Final

PRE-MINING WATER QUALITY
NEW WORLD MINING DISTRICT
RESPONSE AND RESTORATION PROJECT

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April 2009

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1.0 INTRODUCTION

The State of Montana has classified streams in the New World Mining District as B-1 under the State of Montana Water Quality Act (§§ 75-5-101 et seq., Montana Code Annotated {MCA}). The definition of B-1 is waters that are suitable for drinking, culinary and food processing (after conventional treatment), bathing, swimming and recreation, growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers, and agricultural and industrial water supply. Water quality in certain upper reaches of the District's streams does not meet B-1 narrative standards and also exceeds other water quality criteria specified in Montana Department of Environmental Quality (MDEQ) Circular DEQ-7 (MDEQ, 2008), in part due to past mining activities. Reclamation activities for the New World District Response and Restoration Project have been conducted under temporary water quality standards approved by the Board of Environmental Review on June 4, 1999. The standards were adopted for Fisher Creek, Daisy Creek, and a portion of the upper Stillwater River for a period of 15 years from the date of approval and will expire in 2014.

It is unlikely that the water quality in streams for which the New World temporary standards were issued will improve sufficiently to support the designated uses for waters classified B-1. This is likely, in part, due to natural mineralization in the New World District. It is known that surface water in mineralized areas can sometimes be impacted by acid rock drainage and metal loading even in the absence of mining disturbance (Runnells et al., 1992). Many mineralized areas have been historically mined and it can be difficult to quantify the relative impacts of mine-related versus natural inputs to surface water quality. A variety of approaches have been reported for estimating pre-mining metal concentrations in areas affected by mining, although none have gained widespread acceptance by the regulatory community. These approaches include analysis of historical data (Maest et al., 1998; Maest et al., 2004), using other similarly mineralized areas as analogs (Rose et al., 1979; Davis et al., 2000; Bove et al., 2007), collecting stream sediment deposited prior to mining (Persaud et al., 1993; Church et al., 2000; Hren et al., 2001), using stable isotopes to distinguish mining-affected water (Verplanck et al., 2001; Nordstrom et al., 2007), geochemical modeling (Runnells et al., 1992; Walton-Day et al., 1999; Runkel et al., 2007), statistical analyses (Sinclair 1976; Runnells et al., 1998), detailed synoptic sampling (Kimball et al., 1999), using the geochemistry of ancient ferricrete deposits (Nimick et al., 2009). Because of the potential lack of certainty of any single method, the simultaneous use of a combination of these methods has been recommended to increase the confidence in estimating pre-mining water quality (Maest et al., 2007).

This report uses multiple methods to quantify surface water quality in the New World mining district as it existed prior to historic mining operations. These data could provide a basis for evaluating potential changes to the B-1 classification of Daisy Creek, Fisher Creek, and a portion of the upper Stillwater River as it may not be possible to remediate these streams to meet standards that are lower than pre-mining background conditions.

1.1 PROJECT BACKGROUND

On August 12, 1996, the United States signed a Settlement Agreement (Agreement) with Crown Butte Mines, Inc. (CBMI) to purchase CBMI's interest in their New World Mining District (District) holdings. This transfer of property to the U.S. government effectively ended CBMI's proposed mine development plans and provided $22.5 million to cleanup historic mining impacts in the District. In June 1998, all interested parties and CBMI signed a Consent Decree (Decree). The Decree, approved by the United States District Court, finalized the terms of the Agreement and made available the funds that are being used for mine cleanup. As specified in the Decree, monies available for cleanup will be spent first on

District Property, which, as defined, includes all property or interests in property that CBMI relinquished to the United States. As funds are available after District Property is cleaned up to the satisfaction of the United States, other mining disturbances in the District may be addressed.

The USDA Forest Service, as the lead agency responsible for implementing the cleanup, has assembled a management team and has published objectives to guide reclamation and restoration of the historic mining impacts in the District. Under their Superfund authority, the USDA Forest Service continues to execute the response and restoration project by following guidance provided by the Environmental Protection Agency (EPA) for non-time-critical removal actions (EPA, 1993). Non-time-critical removal actions are defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) as actions that are implemented by the lead agency to respond to "the cleanup or removal of released hazardous substances from the environment … as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment…" (EPA, 1993).

