection.

As in previous years of the caged fish study, the only time period considered for survival analysis was after an acclimation period and before August. The acclimation period included mortalities that were thought to be due to moving fish from a controlled hatchery environment to cages in more variable stream environments. In previous years the acclimation period was considered the first week of the study. In 2014 the acclimation period was extended to two weeks (ending April 10) because mortality tended to be high at most sites up to this date. August mortalities are typically excluded because of significant mortality at the Clinton Spring control site during this month. Survival within a cage was expressed as the number of fish remaining in the cage on July 31 divided by the net number of fish placed in the cage up to that time. Survival can be expressed as:

Survival = (Fish remaining) / (net number of fish added)

or

Survival = (Fish remaining) / (Initial 50 fish + replacements - removals)

Numbers of fish remaining and added were combined for cages one and two at each site to yield an overall survival estimate for that site. Survival at each of the nine mainstem treatment sites were compared to survival at the tributary sites (Lil Black and Flint) with chi-square tests incorporating Yate's correction for continuity [Yates, 1934]. This test is identical to a test of two proportions where fish remaining are "hits" or "successes" and total fish added are "events". Numbers of fish remaining and fish added at Lil Black and Flint were averaged for analysis and these averages were used as the control to which survival at each treatment site was compared. Alpha was set as 0.05 for statistical analyses.

8.2.6 Growth and Condition

Lengths and weights of half (450) of the total number (900) of specimens placed in cages were taken prior to stocking the fish cages. Initial lengths did not differ significantly among sites in 2014 ($F_{5,444}$ = 1.1230, *p-value*= 0.3473), so mean of all measured fish was used as the initial length to compare growth over the field season. At the completion of the field season a subsample of 30 fish (10 surviving fish randomly selected from cages 1, 2, and 3) were measured and weighed. If there were less than 30 surviving fish at the end of the field season all surviving fish at a site were sampled. Growth was calculated as the mean change in length at each site. Relative weight (Wr) was used as an index of conditions. Relative weight was calculated using the standard weight equation of Milewski and Brown [1994]. Although Milewski and Brown [1994] developed their standard weight equation for Brown Trout >140 mm, and fish in this caged fish study were all <140 mm, Wr still provides a meaningful way to compare body condition between live and dead fish, between sites, and over time. Mean Wr for live and dead fish each month at each site were depicted graphically. Only fish from cages one and two were used for growth and condition calculations.

Because most sites were depleted of replacement (cage 3) fish by the end of the field season, cages one and two contained different numbers of fish by the end of the season at all sites except Deer Lodge. There was some concern that growth and condition would be dependent on the density of fish in the cages. All cages received the same amount of food, so it is possible that competition would result in less food available for each individual in the cages with more fish. To test for density dependent growth and condition, two general linear models were performed. Mean increase in length and mean Wr for each cage (cages one and two at each site), were considered response variables in separate models. For each of these models, fish remaining in the cages (an index of fish density) was the continuous predictor variable and site was used as a categorical predictor variable. The site variable was necessary to account for significantly different growth and condition between sites (see Section 8.3).

Rates of feeding, digestion, absorption, excretion, and metabolism for fish are heavily dependent on water temperature [Elliot, 1994; Ojanguren et al., 2001]. As a result water temperature is a primary determinant of growth. Elliot et al. [1995] developed a model to quantify the effects of varying water temperatures on growth in weight of Brown Trout in a controlled laboratory setting. This model predicts increased growth at water temperatures near the optimum temperature of 13.1 °C and slower growth as temperatures approach the lower (3.6 °C) and upper (19.5 °C) thermal limits for Brown Trout growth. Specifically, the Elliot et al. [1995] model predicts the final weight of a fish of a given initial weight after a given length of time at a given temperature. Mean weight of the 450 Brown Trout weighed prior to cage stocking (4.2 g) was used for the initial weight in the model. Mean daily temperatures recorded by temperature loggers mounted to the fish cages at each site were input into the model to predict daily growth. These daily growth increments were summed for the entire time fish were in the cages (March 27 to the time the fish was sampled), resulting in a predicted final weight of individual fish at each site. The observed mean weight of surviving live fish at each site was plotted against weights predicted by the temperature based model. Differences in observed weights from those predicted by the temperature model could be evidence of influences of factors other than temperature (i.e., food availability, heavy metal toxicity) on growth.

8.2.7 Tissue Metals Burdens

Three live fish were collected from each site the last week of the month April-July for tissue burden analysis. Three fish from each site were also collected upon the completion of the field season on September 2, 2014. Five fish from the hatchery were sacrificed prior to stocking fish cages in order to determine baseline tissue metals burdens. In addition to live fish, a subsample of fish that died during the 2014 season was collected for tissue burden analysis. However, preliminary analyses indicated that tissue burdens of the dead fish were abnormally, perhaps artificially high. A previous study conducted on an estuarine species (Mummichog, Fundulus heteroclitus) suggested that fish corpse may gain copper and zinc after death, thus limiting the research value of whole body metal concentrations from dead fish [Eisler and Gardener, 1973]. Due to these concerns, only tissue burden data from fish collected alive will be discussed in the remainder of this report.

Fish samples were submitted to the Montana Department of Health and Human Services Environmental Laboratory in Helena for determination of whole-fish metal concentrations. Fish samples were blended to a powder to ensure homogeneity, and then the samples were weighed, dried, and reweighed to determine moisture content. The dried samples were then crushed and dissolved with nitric acid, diluted with deionized water, and analyzed for copper and zinc with inductively coupled plasma optical emission spectrometry (ICP-OES) using the U.S. Environmental Protection Agency (USEPA) Method 200.7 [USEPA, 2001]. All results were reported as µg/g dry weight.

Graphical comparisons were made between tissue metals burdens (copper and zinc) and each of the following variables: site, month, and site location (hatchery controls vs. tributary sites vs. mainstem sites, upstream construction vs. downstream construction.) For the purposes of these comparisons between tributary and mainstem sites, Clinton Spring was not included because it does not experience significant temperature and flow fluctuations typical of the flowing water sites. For each comparison, 95% confidence intervals were displayed and tissue burden vales were considered statistically different if their confidence intervals did not overlap. Statistical differences in tissue burdens between sites were also assessed using an analysis of variance (ANOVA). Pairwise T tests (with Bonferroni-adjusted *p-value*s to account for multiple comparisons) were then conduced to identify pairs of sites with statistically different tissue burdens.

To evaluate possible temporal trends in copper and zinc tissue burdens, annual mean tissue burdens at each site were compared. Mean tissue burdens from caged fish studies conducted 2011-2014 [Schreck et al., 2012; Richards et al, 2013; Leon et al., 2014] were compared graphically by site. Tissue samples from individual fish were combined into composite samples in 2011 and 2012 to reduce costs, which did not allow for measures of variation such as confidence intervals or ANOVA. Tissue burdens in 2013 and 2014 were analyzed for individual fish, so confidence intervals could be generated for these years. Average annual survival at each site used in caged fish studies 2011-2014 were also compared to evaluate potential temporal trends in fish survival. Annual survival comparisons could also reveal sites that have consistently low fish survival due to high metal tissue burdens, high water temperatures, or some combination of these factors.

8.2.8 Water Contaminants

MFWP collected water samples at each of the twelve sites on 4/21/14 and 7/28/14. An additional collection was done on 8/14/14 at the eight sites upstream of confluence of the Little Blackfoot River. One sample was collected at the U/S Lil Black site on 7/21/14 which was four days after a large mortality event at that site. Samples were collected using the techniques outlined by the MDEQ Field Procedures Manual for Water Quality Assessment Monitoring [MDEQ, 2012a]. All samples were delivered to Energy Laboratories Inc. in Helena, Montana and were analyzed for dissolved and total recoverable metals including copper, arsenic, lead, cadmium, and zinc, as well as calcium, magnesium, and total ammonia nitrogen (NH_3-N). RESPEC Consulting collected additional water data under a contract for MDEQ during the quarterly monitoring of the Clark Fork River Operating Unit (CFROU).

Performance standards have been identified for contaminants in the upper Clark Fork River [USEPA, 2004] and are defined as the more stringent of the freshwater aquatic life standards (ALS) published by the MDEQ [2012b]. Because the chronic ALS is the most stringent and since this study focuses on chronic effects, the chronic ALS was used to evaluate contaminant data. Freshwater ALS are a function of total water hardness and are evaluated on the basis of total recoverable metals concentrations [MDEQ, 2012b]. Chronic freshwater ALS values were obtained from the table of standards for Montana waters or calculated using the hardness relationships described by MDEQ [2012b]. The chronic ALS values were calculated as:

$$Chronic = exp.\{mc[ln(hardness)]+bc\}$$

where *mc* and *bc* = values listed by MDEQ [2012b]. Chronic ALS compliance ratios were calculated by dividing the measured contaminant values by the calculated chronic ALS values. Compliance ratio values <1 indicate contaminant levels below the chronic ALS, while values >1 indicate contaminant levels above the chronic ALS.

8.2.9 Discharge and Water Temperature

Discharge data presented in this report were obtained from USGS gauge stations recording measurements four times per hour. Estimates of mean daily discharge were downloaded from the USGS National Water Information System web interface. It is important to note that not all estimates presented in this report have been reviewed and approved for publication. No station existed at the Pond 2, Galen, Racetrack, and Spring sites. Maximum daily water temperatures were obtained for each site with water temperature data loggers mounted to fish cages described above.

8.2.10 Water Quality

Water quality parameters were recorded in the Clark Fork River at five sites in 2014 with continuously recording multiparameter water quality probes (Hydrolab ® MS5). Cross referencing of Hydrolab data was achieved by sampling intermittently at the nine mainstem and three control sites using a handheld multiprobe (YSI ® 556 MPS). Hydrolab and YSI probes were calibrated periodically during the field season. Probes were deployed at Pond 2, Silver Bow, Galen, Racetrack, and U/S Lil Black in 2014. Water quality parameters recorded include temperature, pH, specific conductivity, and luminescent dissolved oxygen (LDO) at all sites, with the addition of total ammonia (NH_4 + NH_3) at Pond 2 and Silver Bow. Toxicity of total ammonia is dependent on other water parameters including water temperature and pH [Emerson et al., 1975; MDEQ, 2012b]. The increased toxicity is due to the conversion of the generally inert form (NH_4) to the highly toxic form (NH_3) through the process of de-ionization [Barton, 1996]. Acute freshwater ammonia ALS values were calculated as:

$$Acute = [0.275/(1+10^{7.204\text{-}pH})) + (39.0/(1+10^{7.204\text{-}pH})]$$

and the chronic ALS were calculated as:

$$Chronic = [0.0577/(1+10^{7.688\text{-}pH}) + 2.487/(1+10^{pH4\text{-}7.688})] \ x \ MIN(2.85, 1.45 \ x \ 10^{0.028 \ x \ (25\text{-}T)})$$

where T = temperature (°C). Ammonia and ALS value were then plotted graphically to determine if and when exceedance events occurred.

8.3 RESULTS

8.3.1 Trout Population Monitoring

Figure 8-4 displays all Brown Trout population estimates by sample reach from 2008-2014, including population estimates reported in Lindstrom [2011]. Population estimates from 2008-2010 for the Below Sager Lane, Williams-Tavenner, and Phosphate electrofishing sections from Lindstrom [2011] are included in Appendix K. The pH shack Section had the highest Brown Trout population estimate in 2014 with 1,177 fish/mile. Conversely, the Bearmouth Section had the lowest Brown Trout population estimate, with 57 fish/mile in 2014. Flint Creek Mouth, Below Sager Lane, Williams-Tavenner, and Phosphate sections had 2014 Brown Trout population estimates of 199, 594, 618, and 596 fish/mile respectively.

Across all years that Brown Trout population estimates were available, Bearmouth consistently had the lowest numbers, while pH Shack had the highest numbers [Figure 8-5]. Estimates at Flint Creek Mouth tended to be relatively low while Phosphate, Williams-Tavenner, and Below Sager Lane tended to have intermediate Brown Trout numbers. At most sections, Rainbow or Cutthroat trout recaptures were too low to generate population estimates.

Generally speaking, the Bearmouth section tends to have higher numbers of Cutthroat and Rainbow trout than other reaches [Table 8-1 through Table 8-6].

At the two sampling sections where all fish species were netted, a total of eight species were captured including Brown Trout, Longnose Dace (Rhinichthys cataractae), Longnose Sucker (Catostomus catostomus), Largescale Sucker (Catostomus macrocheilus), Mountain Whitefish (Prosopium williamsoni), Redside Shiner (Richardsonius balteatus), Slimy Sculpin (Cottus cognatus), and Westslope Cutthroat Trout [Table 8-7; Table 8-8]. Mountain Whitefish were the most commonly captured species at both sections. Brown Trout were the second most common species found at the Jens section whereas Largescale Sucker were the second most common species captured at the Above Deer Lodge section.

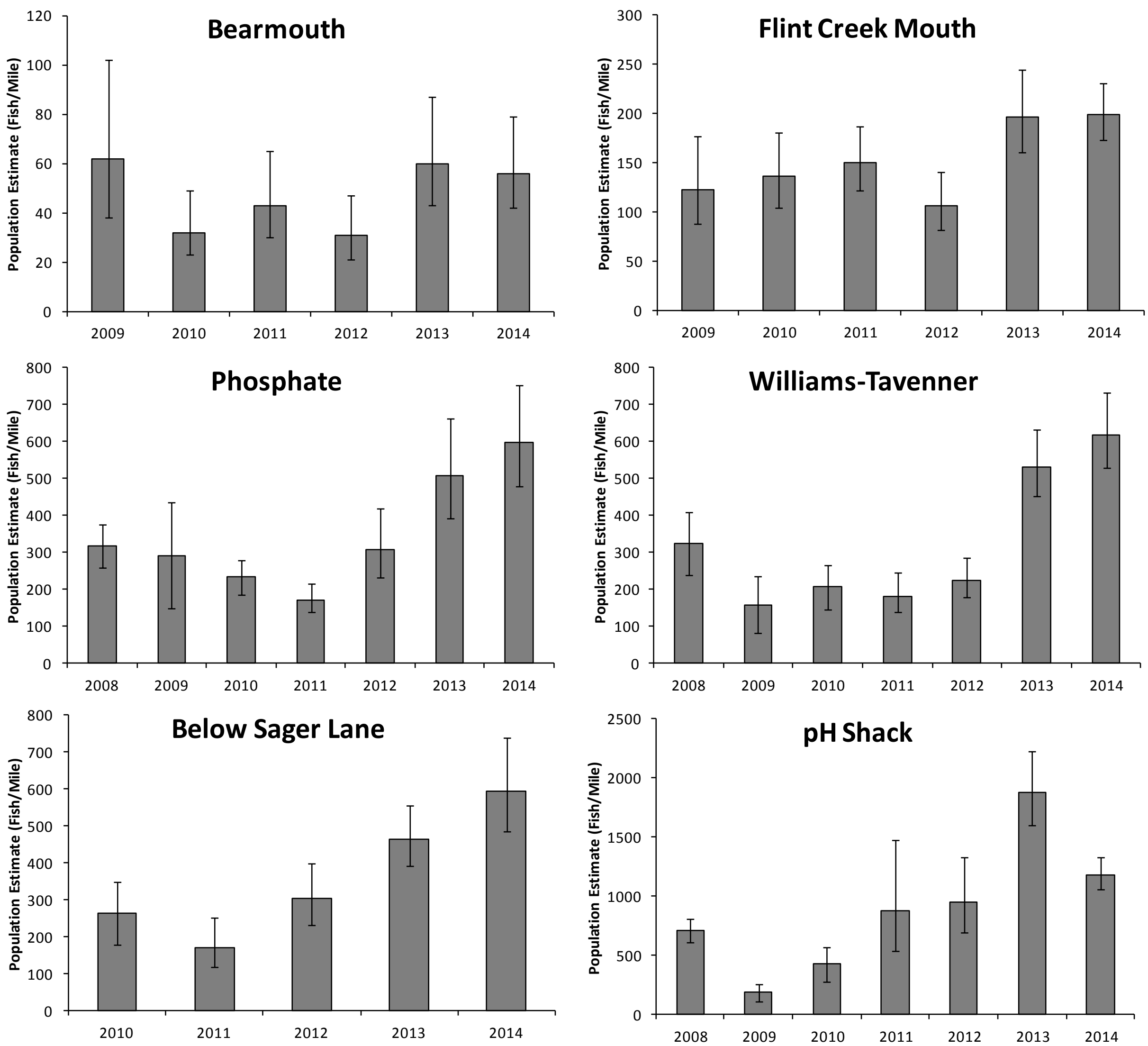


Figure 8-4. Clark Fork River Brown Trout population estimates from 2008-2014 by sample reach. Sample reaches are displayed downstream to upstream, left to right then top to bottom. Please note that x-axis and y-axis values are not the same for every sample reach.

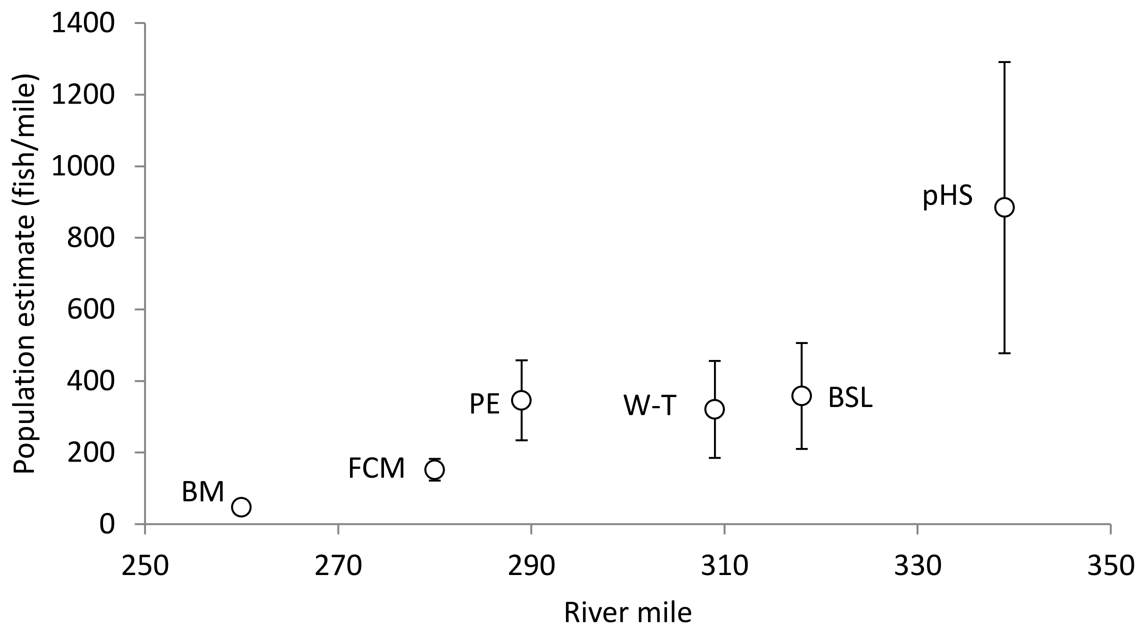


Figure 8-5. Average Brown Trout population estimates and 95% confidence intervals for the six monitoring sections in the upper Clark Fork River by river mile. All years of available estimates were averaged for each section. Number of years with estimates varied among (see Figure 8-4 for years averaged for each). Station abbreviations are Bearmouth (BM), Flint Creek Mouth (FCM), Phosphate (PE), Williams-Tavenner (W-T), Below Sager Lane (BSL), pH Shack (pHS).

Table 8-1. Electrofishing data collected on the Upper Clark Fork River at the pH Shack Section from 2011-2014. Population estimates and capture efficiencies are for trout greater than 175 mm (~7") in total length. Numbers following the population estimate (in parentheses) represent the 95 % confidence interval. Cutt x Rbow represents a phenotypic hybrid between a Cutthroat and Rainbow trout.

Year	Trout Species	Population Estimate (fish/mile)	Capture Efficiency (%)	# Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2011	Brown	878 (531-1476)	13	265	311	89-498	98
	Rainbow	-	-	2	531	472-590	1
	Cutthroat	-	-	3	350	292-424	1
	Cutt x Rbow	-	-	1	423	-	<1
2012	Brown	943 (686-1322)	17	403	293	105-473	98
	Rainbow	-	-	7	369	256-540	2
	Cutthroat	-	-	2	306	292-319	<1
	Cutt x Rbow	-	-	1	323	-	<1
2013	Brown	1,878 (1,595-2,223)	19	1,056	296	156-630	98
	Rainbow	-	-	13	447	314-610	1
	Cutthroat	-	-	6	327	271-352	1
	Cutt x Rbow	-	-	1	282	-	<1
2014	Brown	1,177 (1054-1322)	38	1,018	323	160-518	99
	Rainbow	-	-	12	367	240-541	1

Table 8-2. Electrofishing data collected on the Upper Clark Fork River at the Below Sager Lane Section from 2011-2014. Population estimates and capture efficiencies are for Brown Trout greater than 175 mm (~7") in total length. Numbers following the population estimate (in parentheses) represent the 95 % confidence interval.

Year	Trout Species	Population Estimate (fish/mile)	Capture Efficiency (%)	# Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2011	Brown	170 (119-251)	20	205	313	103-495	98
	Cutthroat	-	-	4	335	280-392	2
	Brook	-	-	1	202	-	<1
2012	Brown	302 (232-397)	17	533	240	90-595	96
	Cutthroat	-	-	6	314	277-347	1
	Brook	-	-	15	216	134-273	3
2013	Brown	462 (390-553)	25	655	308	139-497	99
	Rainbow	-	-	1	324	-	<1
	Cutthroat	-	-	2	323	308-337	<1
	Brook	-	-	6	245	194-275	1
2014	Brown	594 (484-737)	19	666	350	122-532	99
	Rainbow	-	-	1	197	-	<1
	Cutthroat	-	-	2	321	300-342	<1
	Brook	-	-	2	297	245-350	<1

Table 8-3. Electrofishing data collected on the Upper Clark Fork River at the Williams-Tavenner Section from 2011-2014. Population estimates and capture efficiencies are for Brown Trout greater than 175 mm (~7") in total length. Numbers following the population estimate (in parentheses) represent the 95 % confidence interval.

Year	Trout Species	Population Estimate (fish/mile)	Capture Efficiency (%)	# Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2011	Brown	182 (140-244)	26	247	311	108-514	90
	Cutthroat	15 (9-28)	29	24	275	213-328	9
	Brook	-	-	2	203	196-209	1
2012	Brown	224 (180-285)	29	351	266	109-497	88
	Cutthroat	23 (18-34)	46	48	301	170-373	12
	Brook	-	-	1	221	-	<1
2013	Brown	532 (453-632)	26	636	317	129-507	93
	Cutthroat	33 (22-56)	32	47	295	193-383	7
	Brook	-	-	1	320	-	<1
2014	Brown	618 (528-731)	25	712	368	138-535	95
	Cutthroat	-	-	34	351	260-443	4
	Brook	-	-	2	292	272-312	<1

Table 8-4. Electrofishing data collected on the Upper Clark Fork River at the Phosphate Section from 2011-2014. Population estimates and capture efficiencies are for trout greater than 175 mm (~7") in total length. Numbers following the population estimate (in parentheses) represent the 95 % confidence interval. Cutt x Rbow represents a phenotypic hybrid between a Cutthroat and Rainbow trout.