In 1995, EPA began a site investigation after the initial announcement of the property transfer from CBMI. The EPA investigation included, among other things, the installation of monitoring wells, surface water sampling, groundwater monitoring, and completion of a groundwater tracer study. In October 1998, the USDA Forest Service assisted CBMI in completing and submitting a Support Document and Implementation Plan in support of the CBMI's petition for temporary modification of water quality standards. Under the Decree and Agreement, CBMI is required to submit petitions regarding temporary standards if requested by the USDA Forest Service. The Support Document and Implementation Plan (Stanley and Maxim, 1998) was submitted to the State of Montana Board of Environmental Review (Board) on January 22, 1999. The petition for the adoption of temporary standards for Fisher Creek, Daisy Creek, and a portion of the upper Stillwater River was accepted by the Board and noticed for public hearing. The proposed rule was modified to reflect public comment and the temporary water quality standards were approved and adopted by the Board on June 4, 1999. The goal of the temporary standards is to allow the project to proceed so that water quality in Fisher Creek, Daisy Creek, and the Stillwater River can be improved to the point where these streams meet beneficial uses for waters classified B-1 under classification standards established by the State of Montana.

The temporary standards can be changed as improvements in water quality are realized. The standards are reviewed every three years to determine if changes are desirable. The first review occurred in July 2002 when the Board held a hearing on July 26, 2002, to review the long-term water quality data collected since the standards became effective in June 1999 and to compare project progress with that presented in the implementation plan (Maxim, 2002). As a result of this review, the Board took no action to modify the temporary standards as originally defined in June 1999. A second tri-annual review hearing on temporary water quality standards was held by the Board on June 3, 2005, with the same result. A third tri-annual review was held before the Board on May 30, 2008, and again resulted in no adjustment to the existing temporary water quality standards.

1.2 SITE LOCATION AND DESCRIPTION

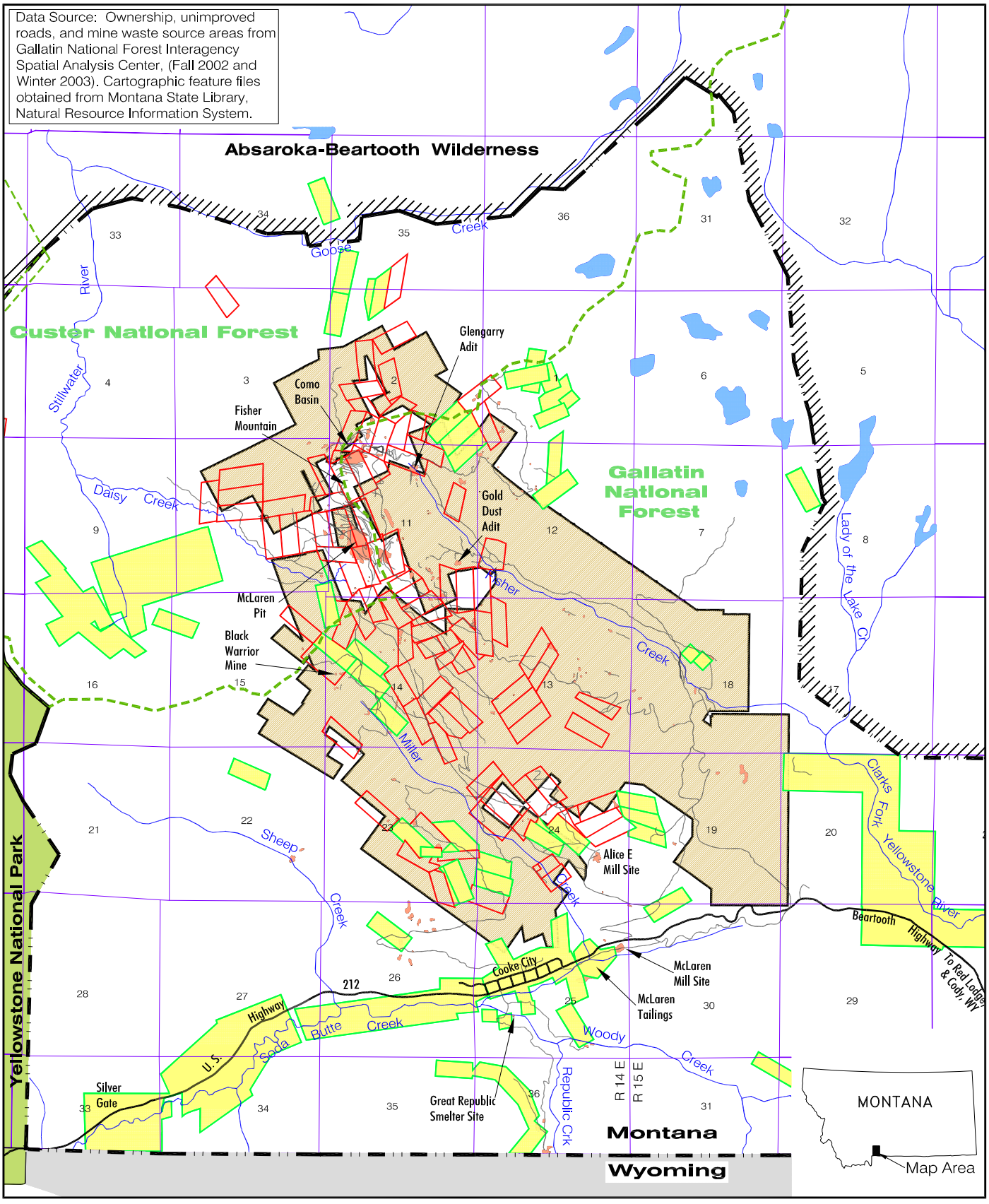
The District falls within the Gallatin and Custer National Forests and abuts Yellowstone National Park's northeast corner. The Absaroka-Beartooth Wilderness Area bounds the District to the north and east, with the Montana-Wyoming state line forming the southern boundary of the District. The District lies entirely within Park County, Montana (**Figure 1-1**).