Year	Trout Species	Population Estimate (fish/mile)	Capture Efficiency (%)	# Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2011	Brown	171 (140-215)	41	239	300	104-474	97
	Cutthroat	-	-	7	294	207-378	3
	Cutt x Rbow	-	-	1	367	-	<1
2012	Brown	308 (231-419)	21	282	270	111-464	92
	Rainbow	-	-	2	423	215-630	1
	Cutthroat	-	-	23	267	187-364	7
	Brook	-	-	1	305	-	<1
2013	Brown	506 (393-664)	22	387	301	120-461	96
	Cutthroat	-	-	14	305	255-357	3
	Cutt x Rbow	-	-	1	389	-	<1
2014	Brown	596 (479-751)	22	490	328	124-452	98
	Cutthroat	-	-	10	354	289-416	2
	Cutt x Rbow	-	-	1	415	-	<1

Table 8-5. Electrofishing data collected on the Upper Clark Fork River at the Flint Creek Mouth Section from 2009-2014. Population estimates and capture efficiencies are for trout greater than 175 mm (~7") in total length. Numbers following the population estimate (in parentheses) represent the 95 % confidence interval. Cutt x Rbow represents a phenotypic hybrid between a Cutthroat and Rainbow trout. Brook x Bull represents a phenotypic hybrid between an eastern Brook and Bull trout.

Year	Trout Species	Population Estimate (fish/mile)	Capture Efficiency (%)	# Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2009*	Brown	123 (88-177)	18	273	369	97-550	95
2010	Brown	136 (105-181)	20	377	345	115-535	94
	Rainbow	-	-	4	389	326-421	1
	Cutthroat	-	-	16	284	227-355	4
	Cutt x Rbow	-	-	4	332	305-352	1
2011	Brown	150 (122-187)	25	481	311	110-509	89
	Rainbow	-	-	3	441	425-468	1
	Cutthroat	14 (8-24)	20	54	275	195-390	10
	Brook	-	-	1	287	-	<1
	Brook x Bull	-	-	1	393	-	<1
2012	Brown	107 (82-141)	19	334	293	124-515	87
	Rainbow	-	-	6	352	232-468	2
	Cutthroat	-	-	42	289	186-445	11
	Bull	-	-	2	374	373-375	1
2013	Brown	197 (161-245)	20	572	315	195-502	96
	Cutthroat	6 (3-11)	21	25	326	220-378	4
	Bull	-	-	1	273	-	<1
2014	Brown	199 (173-231)	26	778	357	185-519	96
	Rainbow	-	-	2	294	250-374	<1
	Cutthroat	4 (2-7)	36	25	351	202-451	3
	Bull	-	-	2	270	252-288	<1

* In 2009 entire Upper Clark Fork River was sampled and as a result the Flint Creek Mouth Section is roughly half a mile longer than in other years.

Table 8-6. Electrofishing data collected on the Upper Clark Fork River at the Bearmouth Section from 2009-2014. Population estimates and capture efficiencies are for trout greater than 175 mm (~7”) in total length. Numbers following the population estimate (in parentheses) represent the 95 % confidence interval. Cutt x Rbow represents a phenotypic hybrid between a Cutthroat and Rainbow trout.

Year	Trout Species	Population Estimate (fish/mile)	Capture Efficiency (%)	# Fish Handled	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2009*	Brown	62 (38-102)	13	134	358	119-528	84
	Cutthroat	7 (4-14)	27	26	314	152-410	16
2010	Brown	32 (23-49)	35	106	362	157-525	68
	Rainbow	-	-	13	345	242-442	8
	Cutthroat	6 (4-11)	42	27	308	100-400	17
	Bull	-	-	2	321	297-345	1
	Cutt x Rbow	-	-	8	371	320-458	5
2011	Brown	43 (30-65)	27	123	342	152-523	59
	Rainbow	7 (4-13)	38	28	342	152-479	14
	Cutthroat	13 (9-20)	38	54	309	182-414	26
	Bull	-	-	2	424	362-486	1
2012	Brown	31 (21-47)	29	95	326	177-502	32
	Rainbow	21 (14-34)	31	69	285	178-467	23
	Cutthroat	41 (30-59)	27	134	290	168-434	45
	Bull	-	-	2	266	260-272	<1
2013	Brown	60 (43-87)	21	169	339	191-476	48
	Rainbow	19 (11-35)	24	49	344	230-455	14
	Cutthroat	45 (32-66)	27	134	321	175-426	38
	Bull	-	-	3	379	337-400	<1
2014	Brown	56 (42-79)	24	173	367	183-534	55
	Rainbow	28 (16-49)	21	68	331	188-493	21
	Cutthroat	19 (14-28)	36	74	355	180-452	25

* In 2009 entire Upper Clark Fork River was sampled and as a result the Flint Creek Mouth Section is roughly half a mile longer than in other years.

Table 8-7. Electrofishing data collected on the Upper Clark Fork River at the Jens CPUE section.

Year	Trout Species	CPUE (fish/mile)	CPUE (fish/min)	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2014	Brown Trout	58	1.98	343	165-460	29
	Cutthroat Trout	1	0.03	405	-	<1
	Mountain Whitefish	129	4.41	338	228-445	64
	Largescale Sucker	10	0.34	507	440-578	5
	Sculpin	1	0.03	74	-	<1
	Redside Shiner	1	0.03	87	-	<1
	Longnose Dace	1	0.03	97	-	<1

Table 8-8. Electrofishing data collected on the Upper Clark Fork River at the Above Deer Lodge CPUE section.

Year	Trout Species	CPUE (fish/mile)	CPUE (fish/min)	Mean Length (mm)	Length Range (mm)	Species Composition (%)
2014	Brown Trout	36	1.40	349	261-440	14
	Mountain Whitefish	181	7.03	323	142-463	70
	Largescale Sucker	39	1.52	505	-	15
	Longnose Sucker	1	0.04	116	-	<1

8.3.2 Cage Fish Mortality, Discharge, and Water Temperature

Figure 8-6 through Figure 8-17 depict total mortalities in cages one and two combined, maximum daily water temperatures, and mean daily discharges at cage sites in 2014. The solid red horizontal line in each figure represents the upper critical temperature threshold for Brown Trout of 19.0 °C [Elliot, 1994]. At temperatures above this critical threshold, significant disturbances to normal Brown Trout behavior may occur, including cessation of feeding and growth and ultimately death [Elliot, 1994]. The dashed red horizontal line in each figure represents the upper incipient lethal temperature for Brown Trout of 24.7 °C, above which thermal stress is lethal with mortality being a function of exposure time [Elliot, 1994].

In 2014, most cage sites displayed bimodal mortality with some mortality occurring early in the study season on the ascending limb of the hydrograph, and some mortality on the descending limb as water temperatures approached and/or exceeded 19 °C. Early season mortality was generally high until early- to mid- April, although sites such as Pond 2, Silver Bow, Warm Springs, Little Blackfoot, and Flint had significant early season mortality that continued until May. Mortality at most sites was relatively low during May and early June then increased as flows decreased and temperatures increased during the summer. Site specific descriptions of discharge, water temperatures, and timing of mortalities at each site are outlined below in order from upstream to downstream.

Of the mainstem sites, U/S Lil Black had the lowest survival at 44% and the Deer Lodge site had the highest survival at 90% [Table 8-9]. Survival at the Flint Creek tributary site was 72% and 79% at the Lil Black tributary site. The average survival estimate at the two tributary sites (0.76) was compared to each mainstem site with chi-square tests. Results of these tests revealed that U/S Lil Black, Silver Bow, and Pond 2 had significantly lower survival than the tributary sites [Table 8-9]. No sites had survival that was significantly higher than tributaries in 2014. From a spatial perspective, survival was ≥ 85% at mainstem sites from Perkins Lane to Deer Lodge [Figure 8-18]. The three most upstream treatment sites (Pond 2, Silver Bow, and Warm Springs) had survival ≤ 60%.

8.3.2.1 Pond 2

There are no discharge data available for Pond 2 in 2014 because there is not a USGS station present at this site. Peak maximum daily water temperature at Pond 2 in 2014 was 24.1 °C on July 14 [Figure 8-7]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 63 days and never exceeded the upper incipient lethal temperature for Brown Trout of 24.7 °C [Figure 8-6]. Pond 2 experienced lower survival than tributary sites [Table 8-9], with most mortality occurring in April. Another peak in mortality occurred at this site in early July after temperatures exceeded 19.0 °C [Figure 8-7].

8.3.2.2 Silver Bow

Peak mean daily discharge at Silver Bow in 2014 was 331 ft^3/s on May 26. In 2014 peak maximum daily water temperature at Silver Bow was 23.6 °C on August 11 [Figure 8-8]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 52 days and never exceeded the upper incipient lethal temperature for Brown Trout of 24.7 °C [Figure 8-8]. Silver Bow experienced significantly lower survival than tributary sites [Table 8-9], with most mortality occurring early and late in the study season.

8.3.2.3 Warm Springs

Peak mean daily discharge at Warm Springs in 2014 was 244 ft^3/s on May 29. In 2014 peak maximum daily water temperature at Warm Springs was 19.1 °C on August 11 [Figure 8-9]. August 11 was the only day maximum daily water temperature exceeded 19.0 °C. The upper incipient lethal temperature for Brown Trout of 24.7 °C was never exceeded [Figure 8-9]. Warm Springs experienced significantly lower survival than the tributary sites [Table 8-9], with most mortality occurring early in the study season before runoff, as well as on the descending limb of the hydrograph water temperatures approached 19.0 °C [Figure 8-9].

8.3.2.4 Perkins Lane

Peak mean daily discharge at Perkins Lane in 2014 was 526 ft^3/s on May 27. In 2014 peak maximum daily water temperature at Perkins Lane was 21.9 °C on August 1 [Figure 8-10]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 49 days and the upper incipient lethal temperature for Brown Trout of 24.7 °C was never exceeded [Figure 8-10]. Survival rate of fish at Perkins Lane was not significantly different from tributaries [Table 8-9]. Most mortalities at this site occurred on the ascending and descending limbs of the hydrographs [Figure 8-10].

8.3.2.5 Galen

There are no discharge data available for Galen in 2014 because there is not a USGS station present at this site. In 2014 peak maximum daily water temperature at Galen Right was 21.9 °C on August 1 [Figure 8-11]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 45 days and the upper incipient lethal temperature for Brown Trout of 24.7 °C was never exceeded [Figure 8-11]. Survival rate of fish at Galen was not significantly different from tributaries [Table 8-9]. Most mortalities at this site occurred during the time period when water temperatures were above 19.0 °C, although four mortalities did occur earlier in the season [Figure 8-11].

8.3.2.6 Racetrack

There are no discharge data available for Racetrack in 2014 because there is not a USGS station present at this site. In 2014 peak maximum daily water temperature at Racetrack was 22.7 °C on August 1 [Figure 8-12]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 44 days and never exceeded 24.7 °C [Figure 8-12]. Survival rate of fish at Racetrack was not significantly different from tributaries [Table 8-9]. Nine mortalities (69%) at this site occurred during the time period when water temperatures were above 19.0 °C, although four mortalities also occurred in April and May [Figure 8-12].

8.3.2.7 Deer Lodge

Peak mean daily discharge at Deer Lodge in 2014 was 748 ft^3/s on June 28. In 2014 peak maximum daily water temperature at Deer Lodge was 24.3 °C on July 13 [Figure 8-13]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 50 days and never exceeded 24.7 °C [Figure 8-13]. Survival rate of fish at Deer Lodge was not significantly different from tributaries [Table 8-9]. Mortality at this site exhibited a bimodal pattern, occurring in the first few weeks of study season on, as well as on the descending limb of the hydrograph as water temperatures began to exceed 19.0 °C [Figure 8-13].

8.3.2.8 Upstream of the Little Blackfoot River

Peak mean daily discharge at U/S Lil Black in 2014 was 978 ft^3/s on June 28. In 2014 peak maximum daily water temperature at U/S Lil Black was 25.1 °C on July 13 [Figure 8-14]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 52 days and exceeded the upper incipient lethal temperature for Brown Trout of 24.7 °C for one day [Figure 8-14]. Fish at the U/S Lil Black site experienced significantly lower survival than the tributary sites [Table 8-9], with 28 (93%) of the mortalities occurring when water temperatures were above 19.0 °C [Figure 8-14].

8.3.2.9 Lower Little Blackfoot River (Tributary)

Peak mean daily discharge at Lil Black in 2014 was 1010 ft^3/s on June 5. In 2014 peak maximum daily water temperature at Lil Black was 21.4 °C on July 12 [Figure 8-15]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 36 days and never exceeded 24.7 °C [Figure 8-15]. Nineteen (90%) of the 21 mortalities occurred during the month of April, with the other two mortalities occurring when water temperatures were above 19.0 °C [Figure 8-15].

8.3.2.10 Flint Creek (Tributary)

Peak mean daily discharge at Flint in 2014 was 282 ft^3/s on April 9. In 2014 peak maximum daily water temperature at Flint was 19.6 °C on July 13 and August 14 [Figure 8-16]. Maximum daily water temperature in 2014 exceeded 19.0 °C for 8 days and never exceeded 24.7 °C [Figure 8-16]. Twenty-six (90%) of the mortalities at this site occurred between the beginning of the study and May 12 [Figure 8-16].

8.3.2.11 Bearmouth

Peak mean daily discharge at Bearmouth was 1,080 ft^3/s on May 31. In 2014 peak maximum water temperature was 23.8 °C on July 13. Maximum daily water temperature in 2014 exceeded 19.0 °C for 52 days and never exceeded 24.7 °C [Figure 8-17]. Survival rate of fish at Bearmouth was not significantly different from tributaries [Table 8-9]. The number of mortalities at this site generally increased after flows went down and water temperatures exceeded 19 °C [Figure 8-17].

8.3.2.12 Clinton Spring (Handling Control)

There are no discharge data available for Clinton Spring because there is not a USGS station present at this site. In 2014 peak maximum daily water temperature at Clinton Spring was 15.9 °C on August 18 [Figure 8-18]. Maximum daily water temperature never exceeded 19.0 °C or 24.7 °C in 2014 [Figure 8-18]. A relatively large mortality event occurred at this site between August 14-18, when nine fish died. Other mortalities occurred near the beginning of the study and one mortality occurred in June.

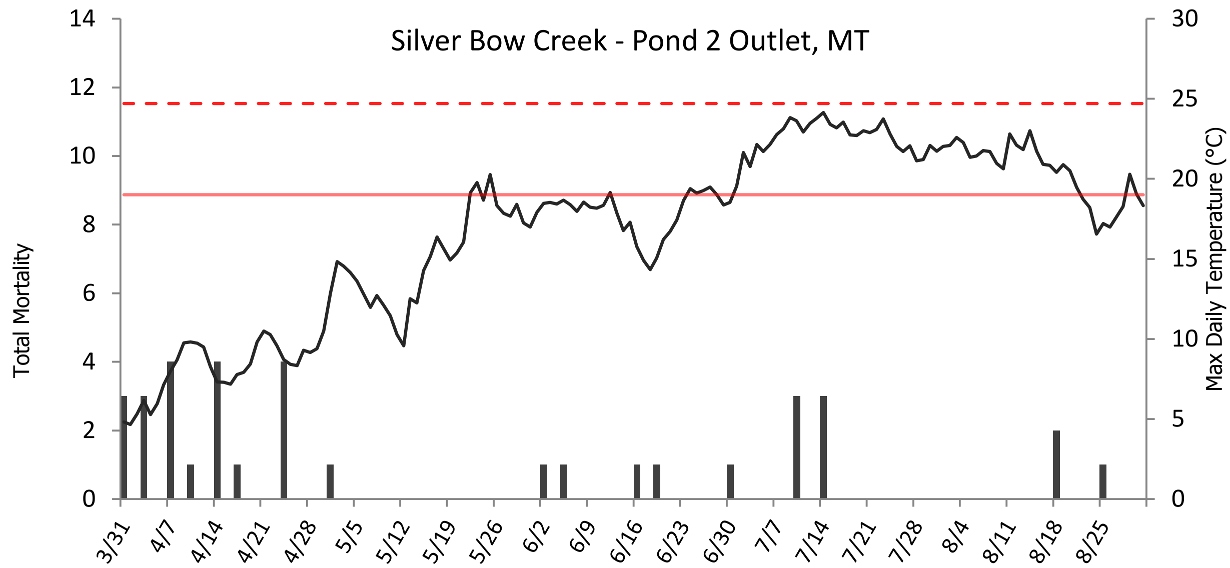


Figure 8-6. Total mortalities between cages one and two combined (gray bars) and maximum daily water temperature (black line) for 2014 in Silver Bow Creek at the Pond 2 outlet site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

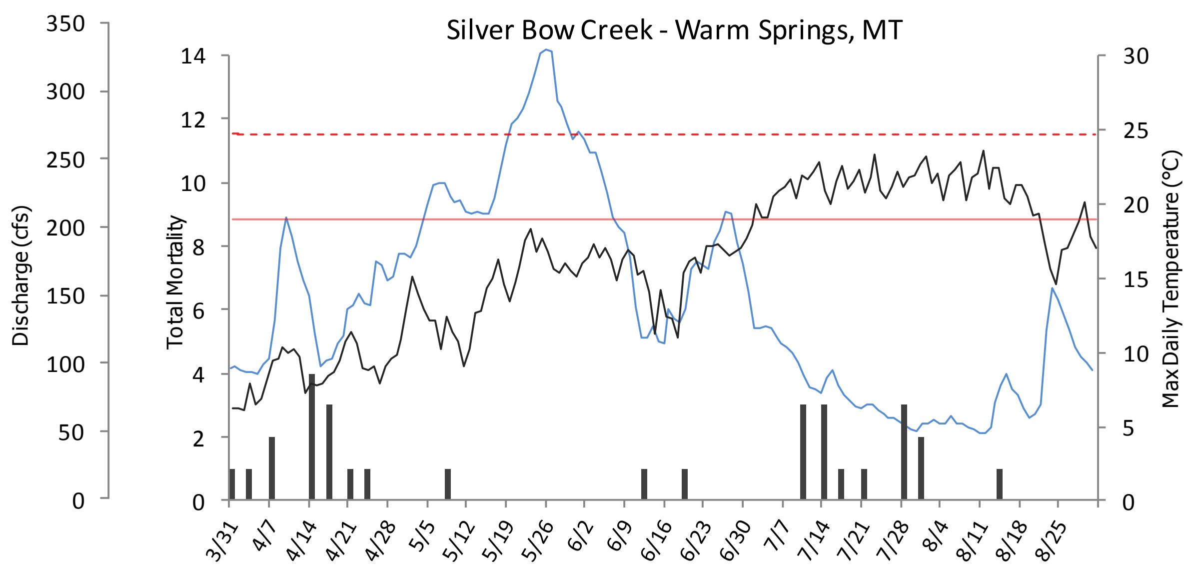


Figure 8-7. Total mortalities between cages one and two combined (gray bars) and maximum daily water temperature (black line), and mean daily discharge (blue line) for 2014 in Silver Bow Creek, Warm Springs, MT. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

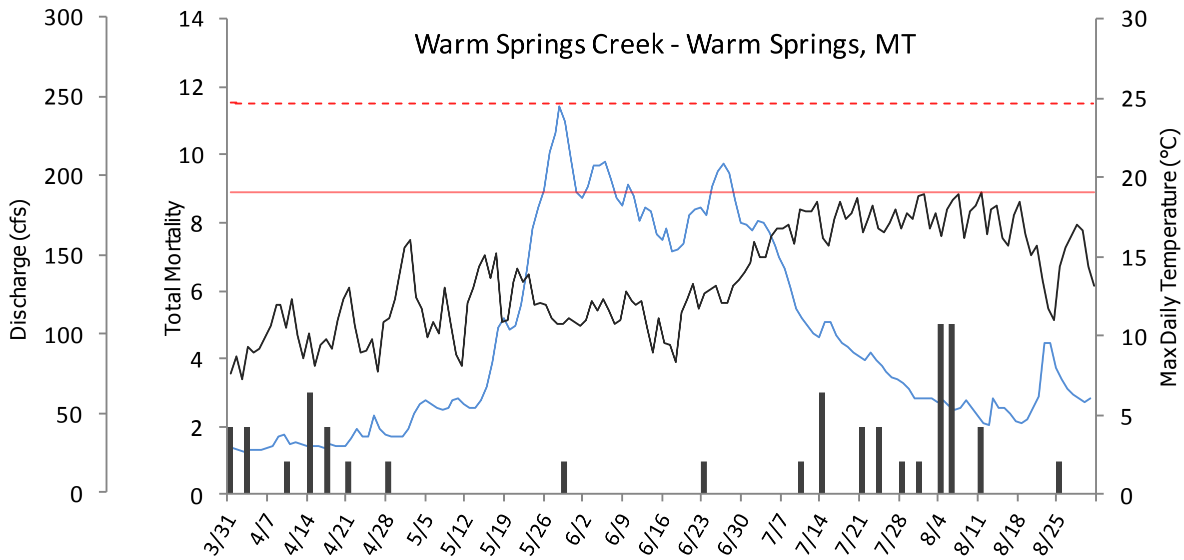


Figure 8-8. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line), and mean daily discharge (blue line) for 2014 in Warm Springs Creek at Warm Springs, MT. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