The communities of Cooke City and Silver Gate, Montana, are the only population centers near the District. The neighboring communities of Mammoth, Wyoming, and Gardiner, Montana, are located about 80 kilometers (50 miles) to the west. Red Lodge, Montana, is located about 105 kilometers (65 miles) to the northeast via the Beartooth Highway, and Cody, Wyoming, is located 95 kilometers (60 miles) to the southeast.

The District is located at an elevation that ranges from 2,400 meters (7,900 feet) to over 3,170 meters (10,400 feet) above sea level. The site is snow-covered for much of the year and only one route of travel is open on a year-round basis -- the highway between Mammoth and Cooke City. The Sunlight Basin road permits access to the District from northwestern Wyoming during the spring, summer, and fall but only allows access to within a few miles of the District in winter. The Beartooth Highway allows access to the District from the northeast but is closed during winter.

The District covers an area of about 10,360 hectares (25,600 acres). Historic mining disturbances affect about 20 hectares (50 acres) located on District Property. Mining disturbances on non-District Property include the McLaren Tailings and McLaren Mill-site, which cover an additional 6.9 hectares (17 acres).

The topography of the District is mountainous with dominant glacial erosional and depositional features, and is situated at the headwaters of three river systems that all flow into the Yellowstone River. The three tributaries are the Clarks Fork of the Yellowstone, the Stillwater, and the Lamar. The Lamar River flows through Yellowstone Park. The major tributary streams in the District include Daisy, Miller, Fisher, Goose, Sheep, Lady of the Lake, Republic, Woody, and Soda Butte creeks.



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Project Vicinity Map
New World Mining District
Response and Restoration Project
Cooke City Area, Montana
FIGURE 1-1

1.2.1 Current Surface Water Quality in Daisy Creek

The main stem of Daisy Creek is monitored at two locations: DC-2, down-gradient of and near the capped and reclaimed McLaren Pit, and farther downstream at DC-5, above the confluence of Daisy Creek with the Stillwater River (Figure 1-2).