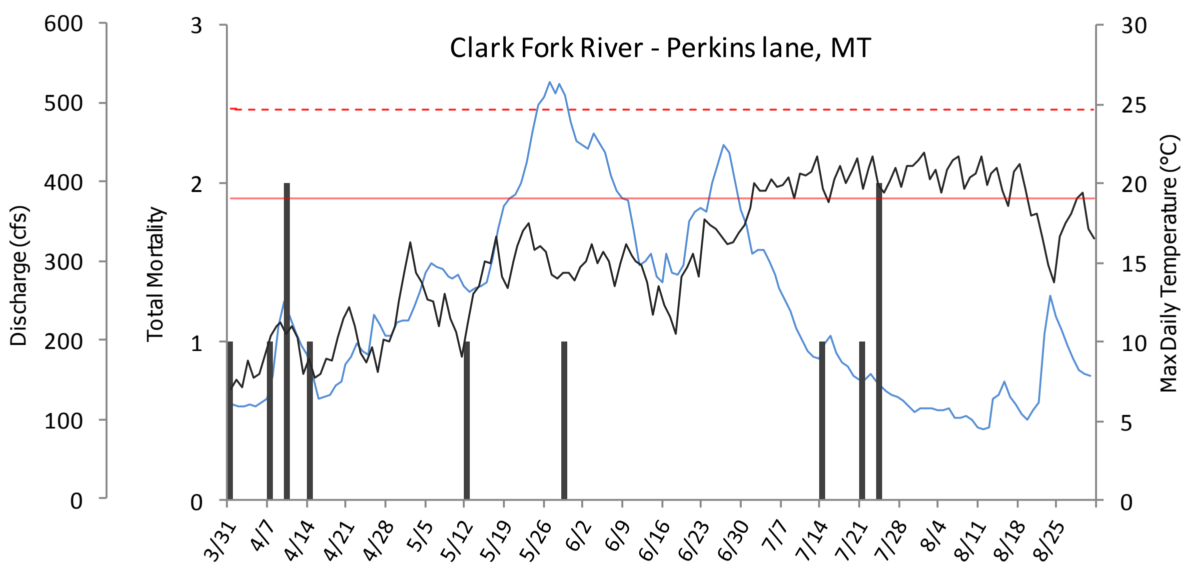


Figure 8-9. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line), and mean daily discharge (blue line) for 2014 in the Clark Fork River at the Perkins Lane site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

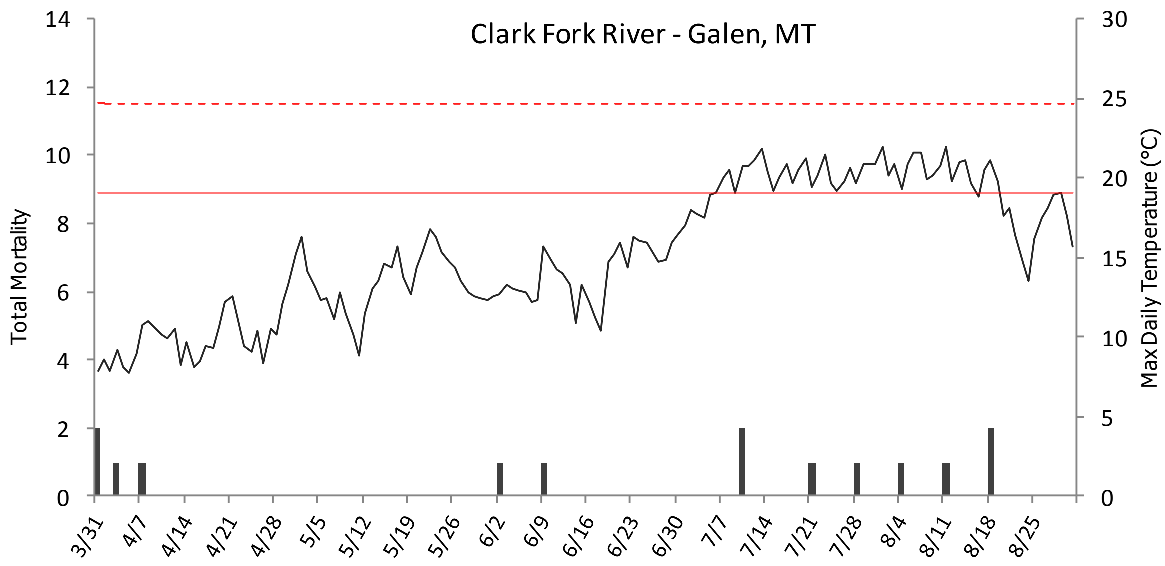


Figure 8-10. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line) in the Clark Fork River at the Galen site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

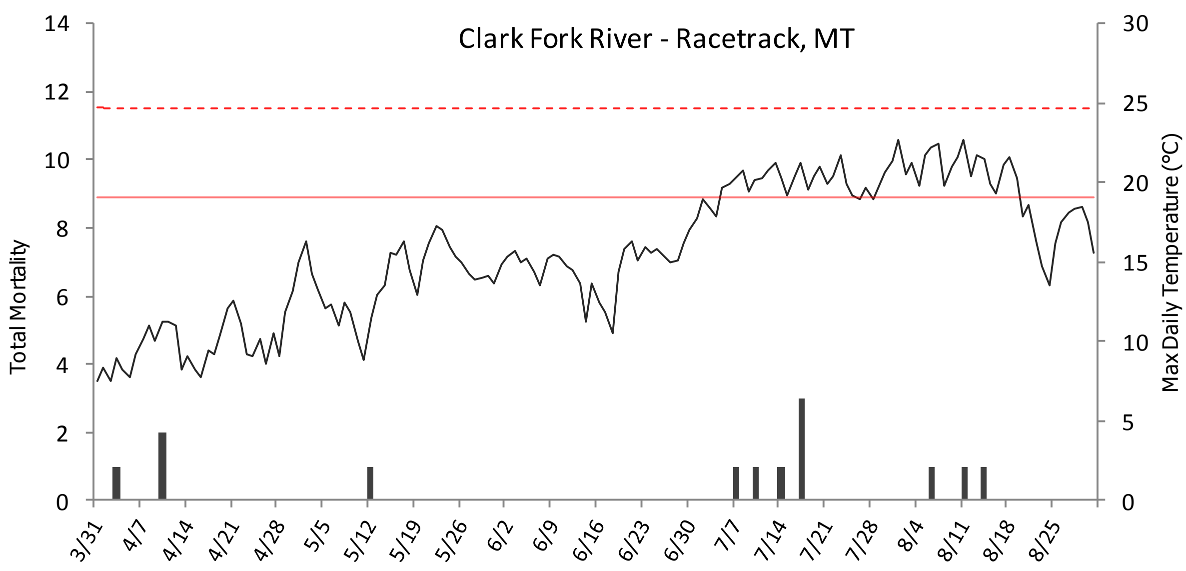


Figure 8-11. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line) in the Clark Fork River at the Racetrack site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

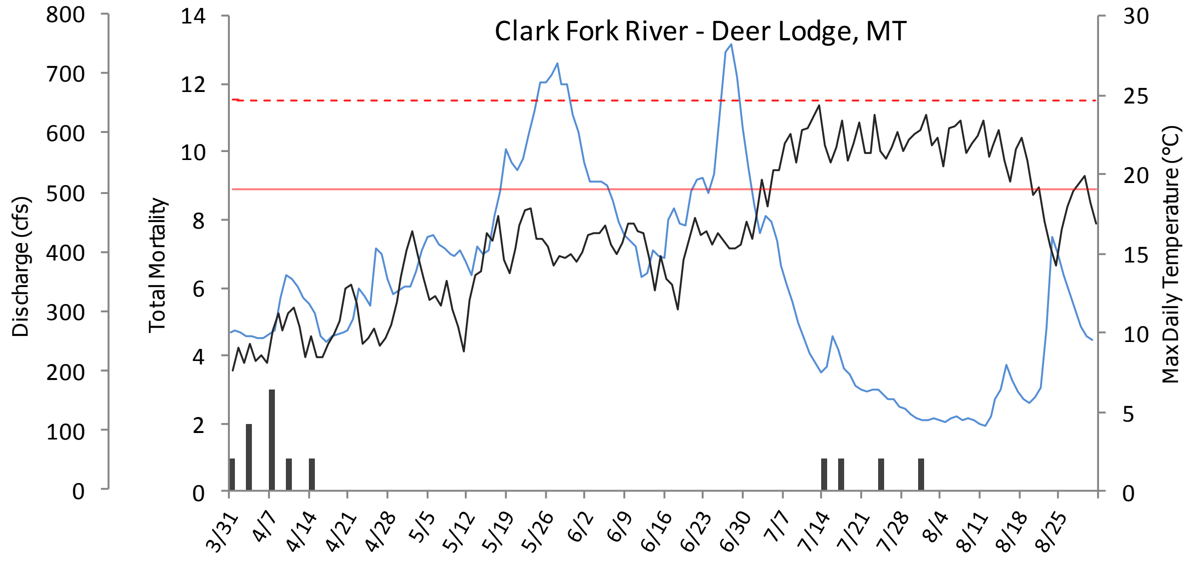


Figure 8-12. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line), and mean daily discharge (blue line) for 2014 in the Clark Fork River at the Deer Lodge site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

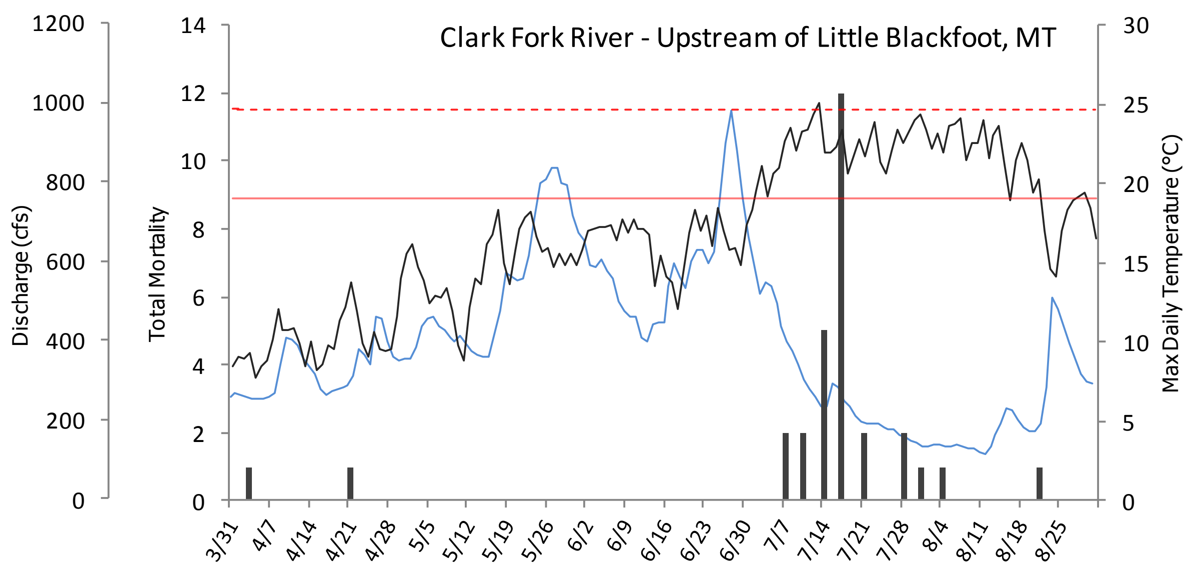


Figure 8-13. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line), and mean daily discharge (blue line) for 2014 in the Clark Fork River at the site upstream of the Little Blackfoot River. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout

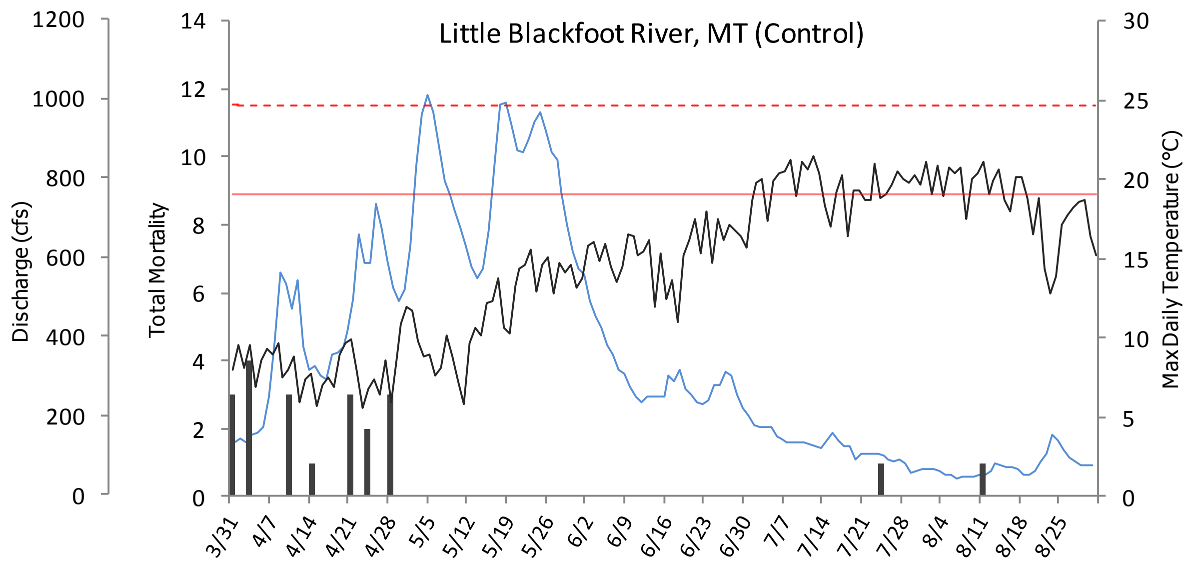


Figure 8-14. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line), and mean daily discharge (blue line) for 2014 at the tributary site in Little Blackfoot River. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

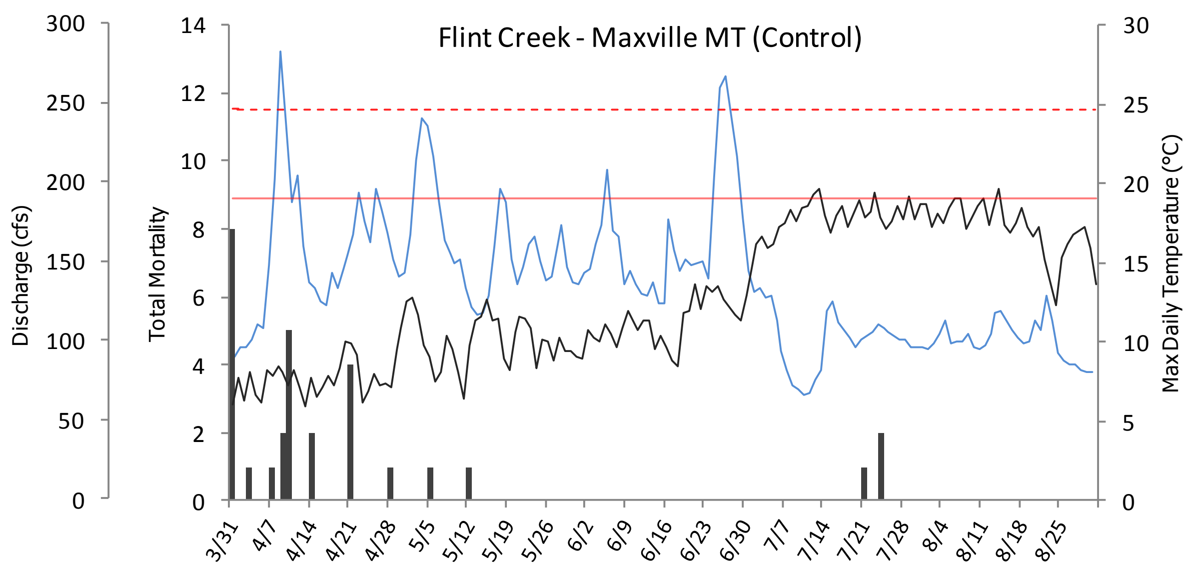


Figure 8-15. Total mortalities between cages one and two combined (gray bars), maximum daily water temperature (black line), and mean daily discharge (blue line) for 2014 at the tributary site in Flint Creek. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

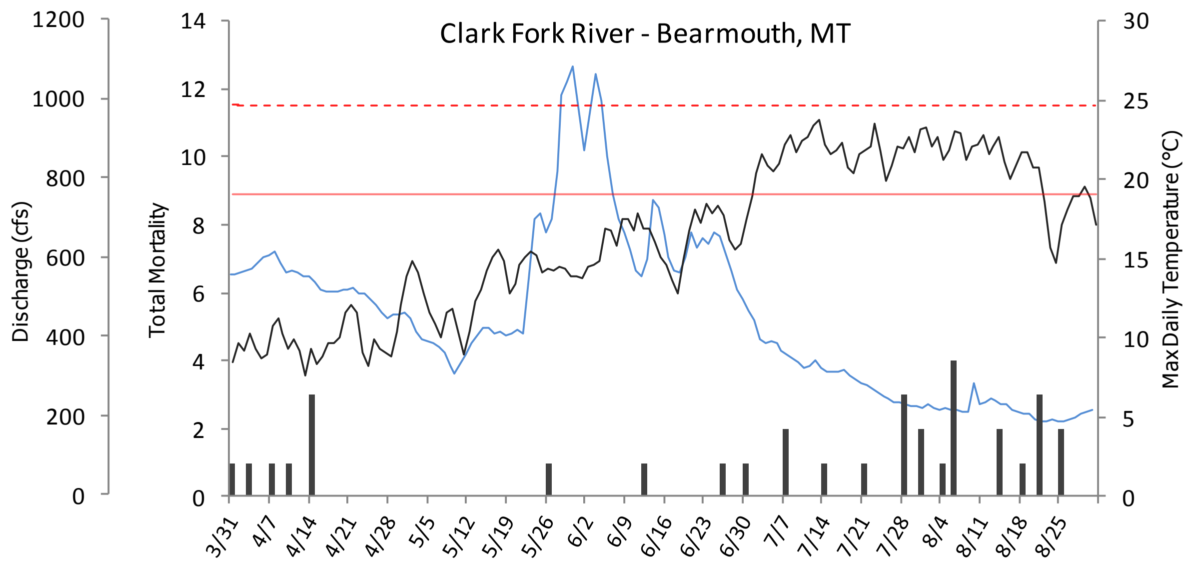


Figure 8-16. Total mortalities between cages one and two combined (gray bars) and maximum daily water temperature (black line) and mean daily discharge (blue line) for 2014 in the Clark Fork River at the Bearmouth site. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

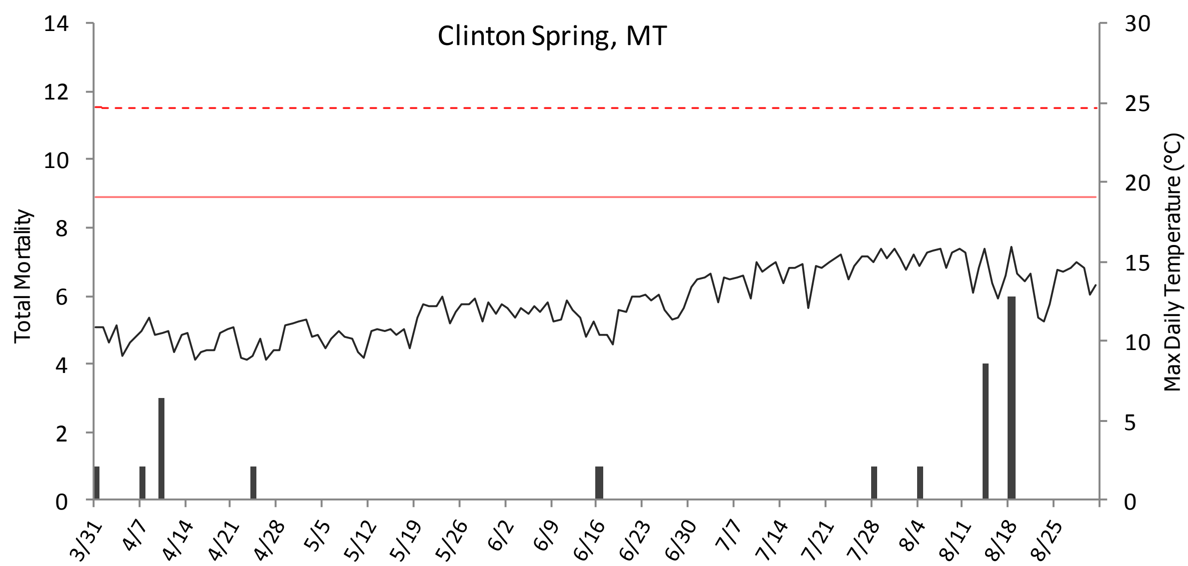


Figure 8-17. Total mortalities between cages one and two combined (gray bars) and maximum daily water temperature (black line) for 2014 at the control site in the spring channel near Clinton, Montana. The solid red line indicates the upper critical temperature threshold and the dashed red line represents the upper incipient lethal temperature for Brown Trout.

Table 8-9. Survival, net number of fish added during the survival study period (April 14 – July 31) and fish remaining in cages one and two on July 31. Results of $\chi2$ tests (df = 1 for all tests) between survival at mainstem treatment sites and mean survival at two tributary control sites are also presented. Statistically significant *p*-values are in bold.

Site	Fish remaining	Net fish added	Survival	$\chi2$	*p*-value
Mainstem					
Bearmouth	39	56	0.7	0.22	0.6386
U/S Lil Black	21	48	0.44	8.68	**0.0032**
Deer Lodge	46	51	0.9	2.63	0.1051
Racetrack	49	56	0.88	1.61	0.204
Galen	38	44	0.86	1	0.3167
Perkins Lane	40	47	0.85	0.75	0.3872
Warm Springs	29	48	0.6	1.89	0.1696
Silver Bow	25	50	0.5	5.71	**0.0169**
Pond 2	22	43	0.51	4.81	**0.0284**
Mainstem average	34.3	49.2	0.7	0.02	0.6631
Tributary					
Flint	31	43	0.72		
Lil Black	38	48	0.79		
Tributary average	34.5	45.5	0.76		

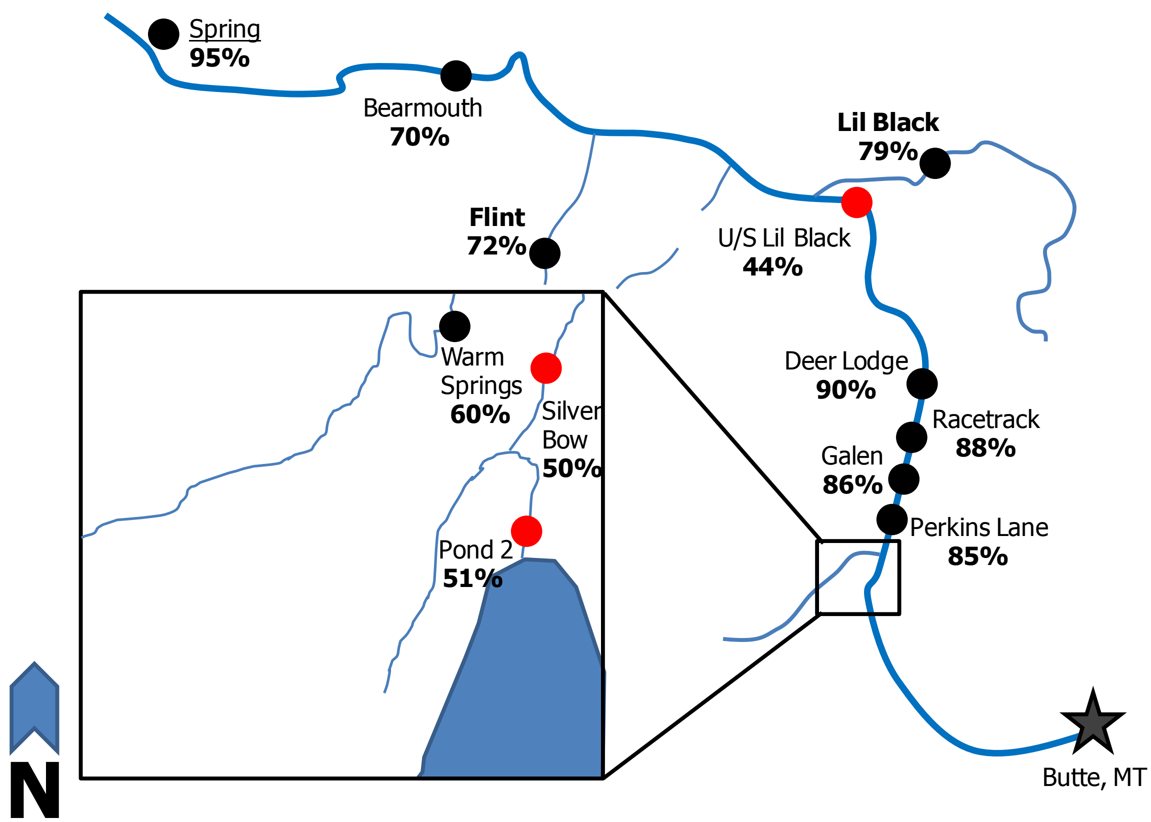


Figure 8-18. Cumulative brown trout survival from April 14th to July 31st, 2014. Tributary sites are shown in bold and the handling control is underlined. Red dots denote sites with survival that was significantly lower than the average of the two tributary control sites. No sites had significantly higher survival than control sites in 2014.

8.3.3 Growth and Condition

Fish at the Deer Lodge site had the lowest increase in length of all sites, growing an average of 17.6 mm over the course of the study [Figure 8-19a]. Fish in the Spring control site grew 34.1 mm on average, the most of any site. Bearmouth fish had the lowest Wr for fish surviving to the end of the field season (mean = 71; Figure 8-19b) whereas the Warm Springs site had fish in the best condition at the end of the study (mean Wr = 95). Dead fish tended to have higher Wr than live fish at all sites and during most months [Figure 8-20]. Mean Wr of all dead fish measured and weighed in 2014 was 99.5 (n = 202; SD = 24.2) compared to a mean Wr of 83.3 (n = 417; SD = 8.7) for all live fish. The Wr data of dead fish should be interpreted with caution because many of this fish had saprolegnia coating their bodies, which may have absorbed water and increased the weight of these specimens. Also, fish in freshwater tend to gain water when osmoregulation is disrupted by stress or death, which would also increase post-mortem weight [Mazeaud et al., 1977; Bronstein et al., 1985]. There were not statistically significant relationships between the number of fish remaining in the cages and the increase in mean length (*p*-value = 0.879) or Wr (*p*-value= 0.778) within cages. Thus, there was no evidence of density dependent growth or condition.

Growth (increase in weight) at all but one site was lower than the Elliot et al. [1995] temperature based model predicted [Figure 8-21]. Fish at the Pond 2 site was predicted to have the lowest increase in weight of any site, but growth at this site was actually greater than at any other site. High growth and productivity at this site has been attributed to a tail water effect in previous caged fish studies [Richards et al., 2013; Leon et al., 2014]. After removing the Pond 2 site from analysis, a linear regression of observed weights versus predicted weights indicated a significant relationship (*p*-value = 0.003; r^2 = 0.776), suggesting a strong influence of temperature on Brown Trout growth in this study.

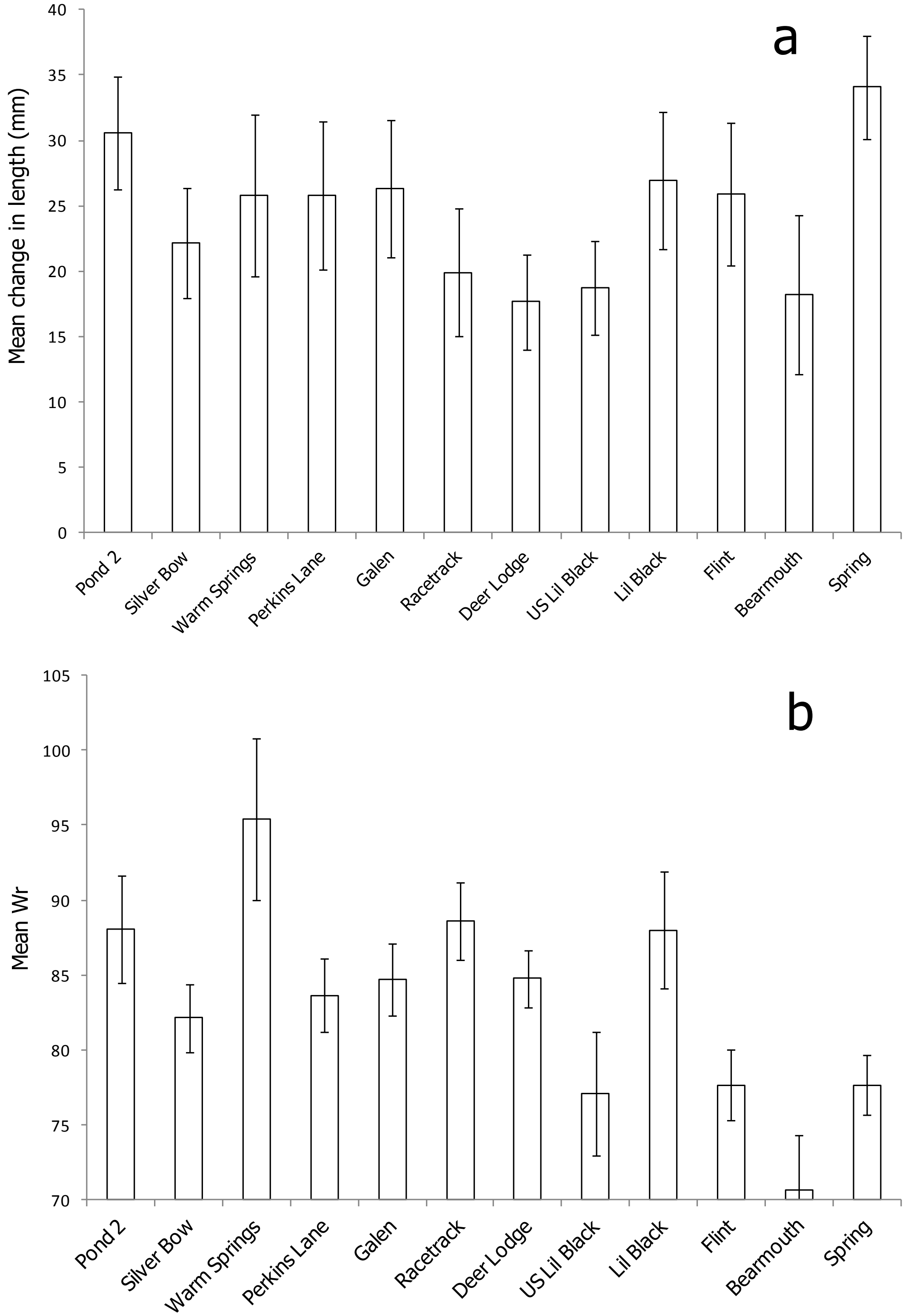


Figure 8-19. Mean change in length (a) and mean relative weight (b) by site for live fish at the end of the 2014 caged fish study. Error bars are 95% confidence intervals.

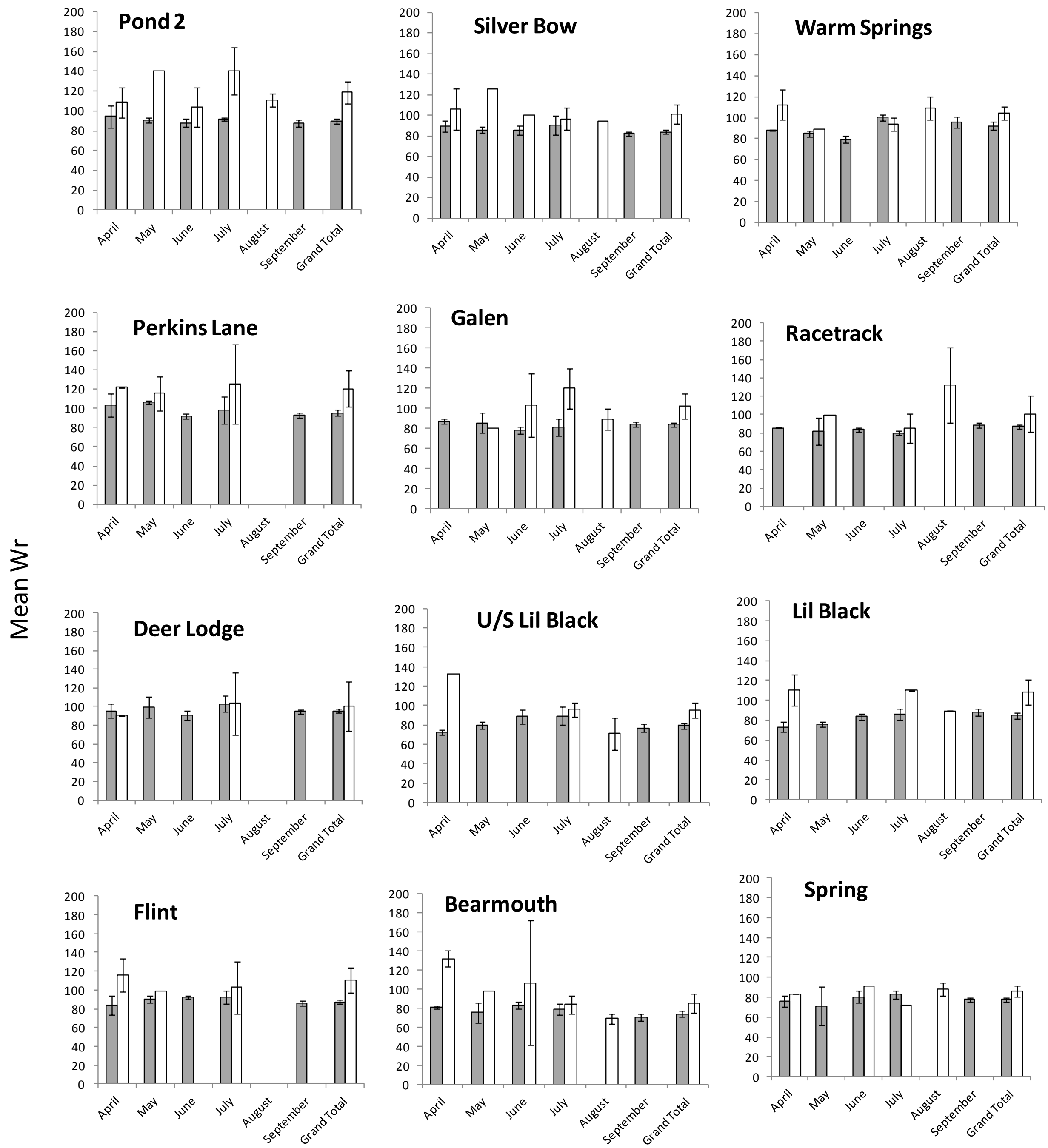


Figure 8-20. Mean relative weight (Wr) for live (white bars) and dead (grey bars) fish by site and month for the 2014 caged fish study. Error bars are 95% confidence intervals.

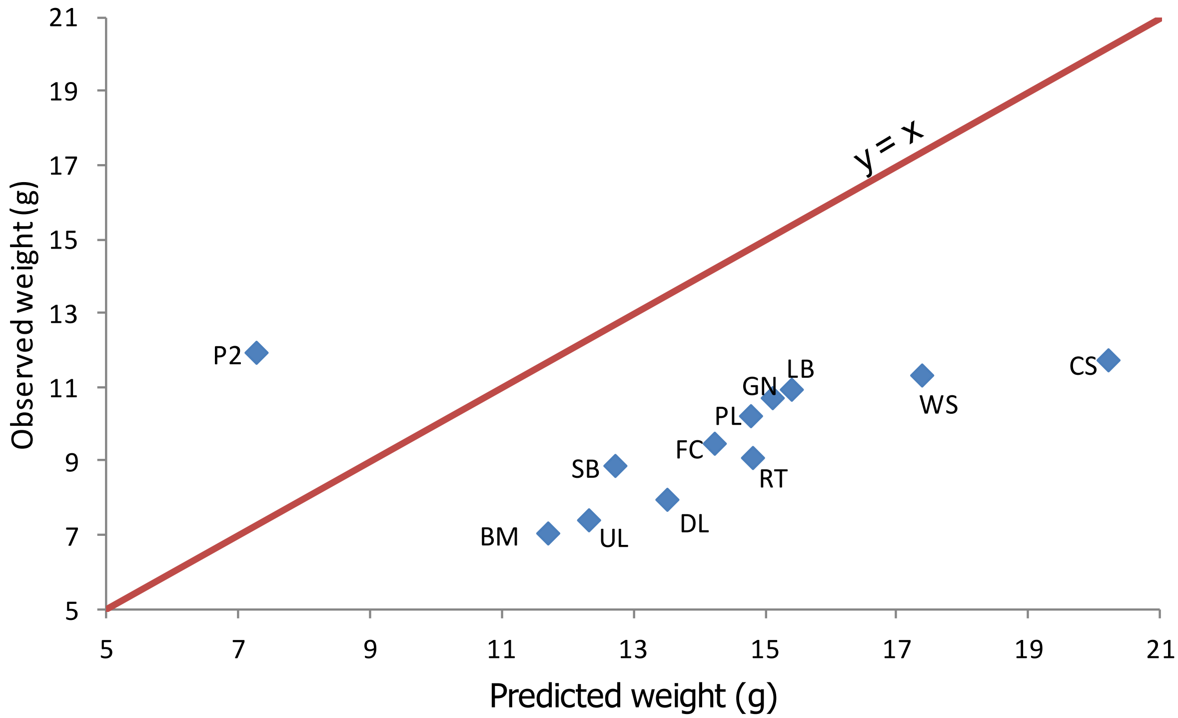


Figure 8-21. Observed mean final weight of live fish versus weights predicted by the temperature based model of Elliot et al. [1995] for twelve caged fish sites in the Upper Clark Fork River drainage, 2014. Site abbreviations are Pond 2 (P2), Silver Bow (SB), Warm Springs (WS), Perkins Lane (PL), Galen (GN), Racetrack (RT), Deer Lodge (DL), Upstream of the Little Blackfoot (UL), Little Blackfoot (LB), Flint Creek (FC), Bearmouth (BM), and Clinton Spring (CS). The red line represents the 1:1 line.

8.3.4 Tissue Metals Burdens

Mean (+/- 95% CI) whole body metal concentrations in the five hatchery control Brown Trout were 4.31 (+/- 1.26) µg/g for copper and 136.8 (+/- 9.45) µg/g for zinc. Therefore, concentrations above these values for fish held in cages represent accumulation of copper or zinc while in the cages. U/S Lil Black had the highest average copper tissue burden (11.4 µg/g; SD = 2.9; Figure 8-22), followed by Deer Lodge (9.3 µg/g; SD = 3.5), and Perkins Lane (8.67 µg/g; SD = 4.5). Copper tissue burdens at U/S Lil Black were significantly higher than every site except Deer Lodge and Perkins Lane [Table 8-10]. Copper tissue burdens at Deer Lodge were significantly higher than Pond 2, Silver Bow, and the tributary and control sites. Perkins Lane had higher tissue burdens than the Lil Blackfoot site. Of the mainstem sites, Silver Bow had the lowest copper tissue burdens (5.7 µg/g; SD = 1.7), followed by Pond 2 (6.0 µg/g; SD = 1.5), and Galen (6.83 µg/g; SD = 1.3). The tributary sites and Clinton Spring the lowest copper tissue burdens of all the sites. Copper tissue burdens generally increased upstream to downstream from the Pond 2 to the U/S Lil Black sites.

The Pond 2 site had the highest zinc tissue burdens (216.8 µg/g; SD = 65.1), followed by Silver Bow (198.7 µg/g; SD = 34.5), and U/S Lil Black (178.7; 27.0). Zinc tissue burdens at Pond

2 were significantly higher than all sites except Silver Bow [Table 8-11]. Silver Bow had zinc tissue burdens significantly higher that Warm Springs, Galen, Racetrack, Lil Black, and Spring. Racetrack had the lowest zinc tissue burdens (156.9 µg/g; SD = 156.9) of the mainstem sites, followed by Galen (162.3 µg/g; SD = 16.8), and Perkins Lane (167.2 µg/g; SD = 25.1).

Copper Tissue Burdens reached the highest levels of the season in July and or September at Pond 2, Silver Bow, Warm Springs, Galen, Deer Lodge, Lil Black, and Bearmouth [Figure 8-23 through Figure 8-26]. Other sites had less distinct patterns in tissue burdens over the season. Zinc Tissue Burdens were highest in July and/or September at Pond 2, Silver Bow, and Bearmouth [Figure 8-23 through Figure 8-26].

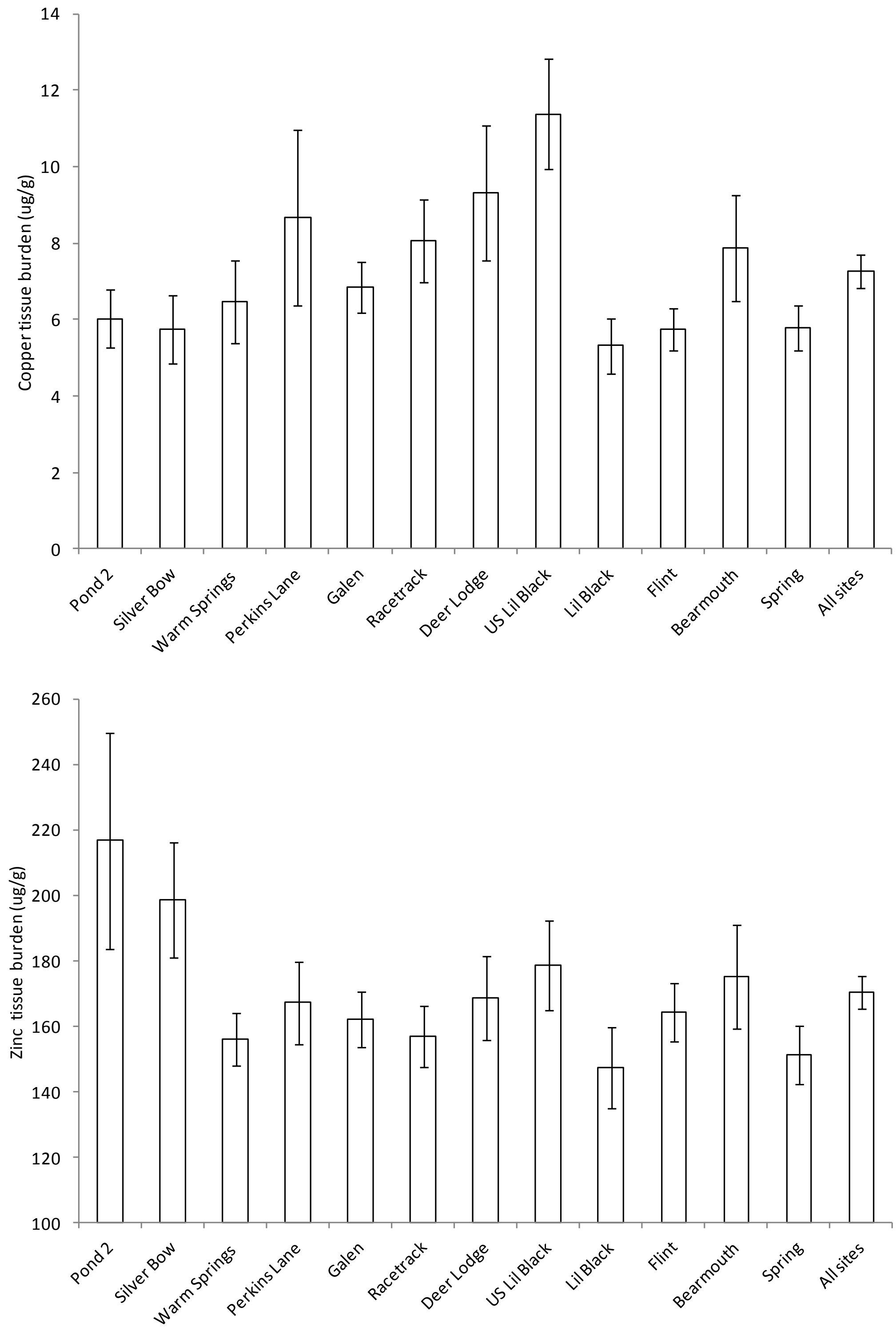


Figure 8-22. Mean whole body concentrations of copper (a) and zinc (b) at twelve study sites in the 2014 Upper Clark Fork River Drainage caged fish study. Error bars are 95% confidence intervals.

Table 8-10. Bonferroni-corrected *p*- values from pairwise *t*-tests of whole body copper tissue burdens between 12 sites in the Upper Clark Fork River Drainage. Values <0.05 are in bold.

	Pond 2	Silver Bow	Warm Springs	Perkins Lane	Galen	Racetrack	Deer Lodge	US Lil Black	Lil Black	Flint	Bearmouth
Pond 2	-	-	-	-	-	-	-	-	-	-	-
Silver Bow	1	-	-	-	-	-	-	-	-	-	-
Warm Springs	1	1	-	-	-	-	-	-	-	-	-
Perkins Lane	0.1912	0.0685	0.857	-	-	-	-	-	-	-	-
Galen	1	1	1	1	-	-	-	-	-	-	-
Racetrack	1	0.5868	1	1	1	-	-	-	-	-	-
Deer Lodge	**0.0146**	**0.0044**	0.0879	1	0.262	1	-	-	-	-	-
US Lil Black	**0**	**0**	**0**	0.1552	**0**	**0.0144**	1	-	-	-	-
Lil Black	1	1	1	**0.0124**	1	0.1364	**0.0006**	**0**	-	-	-
Flint	1	1	1	0.0708	1	0.6035	**0.0046**	**0**	1	-	-
Bearmouth	1	1	1	1	1	1	1	**0.0065**	0.2645	1	-
Spring	1	1	1	0.079	1	0.6617	**0.0052**	**0**	1	1	1

Table 8-11. Bonferroni-corrected *p*-values from pairwise *t*-tests of whole body zinc tissue burdens between 12 sites in the Upper Clark Fork River Drainage. Values <0.05 are in bold.