Annual monitoring of station DC-2 indicates continued improvement in water quality since construction of the McLaren Pit impermeable membrane/soil composite cap in October 2003. With the cap in place, more melt water during the spring and early summer snowmelt period runs off to upper Daisy Creek without first becoming contaminated by historical mine wastes. The cap prevents snowmelt from infiltrating into the underlying metal and sulfide rich soil, waste materials, and bedrock and thus reduces the load of metals and acid contributed from this area to Daisy Creek. In addition, this large reduction of infiltration (recharge) into the McLaren Pit mine waste is believed to result in lower stream flow of the tributaries to upper Daisy Creek during "low flow" periods (August to April) (Maxim 2005).

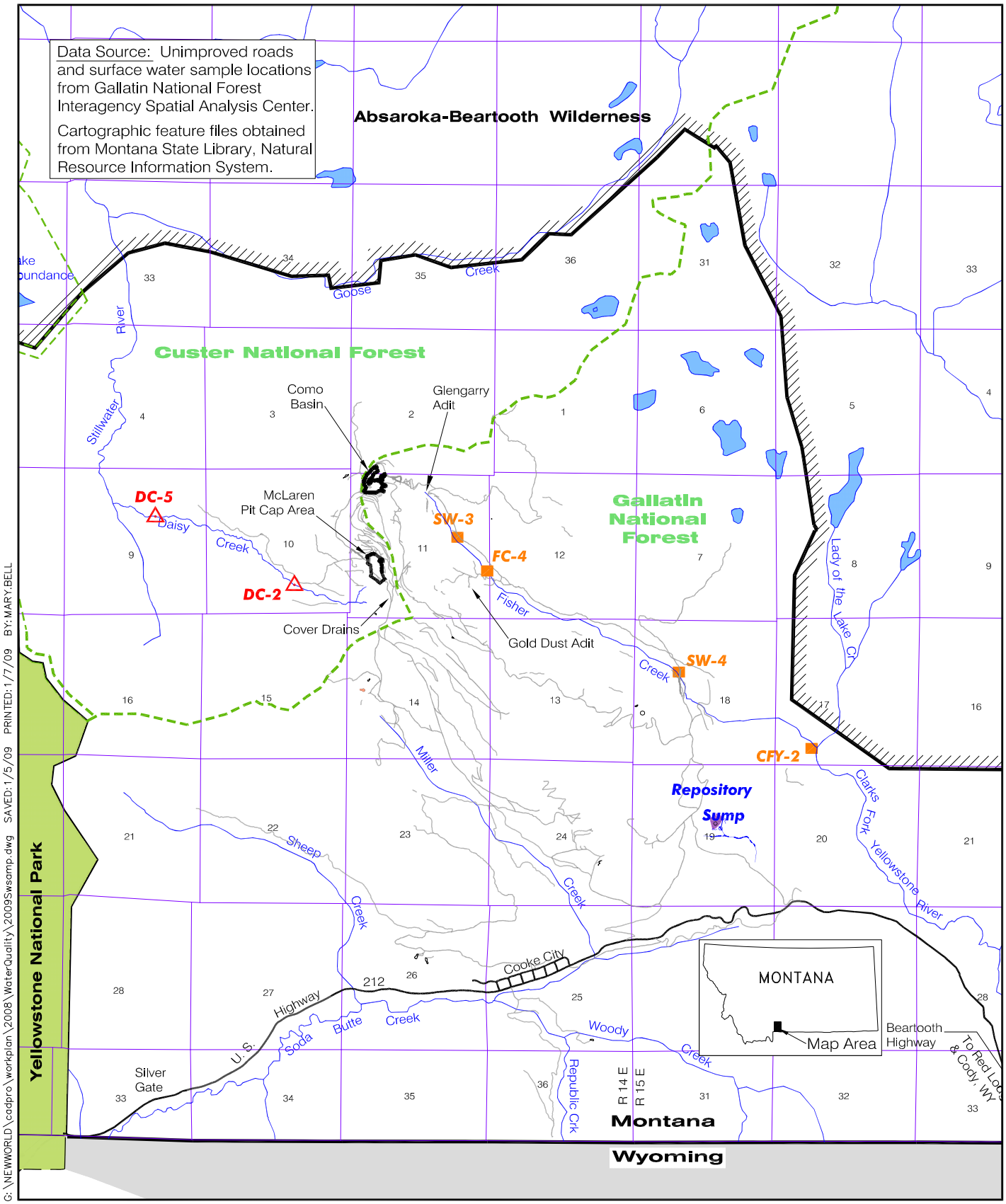
Water quality at DC-2 was poor and acidic during the low flow periods monitored in April and September 2007 (**Table 1-1**), which is consistent with previous data collected at this station during low flow periods, both pre- and post-capping. During high flow conditions in June 2007, the pH of water sampled at this station was only slightly acidic, and concentrations of all metals except lead were much lower. Similar conditions were observed in June monitoring events during 2004, 2005, and 2006.