	Pond 2	**Silver Bow**	**Warm Springs**	**Perkins Lane**	**Galen**	**Racetrack**	**Deer Lodge**	**US Lil Black**	**Lil Black**	**Flint**	**Bearmouth**
Pond 2	-	-	-	-	-	-	-	-	-	-	-
Silver Bow	1	-	-	-	-	-	-	-	-	-	-
Warm Springs	0	0.008	-	-	-	-	-	-	-	-	-
Perkins Lane	0.0006	0.2673	1	-	-	-	-	-	-	-	-
Galen	0	0.0393	1	1	-	-	-	-	-	-	-
Racetrack	0	0.0101	1	1	1	-	-	-	-	-	-
Deer Lodge	**0.001**	**0.3945**	1	1	1	1	-	-	-	-	-
US Lil Black	**0.035**	**1**	**1**	1	**1**	**1**	1	-	-	-	-
Lil Black	0	0.0003	1	**1**	1	1	**1**	**0.2755**	-	-	-
Flint	0.0002	0.1204	1	1	1	1	**1**	**1**	1	-	-
Bearmouth	0.0111	1	1	1	1	1	1	**1**	0.6911	1	-
Spring	0	0.0014	1	1	1	1	**1**	**0.8118**	1	1	1

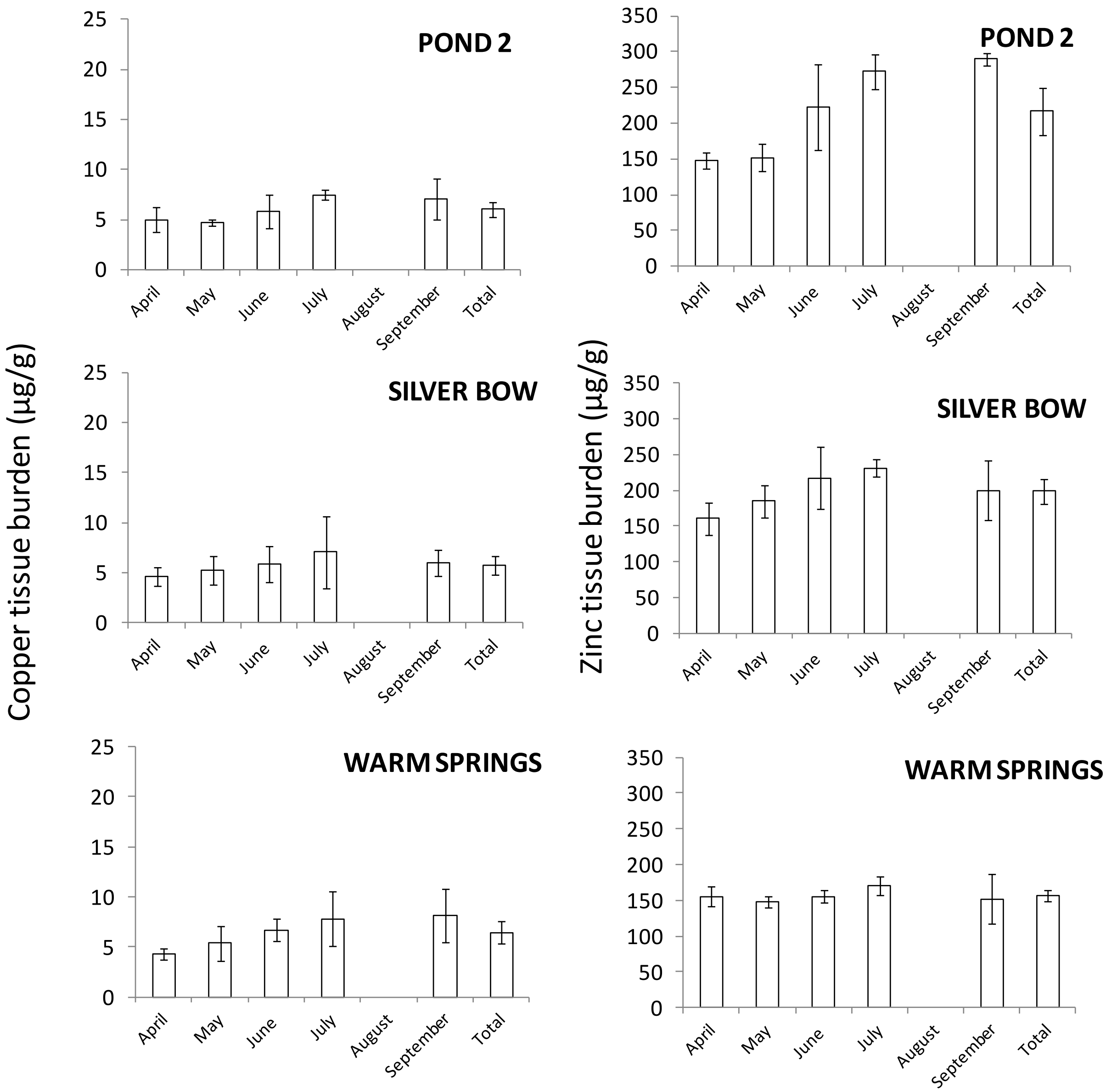


Figure 8-23. Mean whole body copper (left panels) and zinc (right panels) tissue burdens for the Pond 2, Silver Bow, and Warm Springs caged fish sites in the Upper Clark Fork River Drainage. Error bars are 95% confidence intervals.

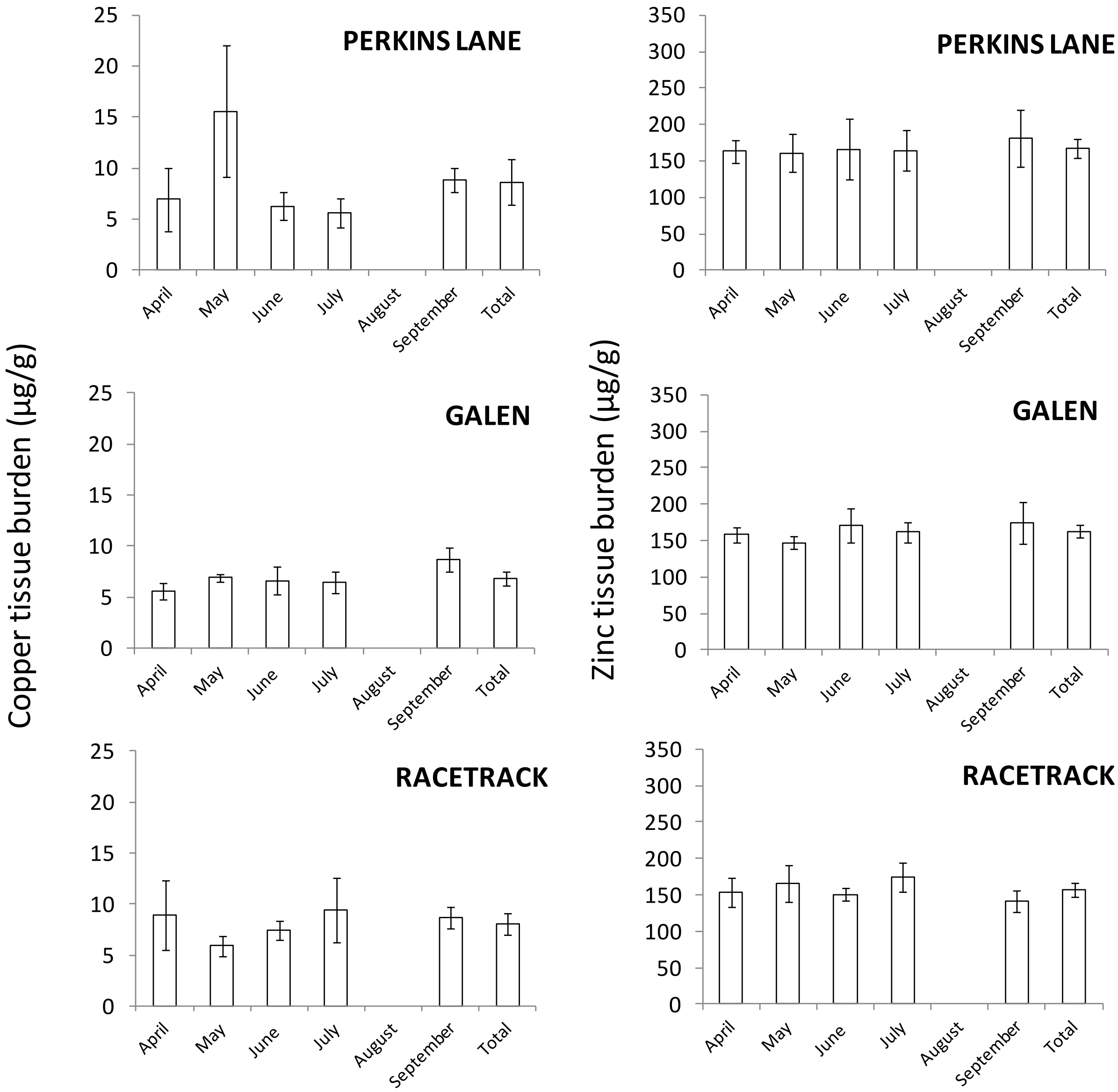


Figure 8-24. Mean whole body copper (left panels) and zinc (right panels) tissue burdens for the Perkins Lane, Silver Galen, and Racetrack caged fish sites in the Upper Clark Fork River Drainage. Error bars are 95% confidence intervals.

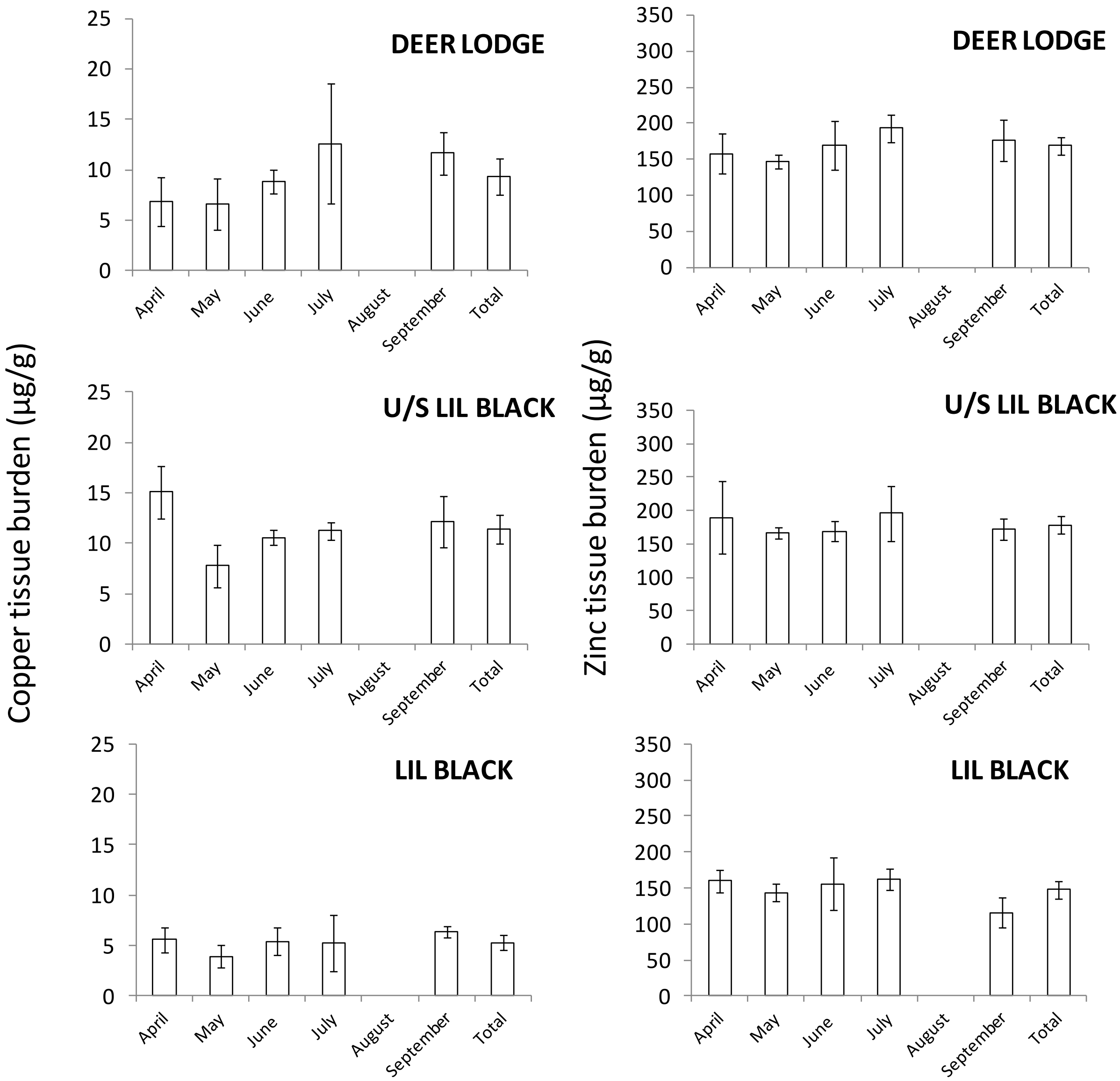


Figure 8-25. Mean whole body copper (left panels) and zinc (right panels) tissue burdens for the Deer Lodge, Upstream Lil Black, and Lil Black caged fish sites in the Upper Clark Fork River Drainage. Error bars are 95% confidence intervals.

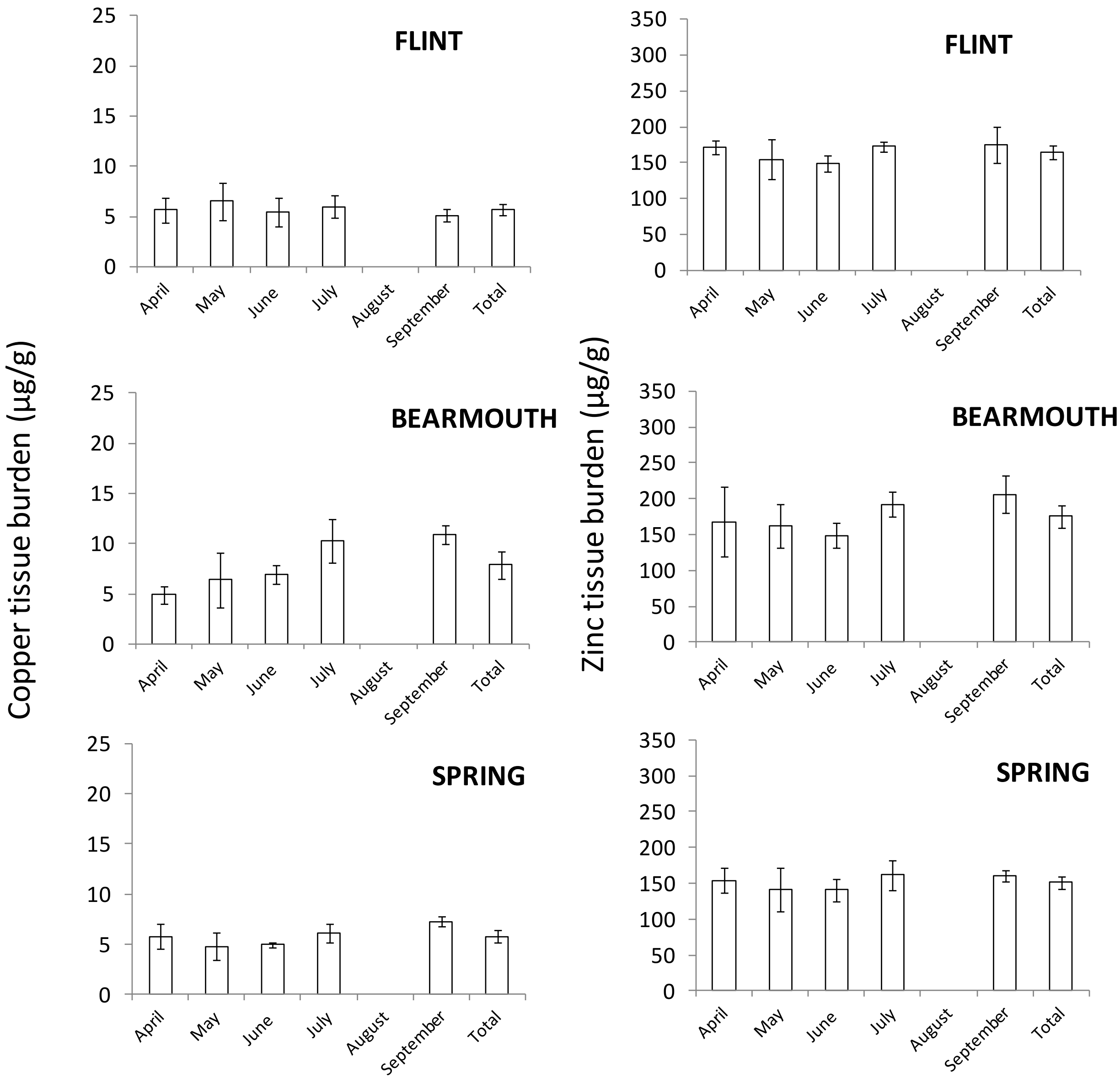


Figure 8-26. Mean whole body copper (left panels) and zinc (right panels) tissue burdens for the Flint, Bearmouth, and Spring caged fish sites in the Upper Clark Fork River Drainage. Error bars are 95% confidence intervals.

8.3.5 Comparisons

8.3.5.1 Tributary vs. Mainstem

For the purposes of the analysis between control tributaries and mainstem treatment sites, Clinton Spring was not included as a control site. For both copper and zinc, tributary sites had significantly lower tissue burdens than mainstem sites and greater tissue burdens than the hatchery controls [Figure 8-28]. The difference in tissue burdens between mainstem and tributary sites was greatest in September for both metals.

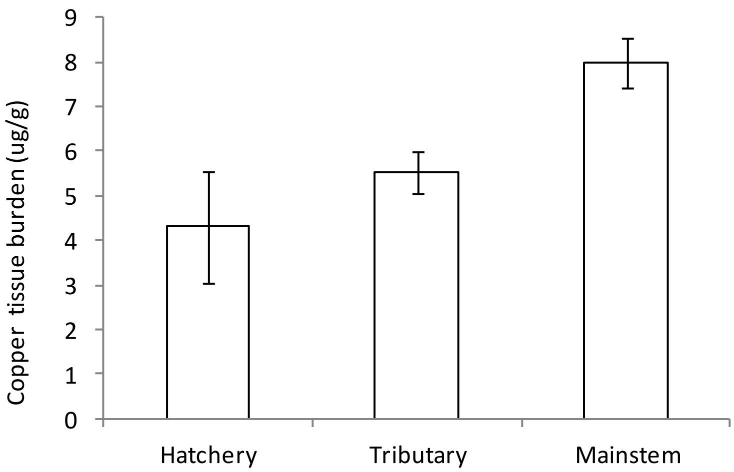
8.3.5.2 Upstream Construction versus Downstream Construction

For the purposes of the analysis, sites located above and below the Phase 5 and 6 construction area near Galen, Montana were compared. The Galen site was considered above the construction area and the Racetrack site was considered downstream of the construction. The tributary sites were analyzed separately. Generally, upstream sites were found to have lower copper tissue burdens than downstream sites [Figure 8-29]. There were greater differences in copper tissue burdens between upstream sites and downstream sites than zinc tissue burdens [Figure 8-29].

8.3.5.3 Annual Comparisons

The number of years with metals tissue burden and fish survival data varied between sites [Figure 8-30; Figure 8-31]. Pond 2, Perkins Lane, Deer Lodge, U/S Lil Black, Lil Black, Flint, and Spring were sampled all fours years for tissue burdens and survival. Bearmouth and Turah were sampled for three years. The remaining sites were sampled for fewer than two years. There was generally more variation in metal tissue burdens between sites than between years at a site. The tributary sites (Flint and Lil Black) consistently had lower copper tissue burdens than most mainstem sites. Deer Lodge and U/S Lil Black tended to have higher copper tissue burdens than other sites over the four years of caged fish studies.

The Spring control site consistently had high survival in each year of caged fish studies [Table 8-12]. Deer Lodge had relatively consistent survival from year to year averaging 90% (range 89-91%). Tributary sites (Flint and Lil Black) had inconsistent survival from year to year. The Pond 2 site had the lowest survival of all sites in the 2012 and 2013 studies and the second lowest survival in the 2014 study. Other sites had inconsistent survival from year to year or lacked enough survival estimates to make conclusions about temporal trends.



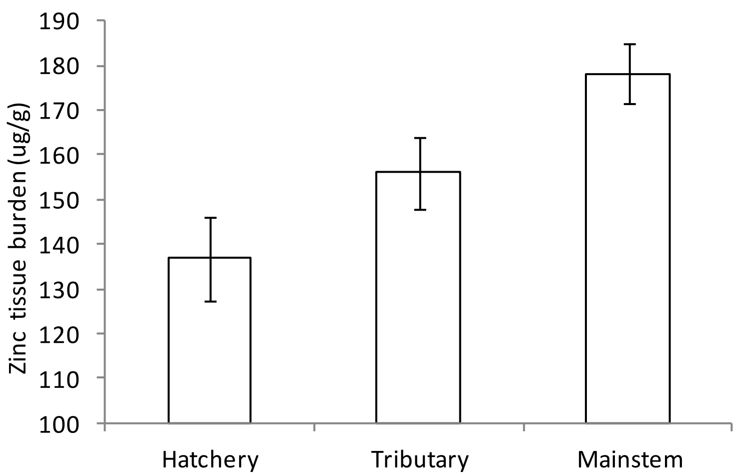


Figure 8-27. Comparisons between copper and zinc tissue burdens in Brown Trout collected immediately from the hatchery, from cages in tributary sites, and cages in mainstem sites. Error bars are 95% confidence intervals.