Cadmium, copper, iron, and zinc exceeded acute and/or chronic aquatic life standards during the three 2007 monitoring events (April, June and September) at DC-2 (**Table 1-1**). In addition, lead exceeded the chronic aquatic life standard during June and September. Human health standards and/or guidelines for copper, iron, and manganese were also exceeded in most samples collected at DC-2 in 2007.

At station DC-5, pH of the water is notably higher than that measured at station DC-2 due to the addition of more carbonate-rich water from bedrock and tributary sources located downstream of DC-2. Total recoverable trace metal concentrations are also considerably lower at DC-5 compared to DC-2 (**Table 1-2**), because of dilution from tributary inflows and settling of some of the particulate metals that precipitate from the relatively high pH water of the upstream reach.

Copper and iron exceeded acute or chronic aquatic life standards during the three 2007 monitoring events at DC-5 (**Table 1-2**). Cadmium and zinc exceeded acute or chronic aquatic life standards in at least one of the three monitoring events. Iron and manganese exceeded human health guidelines during all three sampling events. The temporary water quality standard for manganese was exceeded in the April monitoring event.

At both monitoring stations, metal concentrations are lowest and pH greatest during high flow conditions in June. The one exception to this is lead, which is present at greatest concentrations during high flow.



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Surface Water Monitoring Stations
on Daisy and Fisher Creeks
New World Mining District
Response and Restoration Project
Cooke City Area, Montana
FIGURE 1-2

Table 1-1. Selected Water Quality Data for Daisy Creek Monitoring Station DC-2

Parameter (mg/l)	Aquatic Life (acute)	Aquatic Life (chronic)	Human Health Standard (Iron & Manganese values are guidelines)	DC-2 (Total Recoverable)			
				Narrative Water Quality Standard[1]	Apr-07	Jun-07	Sep-07
Aluminum[3]	0.75	0.087	NA	**28.4**	8.30	3.70	13.4
Cadmium	0.00213[4]	0.00027[4]	0.005	**0.009**	0.0036	0.0004	0.0042
Copper	0.0140[4]	0.0093[4]	1.3	**8.064**	1.44	0.41	3.58
Iron	NA	1	0.3	**29.649**	12.0	5.36	12.90
Lead	0.082[4]	0.0032[4]	0.015	**0.018**	0.003	0.009	0.004
Manganese	NA	NA	0.05	**4.088**	1.76	0.23	2.37
Zinc	0.1198[4]	0.1198[4]	2	**1.104**	0.46	0.07	0.61
Hardness	NA	NA	NA	NA	211	64	270
Lab pH (s.u.)	NA	NA	NA	**2.7**	4.9	6.5	4.1
Flow (cfs)	NA	NA	NA	NA	0.05	10.2	0.15

Table 1-2. Selected Water Quality Data for Daisy Creek Monitoring Station DC-5

Parameter (mg/l)	Aquatic Life (acute)	Aquatic Life (chronic)	Human Health Standard (Iron & Manganese values are guidelines)	DC-5 (Total Recoverable)			
				Temporary Water Quality Standard[2]	Apr-07	Jun-07	Sep-07
Aluminum[3]	0.75	0.087	NA	**9.510**	1.23	1.39	4.23
Cadmium	0.00213[4]	0.00027[4]	0.005	**0.004**	0.0007	0.0002	0.0014
Copper	0.0140[4]	0.0093[4]	1.3	**3.530**	0.250	0.019	1.160
Iron	NA	1	0.3	**6.830**	1.03	1.73	5.04
Lead	0.082[4]	0.0032[4]	0.015	NA	<0.001	0.003	0.002
Manganese	NA	NA	0.05	**1.710**	0.32	0.099	0.740
Zinc	0.1198[4]	0.1198[4]	2	**0.540**	0.09	0.02	0.22
Hardness	NA	NA	NA	NA	156	55	207
Lab pH (s.u.)	NA	NA	NA	**4.6**	7.8	7.9	7.6
Flow (cfs)	NA	NA	NA	NA	0.43	30.7	0.42

Notes for Tables 1-1 and 1-2.