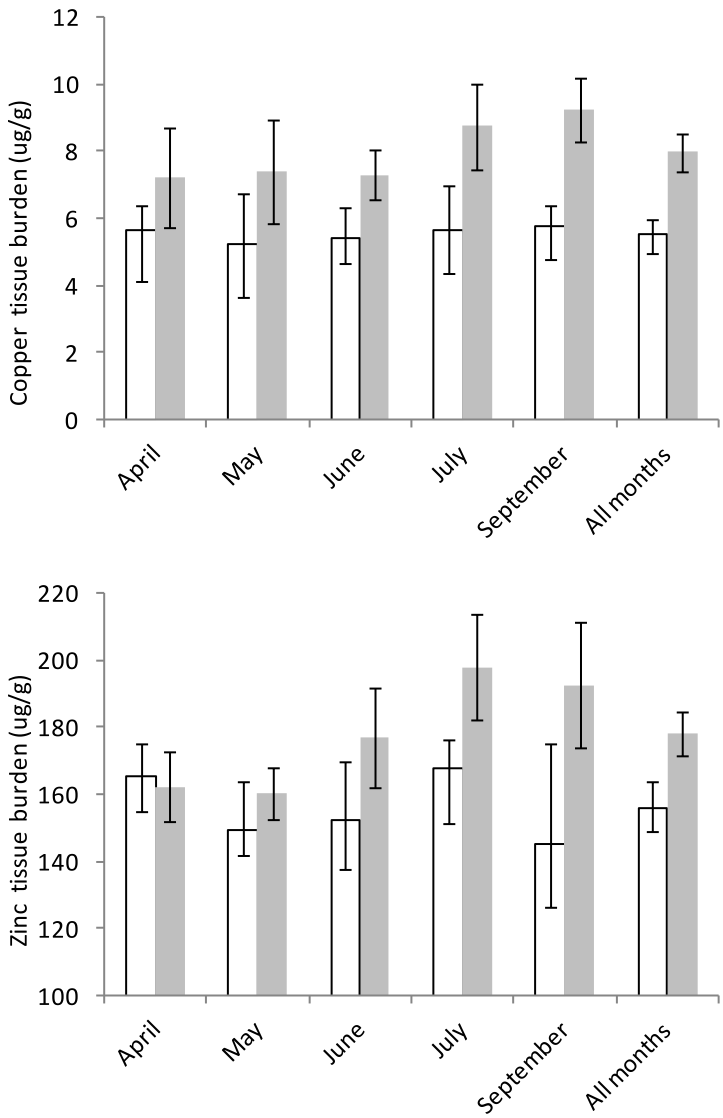


Figure 8-28. Comparisons between tissue metals burdens of fish from tributary (white bars) and mainstem (grey bars) sites. Error bars are 95 % confidence intervals

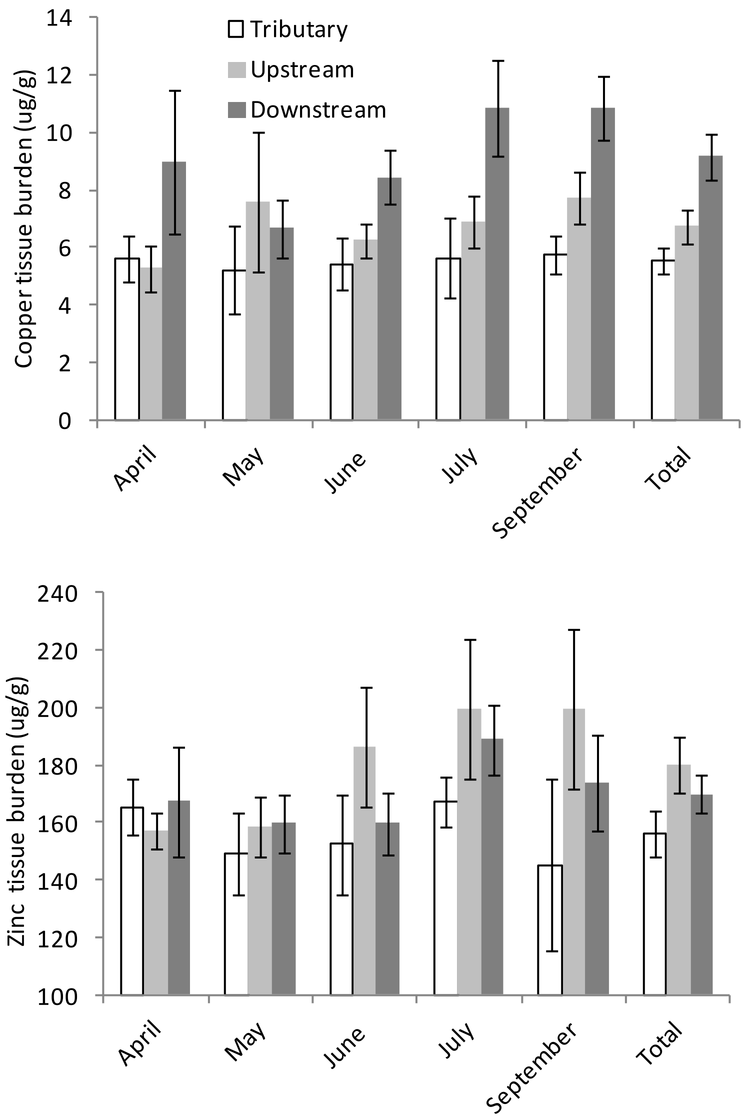


Figure 8-29. Comparisons between tissue metals burdens of fish from sites upstream of construction and downstream of construction. Error bars are 95 % confidence intervals.

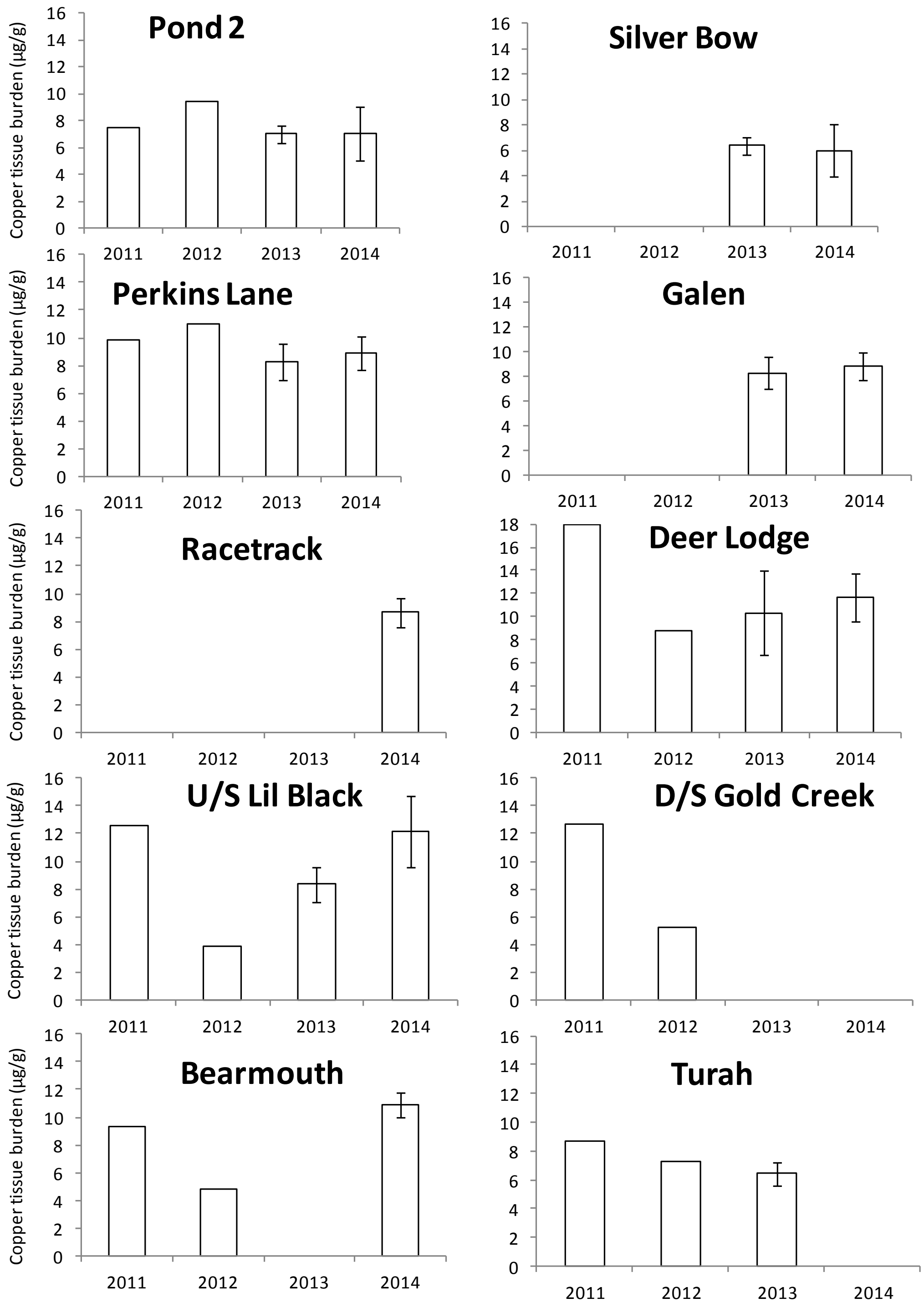


Figure 8-30. Annual mean whole body Brown Trout copper tissue burdens for fish collected at the end of the season from fish cages at mainstem sites in the Upper Clark Fork River Basin, 2011-2014. Location of fish cage sites was dependent on the year; not all sites were sampled each year. Error bars are 95% confidence intervals. Fish samples were combined into composites for tissue burden analysis in 2011 and 2012, so error bars are not available for those years. In 2013 and 2014, individual fish were submitted for tissue burden analysis.

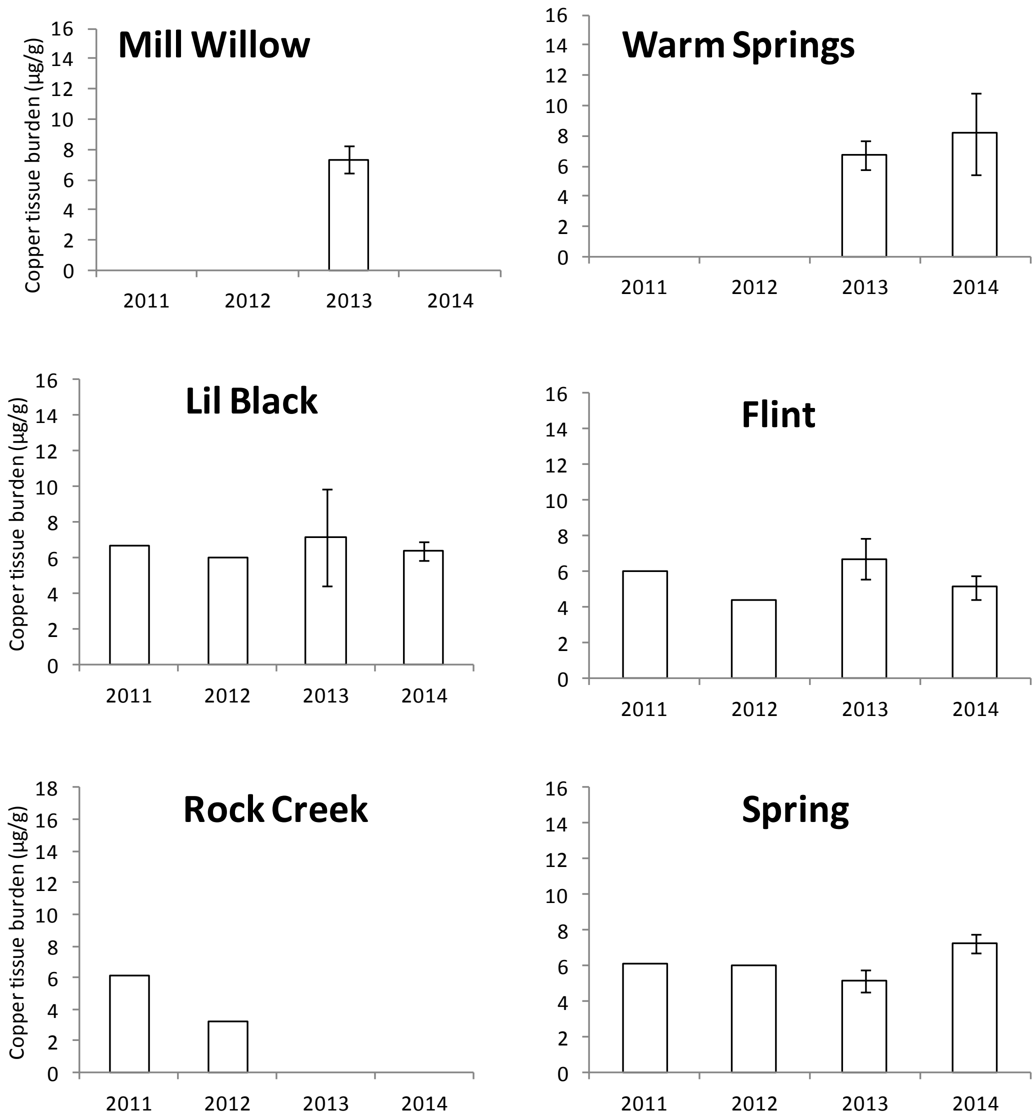


Figure 8-31. Annual mean whole body Brown Trout copper tissue burdens for fish collected at the end of the season from fish cages in tributary sites in the Upper Clark Fork River Basin, 2011-2014. Location of fish cage sites was dependent on the year; not all sites were sampled each year. Error bars are 95% confidence intervals. Fish samples were combined into composites for tissue burden analysis in 2011 and 2012, so error bars are not available for those years. In 2013 and 2014, individual fish were submitted for tissue burden analysis.

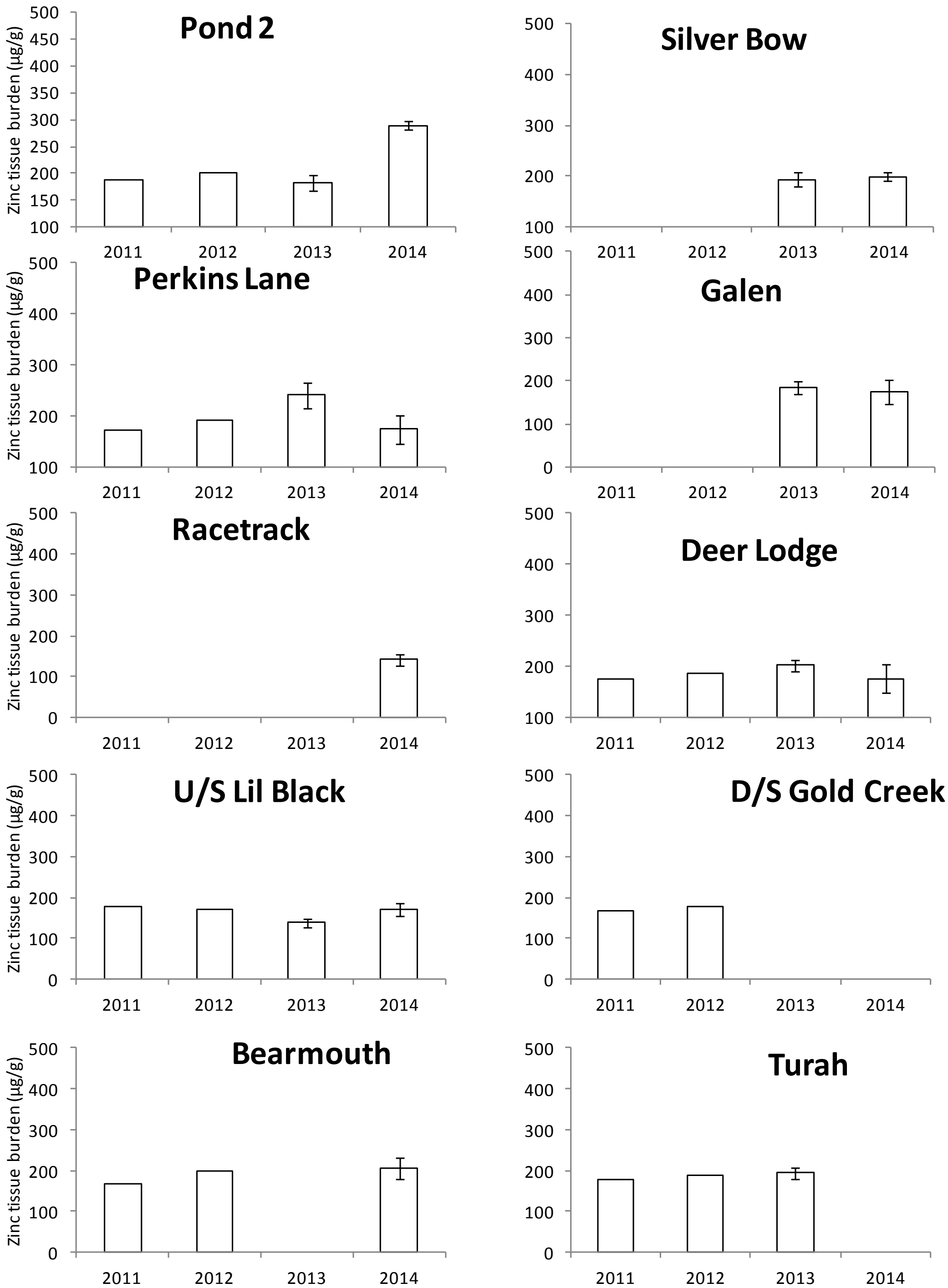


Figure 8-32. Annual mean whole body Brown Trout zinc tissue burdens for fish collected at the end of the season from fish cages at mainstem sites in the Upper Clark Fork River Basin, 2011-2014. Location of fish cage sites was dependent on the year; not all sites were sampled each year. Error bars are 95% confidence intervals. Fish samples were combined into composites for tissue burden analysis in 2011 and 2012, so error bars are not available for those years. In 2013 and 2014, individual fish were submitted for tissue burden analysis.

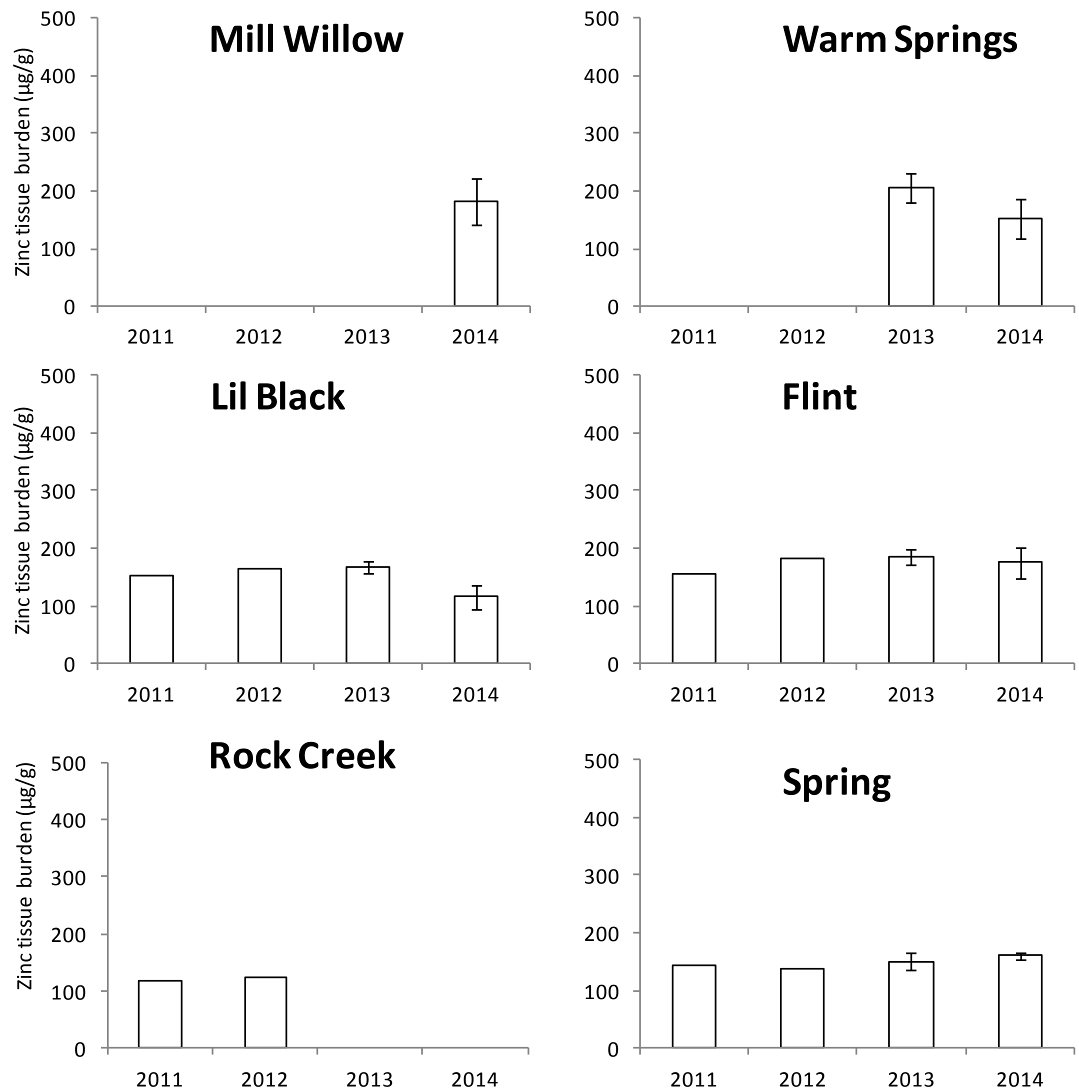


Figure 8-33. Annual mean whole body Brown Trout zinc tissue burdens for fish collected at the end of the season from fish cages at tributary sites in the Upper Clark Fork River Basin, 2011-2014. Location of fish cage sites was dependent on the year; not all sites were sampled each year. Error bars are 95% confidence intervals. Fish samples were combined into composites for tissue burden analysis in 2011 and 2012, so error bars are not available for those years. In 2013 and 2014, individual fish were submitted for tissue burden analysis.

Table 8-12. Mean annual survival at in caged fish studies conducted in the Upper Clark Fork Drainage, 2011-2014.

Site	Year				Mean	Standard deviation
	2011	2012	2013	2014		
Turah	69	89	94		84	13.2
Spring	100	100	88	95	95.8	5.7
Bearmouth	100	88		70	86	15.1
Rock Creek	86	89			87.5	2.1
Flint	93	88	68	72	80.3	12.1
Gold Creek	100	89			94.5	7.8
Lil Black	88	91	75	89	85.8	7.3
U/S Lil Black	89	83	93	44	77.3	22.5
Deer Lodge	89	91	89	90	89.8	1
Racetrack				88	88	
Galen				86	86	
Perkins Lane	73	83	82	85	80.8	
Mill Willow			89		89	
Warm Springs			83	60	71.5	16.3
Silver Bow			83	50	66.5	23.3
Pond 2*	96	78	58	51	70.8	20.4
Mean	89.4	88.1	82	73.3		
Standard deviation	10.5	5.6	11.1	18.1		

* The Pond 2 site was referred to as "Warm Springs" in previous years [Richards et al, 2013]. The Warm Springs site in this study refers to a site in Warm Springs Creek near the confluence with Silver Bow Creek.

8.3.6 Water Contaminants

Chronic freshwater ALS values for metals in surface water are evaluated based upon the analysis of samples following a total recoverable method [MDEQ, 2012b]; therefore discussion of water sampling results will focus on total recoverable levels. Ammonia nitrogen (NH_3-N) was only detected at four sites during two days in March. On March 18, 2014 (prior to fish cage deployment) concentrations of NH_3-N were 1.08 and 0.11 mg/L at Silver Bow and Perkins Lane, respectively. On March 19, 2014 concentrations of NH3-N were 0.06 mg/L at both Racetrack and Deer Lodge.

Total recoverable concentrations of arsenic did not exceed the chronic ALS in any water sample collected at caged fish sites in 2014 [Figure 8-34]. Across all sites, the highest concentrations of arsenic occurred at Pond 2 (mean = 0.030 mg/L; SD = 0.016) followed by the Silver Bow site (mean = 0.025 mg/L; SD = 0.008). Arsenic concentrations were lowest at Spring (mean = 0.001 mg/L; SD = 0.001), followed by the tributary sites at Lil Black (mean = 0.005 mg/L; SD = 0.001), Warm Springs (mean = 0.007 mg/L; SD = 0.001), and Flint (mean = 0.011 mg/L; SD = 0.002).

The cadmium chronic ALS was exceeded at the Pond 2 site on April 21, 2014 [Figure 8-35], and nearly exceeded at Silver Bow, Perkins Lane, and Galen on the same date. The site at U/S Lil Black had a near exceedance event on July 21, 2014. U/S Lil Black had the highest average cadmium concentration (mean = 0.0006 mg/L; SD = 0.0010) while the non-mainstem sites (Lil Black, Spring, Flint, and Warm Springs) had the lowest concentrations (means <0.0002 mg/L; SD <0.0002)

The chronic ALS for copper was exceeded at least once during the 2014 caged fish study at all sites except Lil Black and Spring [Figure 8-36]. The chronic copper ALS was exceeded in all eight samples taken at Deer Lodge and all seven samples taken at U/S Lil Black. Mean copper concentrations were highest at U/S Lil Black (mean = 0.047; SD = 0.031) followed by Deer Lodge (mean = 0.043 mg/L; SD = 0.022). Copper concentrations were lowest at the non-mainstem sites (means 0.001-0.009 mg/L; SD = 0.001-0.004).

Chronic lead ALS values were exceeded at least once at the Deer Lodge, U/S Lil Black, and Bearmouth mainstem sites as well as the Flint tributary site [Figure 8-37]. Lead concentrations were highest on average at U/S Lil Black (mean = 0.006 mg/L; SD = 0.005) followed by Deer Lodge (mean = 0.005 mg/L; SD = 0.003). With the exception of the Flint site, the non-mainstem sites tended to have relatively low lead concentrations (means <0.001).

Total recoverable zinc concentrations in 2014 did not exceed the chronic ALS value at any site at any time [Figure 8-38]. Zinc concentrations tended to be relatively high at U/S Lil Black site (mean = 0.042 mg/L; SD = 0.033) and Deer Lodge (mean = 0.036 mg/L; SD = 0.020). Lil Black, Warm Springs, and Spring had the lowest zinc concentrations (means = 0.001-0.012 mg/L; SD = 0.004-0.004).

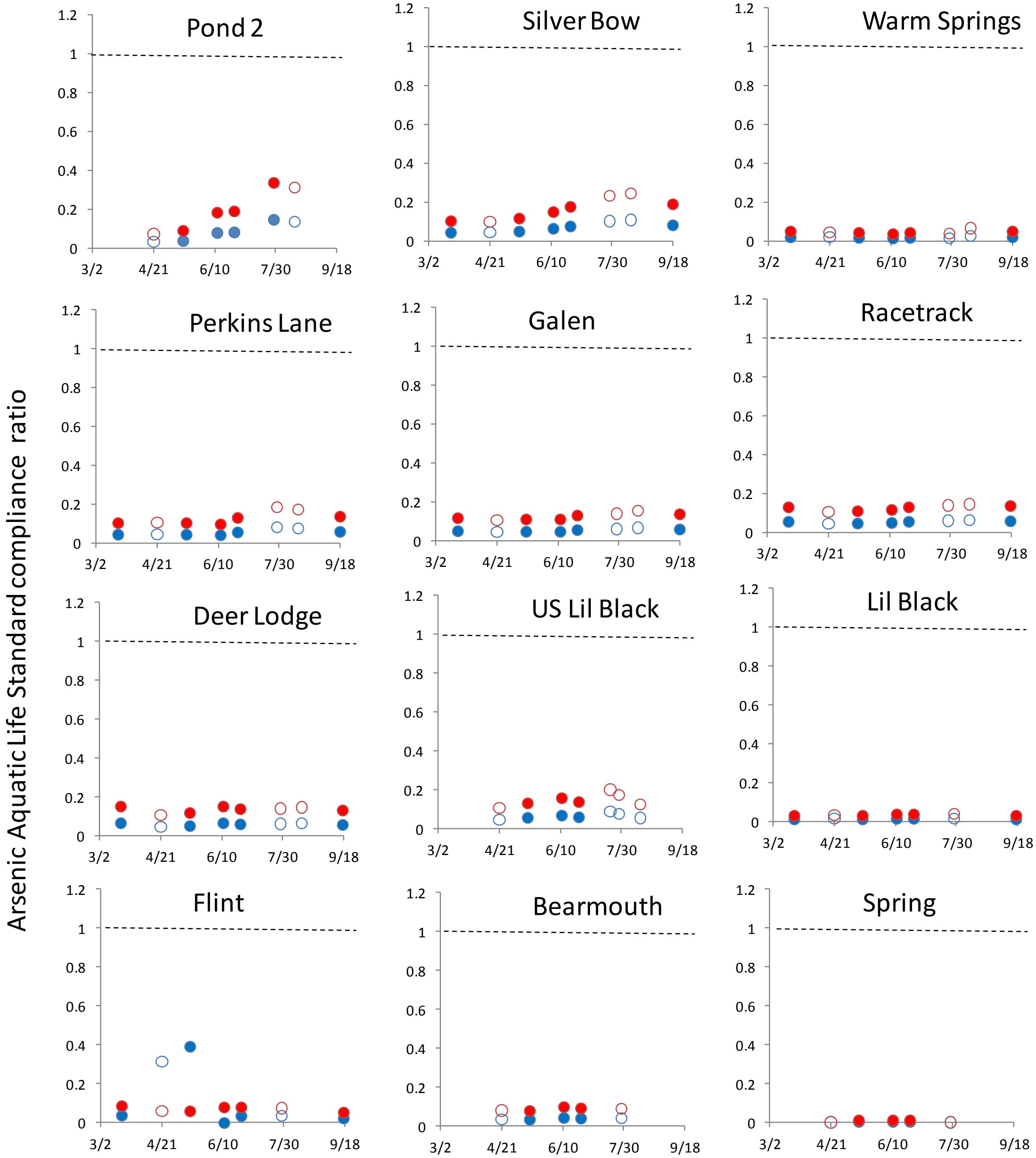


Figure 8-34. Acute (blue dots) and chronic (red dots) compliance ratios for total recoverable arsenic at the 2014 caged fish sites. Compliance ratios were calculated by dividing the measured arsenic concentration by the Aquatic Life Standard value [MDEQ, 2012b]. Water samples collected by MFWP are depicted by the open dots and samples collected by RESPEC are depicted with solid dots. Compliance ratio values <1 indicate arsenic levels below the aquatic life standard while values >1 indicate levels above the standard.

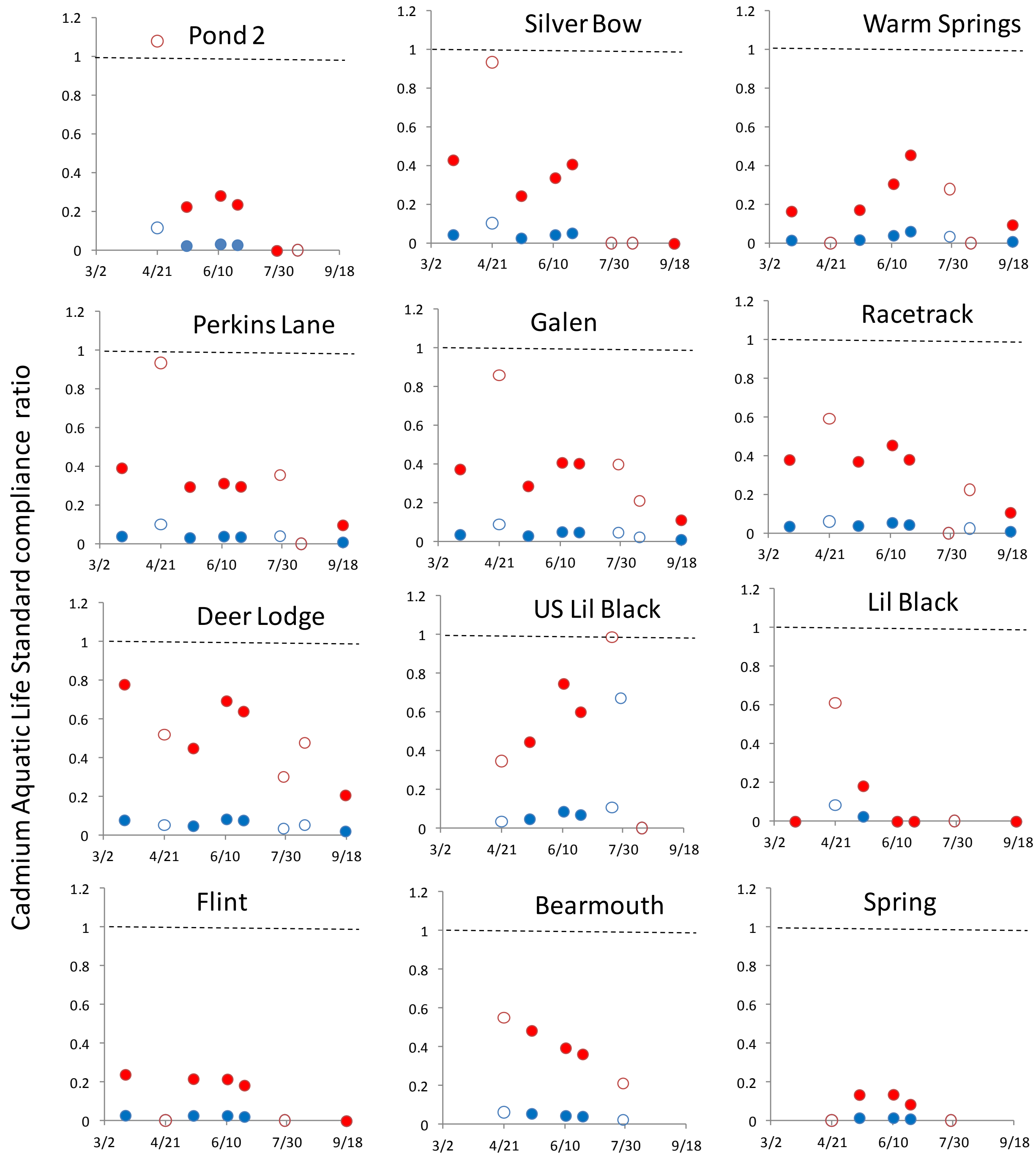


Figure 8-35. Acute (blue dots) and chronic (red dots) compliance ratios for total recoverable cadmium at the 2014 caged fish sites. Compliance ratios were calculated by dividing the measured cadmium concentration by the Aquatic Life Standard value [MDEQ, 2012b]. Water samples collected by MFWP are depicted by the open dots and samples collected by RESPEC are depicted with solid dots. Compliance ratio values <1 indicate cadmium levels below the aquatic life standard while values >1 indicate levels above the standard.

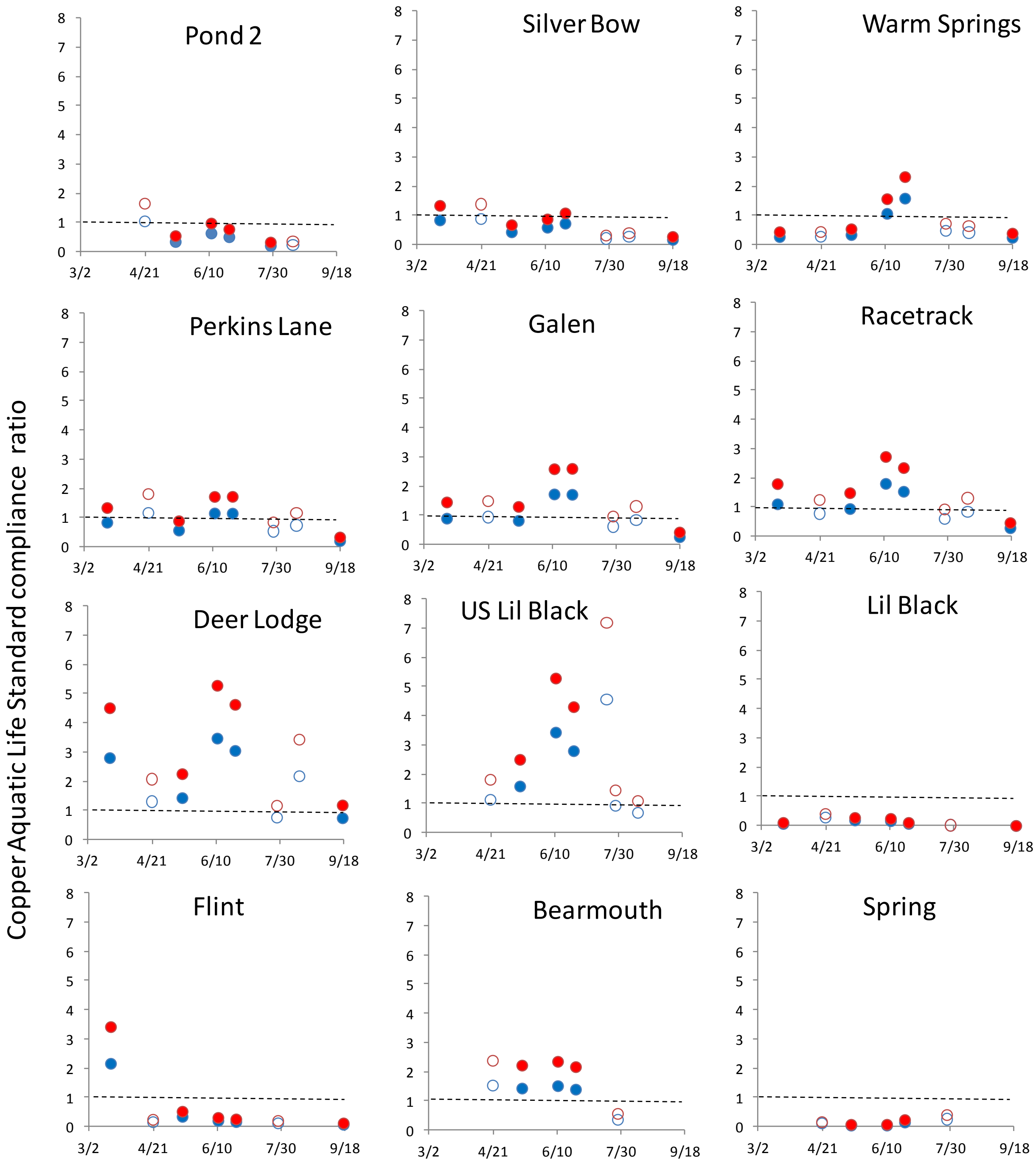


Figure 8-36. Acute (blue dots) and chronic (red dots) compliance ratios for total recoverable copper at the 2014 caged fish sites. Compliance ratios were calculated by dividing the measured copper concentration by the Aquatic Life Standard value [MDEQ, 2012b]. Water samples collected by MFWP are depicted by the open dots and samples collected by RESPEC are depicted with solid dots. Compliance ratio values <1 indicate copper levels below the aquatic life standard while values >1 indicate levels above the standard.

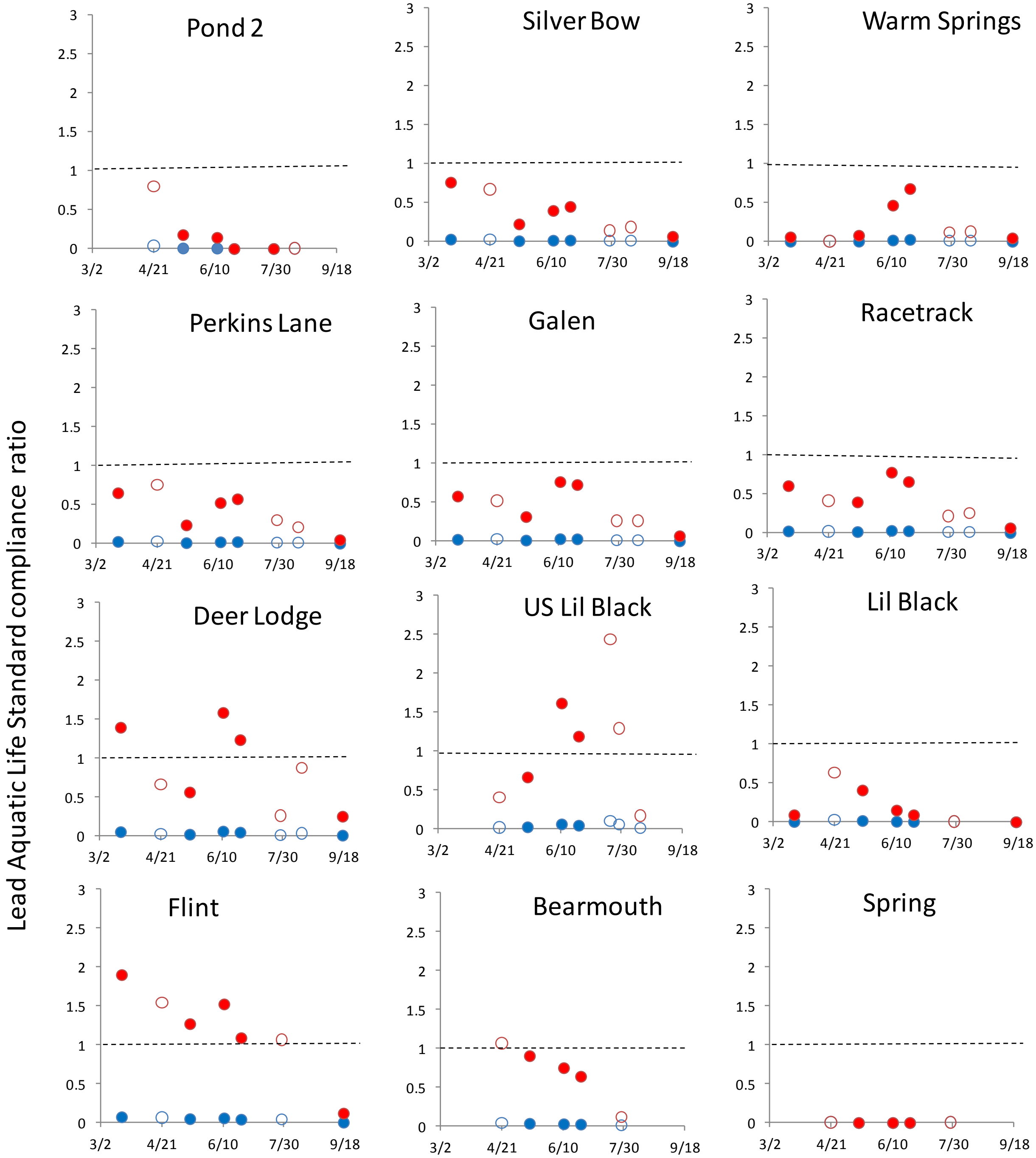


Figure 8-37. Acute (blue dots) and chronic (red dots) compliance ratios for total recoverable lead at the 2014 caged fish sites. Compliance ratios were calculated by dividing the measured lead concentration by the Aquatic Life Standard value [MDEQ, 2012b]. Water samples collected by MFWP are depicted by the open dots and samples collected by RESPEC are depicted with solid dots. Compliance ratio values <1 indicate lead levels below the aquatic life standard while values >1 indicate levels above the standard.

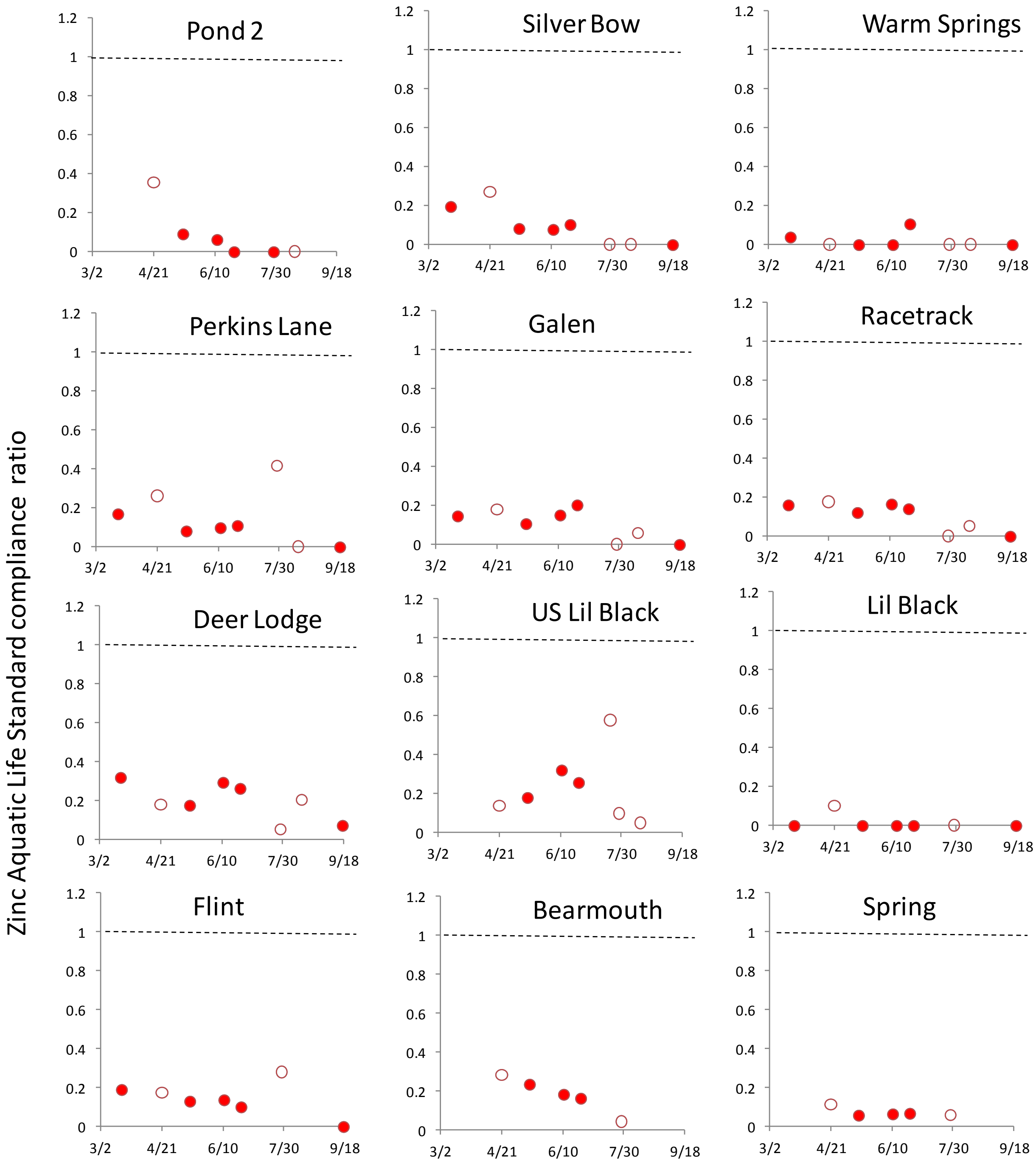


Figure 8-38. Compliance ratios for total recoverable zinc at the 2014 caged fish sites. Compliance ratios were calculated by dividing the measured zinc concentration by the Aquatic Life Standard value [MDEQ, 2012b]. The acute and chronic standards for zinc are identical. Water samples collected by MFWP are depicted by the open dots and samples collected by RESPEC are depicted with solid dots. Compliance ratio values <1 indicate zinc levels below the aquatic life standard while values >1 indicate levels above the standard.

8.3.7 Water Quality

Water quality parameters were recorded on continuously recording Hydrolab ® MS5 water quality probes at Pond 2, Silver Bow, Galen, Racetrack, and U/S Lil Black in 2014. Due to spurious readings in past years, particularly ammonia readings, the Hydrolab was calibrated several times over the course of the field season. Despite recalibration, abnormal data revealed that the specific conductivity probe and dissolved oxygen sensor at Racetrack, dissolved oxygen sensor at Galen, specific conductivity probe at U/S Lil Black, and ammonia sensor at Pond 2 failed for various length of time in 2014. As a result, spurious data were removed from Figure 8-39 through Figure 8-41.

8.3.7.1 pH

Elevated pH was observed at the Pond 2 and at Silver Bow sites [Figure 8-39]. Extended exposure to pH >9 may be harmful to trout [Colt et al., 1979] and results in higher ammonia toxicity (DEQ-7). Mean daily values for pH exceeded 9 in early April, late May, June, July, and August at Pond 2, and at Silver Bow in late June, early July, and much of August. In contrast, mean daily pH at the remaining mainstem sites with probes deployed did not exceed 9 and generally varied from 7.0 to 8.8 [Figure 8-39], which is considered within the ranges suitable for trout [Colt et al., 1979]. For comparison, pH periodically measured with a handheld probe at the tributary sites ranged from 6.6 to7.9.

8.3.7.2 Specific Conductivity

Specific conductivity is a measure of the ability of water to conduct electricity and can be used as a relative measure of water quality. Specific conductivity typically varies from 10 to 1000 μS/cm, but may exceed 1000 μS/cm in polluted waters or waters receiving large quantities of land runoff [Chapman, 1996]. Mean daily specific conductivities at all sites were within normal ranges in 2014 [Figure 8-40]. Specific conductivities ranged from 95 to 711 μS/cm.

8.3.7.3 Luminescent Dissolved Oxygen

The freshwater ALS one day minimum for dissolved oxygen for fish >30 days post- hatch in the Clark Fork River is 4.0 mg/L [MDEQ, 2012b]. Mean daily dissolved oxygen levels never went below this threshold at any site in 2014 [Figure 8-41]. The overall trend in mean daily dissolved oxygen levels was values >11.0 mg/L at all sites up to mid-April then a decrease to between 8-11 mg/L for the remainder of the study. One exception was the U/S Lil Black site that had mean DO values in late August between 7-8 mg/L.

8.3.7.4 Total Ammonia

Water ammonia levels were below the detection limit (0.05 mg/L N) in water samples collected by MFWP and RESPEC during the time period that the Hydrolabs were installed at

Pond 2 and Silver Bow. The Hydrolab recorded mean daily ammonia concentrations of 0.17 mg/L at Silver Bow and 1.45 mg/L at Pond 2 on July 28, and 0.17 mg/L at Silver Bow and 2.84 mg/L at Pond 2 on August 14. The reason for the discrepancy between the Hydrolab and water sample data is likely the result of the ammonia probe not being as reliable as the more common water quality parameters noted above. The precision with which the Hydrolab ® MS5 records total ammonia levels has been questionable in the past (T. Selch, MFWP, personal communication, 2014). As a result of the questionable reliability of the ammonia sensors, ammonia data as recorded by the Hydrolabs are not presented in this report.

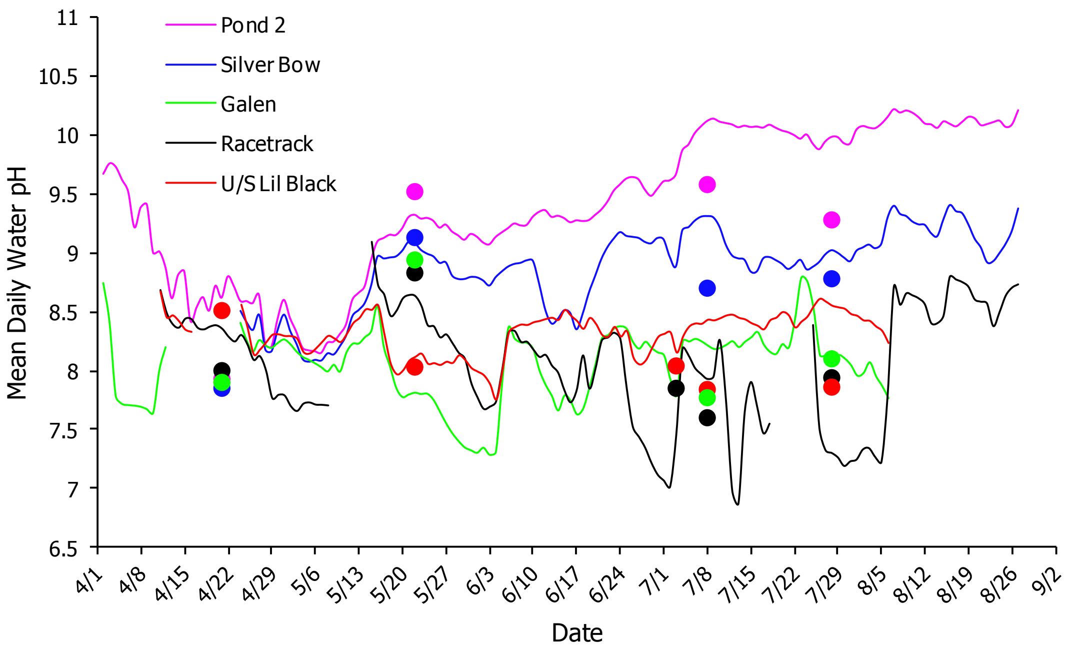


Figure 8-39. Mean daily water pH at sites with probes deployed in 2014. Lines represent Hydrolab data and circles represent handheld multiprobe data.

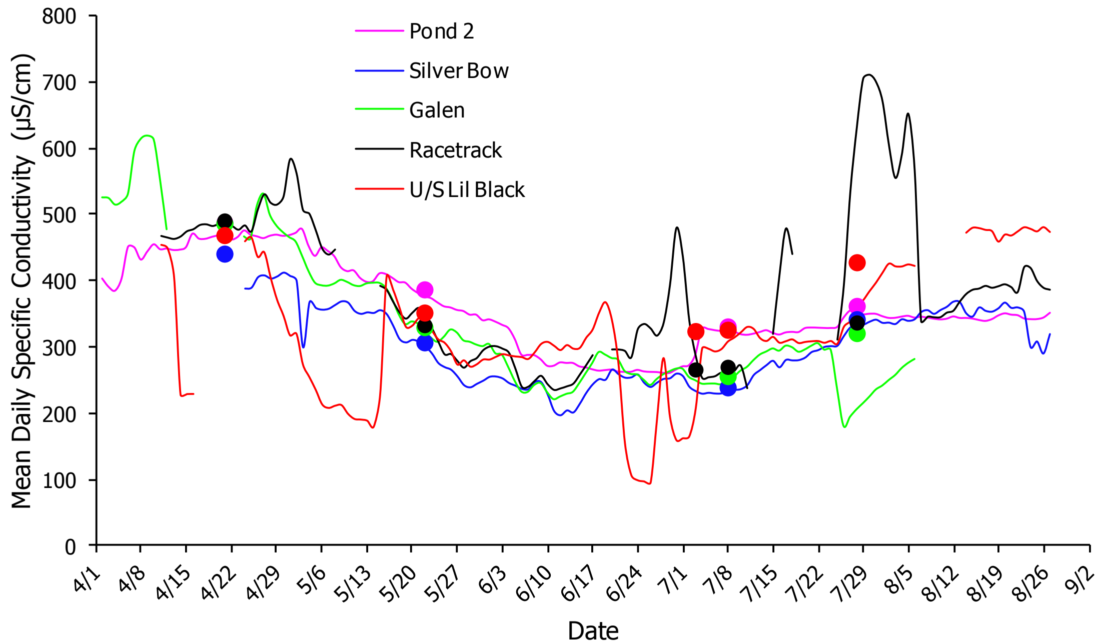


Figure 8-40. Mean daily specific conductivity at sites with probes deployed in 2014. Lines represent Hydrolab data and circles represent handheld multiprobe data.

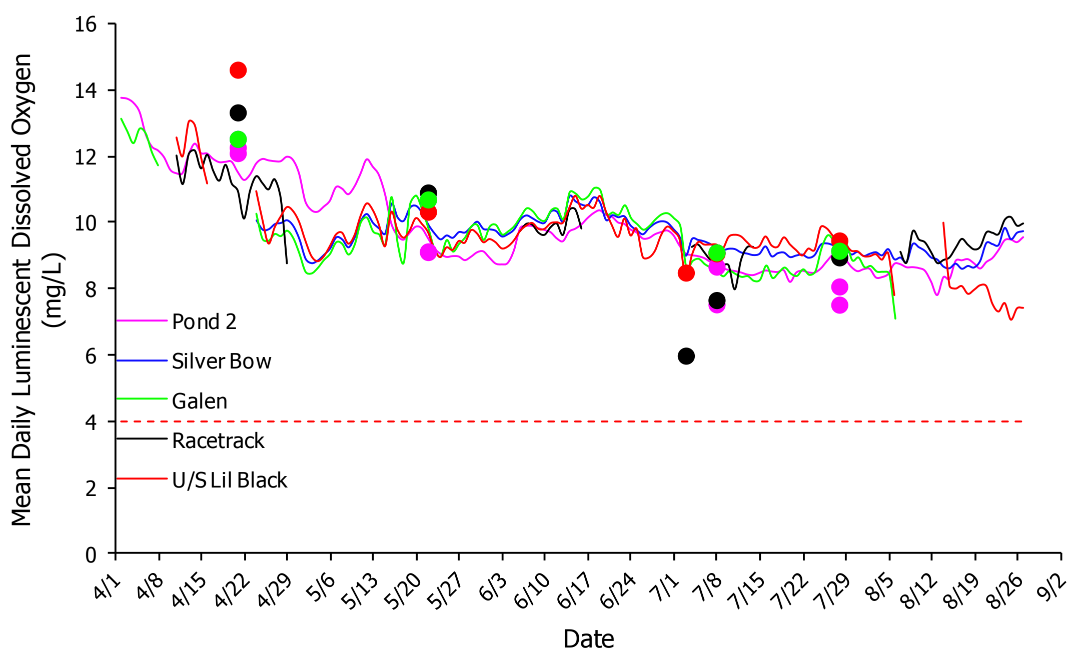


Figure 8-41. Mean daily luminescent dissolved oxygen at sites with probes deployed in 2014. Lines represent Hydrolab data and circles represent handheld multiprobe data. The red dashed horizontal line denotes the freshwater ALS one day minimum.

8.4 DISCUSSION

8.4.1 Trout Population Monitoring

Brown trout population estimates have been generally increasing since 2011 at monitoring sites in the mid- and upper- reaches of the Clark Fork River. Estimates for 2013 and 2014 at the Flint Creek mouth were also slightly higher than previous estimates from this site. The Bearmouth reach consistently supports low numbers of Brown Trout. It is possible that above average discharge in 2011 increased the quality and quantity of Brown Trout spawning and/or rearing habitat in the upper Clark Fork River and tributaries. Based on a telemetry study, most spawning activity in the Upper Clark Fork River drainage takes place in and upstream of the Little Blackfoot River, although a few radio tagged Brown Trout did make spawning related movements into Rock and Flint creeks [Mayfield, 2013].There are many potential reasons for low densities of brown trout in the reach between Flint and Rock Creeks (see Naughton, 2015), but the lack of spawning observed in this reach by Mayfield [2013] may indicate that low recruitment into this reach is an issue.

Fish species composition is dependent on the environmental conditions in the water in which fish live. Heavy metal contamination will tend to favor more tolerant fish species and have more negative effects (reduced survival, growth, or reproduction) for sensitive species [Klerks and Levinton, 1989]. Conversely, as heavy metal contamination in the Upper Clark Fork River is reduced through ongoing remediation efforts, the abundance of sensitive species may increase. There have been numerous studies on the effects of heavy metals on the trout species present in the Upper Clark Fork River, but relatively little is known about how the impacts of heavy metals (or the subsequent cleanup efforts) will affect non-trout species. Therefore, the data collected in 2014 at the two CPUE sections will provide valuable baseline information about the relative abundance of all fish species present in the Clark Fork River.

8.4.2 Survival

Results of this study, as in previous studies in the UCFR [Phillips and Spoon, 1990; Richards et al., 2013; Leon et al., 2014], revealed variation in fish mortality across space and time. Most of the mortality in 2014 in caged fish occurred in April, July, and August. This bimodal pattern is consistent with previous caged fish studies [Richards et al., 2013; Leon et al., 2014] where mortality tended to be highest during spring runoff and on the descending limb of the hydrograph as water temperatures increase. Heavy metal exposure increases in the spring as the concentrations of these metals increase due to the flushing of contaminated soils in the flood plain and river banks [Sando et al., 2014]. Also, hatchery fish used in this study may not have enough time to acclimate to high concentrations of metals in the water. This lack of acclimation could significantly increase their susceptibility to the negative effects of substances such as copper (e.g., Dixon and Sprague [1981]).

The highest mortality rates did not consistently occur at sites with the highest water temperatures or tissue metals burdens. For example Deer Lodge had relatively high survival, but the site also had high copper tissue burdens and 50 days of maximum water temperatures above 19 °C. The U/S Lil Black site also had high copper tissue burdens, 52 days above 19 °C, and the lowest survival of any site in 2014. The site in Warm Springs Creek had relatively low copper tissue burdens, cooler water temperatures, but low survival in 2014. It is clear that environmental factors in the UCFR interact in complex ways to affect fish survival. As such, site-specific survival has not been a clear-cut measure of water quality in caged fish studies in the UCFR [Leon et al., 2013].

Overall, survival was lower (mortality was higher) in 2014 than in previous years. Across all sites, average survival was 89% in 2011, 88% in 2012, 82% in 2013, and 73% in 2014. The reason for the decreased survival is not entirely clear, but could be related to infections of Saprolegnia fungus (Saprolegnia sp.). Saprolegnia is an opportunistic fish parasite that feeds on diseased flesh of injured, diseased, or stressed fish. Saprolegnia is present in most freshwaters and infections are more common during spawning, high water temperatures, or other stressful events. A review of notes from caged fish studies 2011-2014 suggests a possible outbreak of the fungus in 2014. Fungal infections were noted on three Brown Trout mortalities in 2011. There were no noted cases saprolegnia in 2012 or 2013. Fourteen cases were noted in 2014. Cases occurred in every month of the 2014 study from April until July, although July alone had 11 cases. The site at the Pond 2 outflow accounted for 5 of the cases, with other sites having one or two. Fungus was noted at sites from Pond 2 downstream to U/S Little Blackfoot, and was not noted at Bearmouth or in any of the tributaries.

High water temperatures and exposure to copper have been shown to reduce trout growth [Woodward et al., 1995a; Marr et al., 1996; Elliot and Hurley, 2001]. Of all the sites in the 2014 study, the Pond 2 site had the most days with water temperatures above the upper critical threshold of 19 ° C. Based only on water temperature, the fish at the Pond 2 site were predicted to have the lowest growth of any site in this study. Surprisingly, fish at this site displayed the largest increase in weight of any site. The high rate of growth below Pond 2 can be attributed to the "tail water" effect, which results in increased primary and secondary productivity below the ponds. Apparently, food availability has a more significant effect on weight gain than temperature at this site.

8.4.3 Tissue Burdens

Brown Trout used in this study accumulated both copper and zinc in their tissues after they were stocked in cages in both the mainstem Clark Fork River and its tributaries. Tissue burdens of fish straight from the hatchery were low compared to fish sampled from cages in the UCFR drainage. Fish from cages in the mainstem had significantly higher metals burdens compared to fish from tributaries, but the difference was much less for zinc than it was for copper. Higher ratios of copper:zinc in fish tissue in the mainstem versus tributaries is a result consistent with copper:zinc ratios in water sampling conducted in these waters [Leon et al., 2014, Sando et al., 2014].

Copper and zinc tissue burdens of fish collected in tributaries remained relatively stable from month to month over the course of the 2014 study. On the other hand, copper tissue burdens of fish from most mainstem sites appeared to increase over the 2014 field season. Tissue burdens of zinc from Pond 2 and Silver Bow displayed a increasing similar pattern.

From a spatial perspective, copper tissue burdens generally increased upstream to downstream from the Pond 2 site to US Lil Black, an observation consistent with tissue burdens in previous caged fish studies [Leon et al., 2014] and copper concentrations in UCFR water [Sando et al., 2014]. Sando et al. [2014] concluded that suspended sediment and copper concentrations are reduced below Warm Springs Ponds by settling and liming operations within the ponds. Our study supports this conclusion and indicates that less copper is being taken up by fish at sites directly below the ponds. While the Warm Springs Ponds do reduce copper concentrations in the section of the Clark Fork River directly downstream, our results suggest that other water quality factors such as temperature, pH, and ammonia have the potential to negatively affect fisheries downstream. Sando et al. [2014] identified the reach from Galen to Deer Lodge as a major source of additional copper and suspended sediment to the Clark Fork River, a conclusion supported by the increase in copper tissue burdens from the Galen to Deer Lodge sites in this study. The decrease in copper tissue burdens in the Clark Fork River downstream of the Little Blackfoot River indicate that flow from the Little Blackfoot River is important for diluting contaminants and improving water quality.

Comparisons of tissue burdens at sites that were sampled in multiple years indicated relatively consistent values between years. For instance Deer Lodge and U/S Lil Black tended to have high copper tissue burdens from year to year compared to other sites. Pond 2 had copper tissue burdens from year to year that were relatively low compared to other mainstem sites. The Lil Blackfoot site had consistently low copper burdens, whereas the other tributary site in Flint Creek, was more variable from year to year. The Spring control had consistently the lowest copper tissue burdens of all the sites. For zinc, the Spring and Lil Blackfoot sites had consistently low tissue burdens from year to year. Based on the two years that it was sampled, Rock Creek also displayed low tissue burdens. Other sites tended to be more variable in zinc tissue burdens from year to year. Differences in zinc tissue burdens between fish from mainstem and tributary sites were not as apparent as the difference of copper tissue burdens between tributaries and the mainstem.

The consistency in copper tissue burdens from year to year is informative in several ways. First, the technique used to determine tissue metals burdens in this study is repeatable from year to year. Second, sites such as Deer Lodge and U/S Lil Black suggest that the fish in the reach of the Clark Fork River immediately upstream of the Little Blackfoot have the highest potential to be impacted by copper contamination. This conclusion is consistent with concentrations of metals in water samples [Leon et al., 2014; Sando et al., 2014]. Thirdly, reductions in copper tissue burdens following remediation efforts initiated in 2013 are not yet apparent. As remediation efforts continue and remediated sites become revegetated, significant declines in tissue burdens will hopefully become apparent.

8.4.4 Water Contaminants

High pH was observed for much of the study period at the Pond 2 and Silver Bow sites. Liming operations in the Warm Springs Ponds are designed to reduce toxicity of copper, zinc, lead and other cationic metals. However, waters with pH above 9 are considered harmful to trout [Colt et al., 1979]. High pH also causes relatively harmless ammonium (NH_4) to convert to highly toxic ammonia (NH_3) at very low concentrations (<0.885 mg/L). As measured by a continuously logging Hydrolab, ammonia reached highly toxic levels in July and August at Pond 2. However, these values were not supported by periodic water sampling conducted at the site. This discrepancy, coupled with the fact that most caged fish survived through July and August suggest an error in instrumentation occurred. Pond 2 is thought to discharge ammonia when the pond mixes after ice out in March. Water sampling indicates that a pulse of ammonia occurred at the Pond 2 outflow in mid-March of 2014, but this pulse occurred before the caged fish study was initiated for the season.

Periodic water sampling of heavy metal concentrations demonstrated exceedances of the copper ALS at all mainstem sites. Overall, there were more exceedances of copper ALSs than any other contaminant measured in this study. Lack of exceedances of arsenic and zinc are consistent with sampling done in previous years [Leon et al., 2014]. Of all metals measured in this study, copper is present in the Clark Fork River at the highest concentrations relative to its toxicity. The fact that no zinc exceedances were documented in water sampling is interesting considering the elevated levels of zinc in fish tissues. Because zinc is an essential nutrient, it is commonly added to commercial hatchery fish pellets. It is possible that fish in this study obtained at least some of their whole body zinc concentrations from the hatchery food that we used.

8.4.5 Conclusion

Caged fish studies have provided valuable data on fish survival and tissue burdens. These data can be used as baselines to evaluate the efficacy of remediation efforts in the future. For example, post-remediation monitoring may reveal reduced tissue metals burdens and fish mortality as well as changes in the spatial pattern of tissue burdens and water contaminants. Caged fish studies have also highlighted the complex interactions of multiple factors that affect survival of young Brown Trout in the UCFR.

Because sufficient baseline data has been collected, caged fish studies in the next few years will shift to focusing specifically on monitoring potential impacts that remediation activities may have on the UCFR. Better understanding of the processes occurring at the Warm Springs Ponds and the impact that discharge from these ponds have on fish in the UCFR is also needed. We will deploy fish cages earlier in the spring and monitor ammonia concentrations during the period of time that Pond 2 experiences turnover. More information on the influences of mortality, recruitment, and role of water contaminants on wild fish in the UCFR is also needed. Age and growth, mortality, and recruitment studies of wild fish in the UCFR will be completed in coming years. This data will serve as a baseline to assess changes in fish population metrics as remediation and restoration activities continue in both the mainstem and tributaries of the UCFR.

8.5 Acknowledgements

This study would not have been possible without the help of a host of people. MFWP technician Ben Whiteford conducted the majority of the fish cage monitoring. John Day also monitored fish cages and was a great help with data entry. Lindsey Gilstrap diligently maintained water quality monitoring equipment and helped with lab work. Rob Clark provided advice for cage construction, site selection, and maintenance schedules and David Schmetterling provided invaluable advice on study design and assisted with analyses. Jim Drissell provided Brown Trout for the cages from the Big Springs Trout Hatchery. Thanks to Joe Naughton for delivering water sampling equipment, often on short notice.

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