Shading/coloring indicates exceedance of respectively shaded/colored regulatory standard.

[1] Narrative Water Quality Standards apply to any point in affected stream segments and are included in the rule for temporary water quality standards. As with the temporary standards, narrative standards are calculated as the mean plus 2 standard deviations.

[2] Temporary Water Quality Standards are set in accordance to the rule adopted by the Board of Environmental Review. These standards apply to specific surface water sampling stations and shall not be exceeded more than 3% of the time.

[3] Aluminum standard applies to dissolved concentrations in water with a pH between 6.6 to 9.0 s.u.

[4] Based on 100 mg/l hardness.

1.2.2 Current Surface Water Quality in Fisher Creek

Three locations are monitored annually on the main stem of Fisher Creek: SW-3 near the head of the drainage below the Glengarry and Glengarry Mill-site adits, SW-4 at the Lulu road crossing, and CFY-2 above the confluence with the Clark's Fork of the Yellowstone. A fourth location, FC-4, was monitored in 2007. This station is located between SW-3 and SW-4 and is above the confluence of Fisher Creek with the Gold Dust Adit tributary (Figure 1-2).

At SW-3, water quality was poor and acidic during each of the three 2007 monitoring events, which is consistent with previous data collected at this station both before and after closure of the Glengarry Adit. Total recoverable cadmium, copper, iron, lead, and zinc exceeded acute and/or chronic aquatic life standards during at least two of the three 2007 monitoring events (**Table 1-3**). Human health guidelines for iron and manganese were exceeded during all three 2007 monitoring events.

Temporary positive affects on water quality at SW-3 may be occurring due to leaching of carbonate from cement and soil amendments used in closing the Glengarry adit and remediating the Como Basin.

At station FC-4, water quality was improved compared to SW-3 during the September monitoring event (**Table 1-3**) however total recoverable cadmium, copper, iron, and lead still exceeded acute and/or chronic aquatic life standards. Human health guidelines for iron and manganese were also exceeded.

At station SW-4, total recoverable and dissolved cadmium concentrations exceeded the chronic aquatic life standard during the April and September monitoring events. Total recoverable and dissolved copper concentrations exceeded the chronic and acute aquatic life standards during all three monitoring events (**Table 1-4**). However, water quality at SW-4 is considerably better than at stations SW-3 and FC-4, with a higher pH (toward the near-neutral range) that allows metals to precipitate in the stream. Dilution from tributaries and settling of the precipitated metals results in an order of magnitude reduction in aluminum, copper, iron, and manganese concentrations at SW-4.

Decreases in metal concentrations and increases in pH values continue in the reach of stream between SW-4 and CFY-2. At station CFY-2, only total recoverable copper concentrations exceeded the chronic and acute aquatic life standards in the June and September monitoring events. Dissolved copper concentrations also exceeded the chronic and acute aquatic life standards in the June monitoring event (**Table 1-5**).

As is the case with Daisy Creek, metal concentrations other than lead are lowest during periods of high flow at SW-3. Farther downstream at stations SW-4 and CFY-2, concentrations of dissolved aluminum, and total recoverable copper, iron, and manganese are greatest during high flow conditions.

Table 1-3. Selected Water Quality Data for Fisher Creek Monitoring Stations SW-3 and FC-4

Parameter (mg/l)	Aquatic Life (acute)	Aquatic Life (chronic)	Human Health Standard (Iron & Manganese values are guidelines)	SW-3 (Total Recoverable)				FC-4 (Total Recoverable)
				Narrative Water Quality Standard[1]	Apr-07	Jun-07	Sep-07	Sep-07
Aluminum[2]	0.75	0.087	NA	**4.54**	2.14	1.72	2.51	1.11
Cadmium	0.001054[3]	0.000162[3]	0.005	**0.002**	0.001	0.0002	0.0008	0.0004
Copper	0.0073[3]	0.00516[3]	1.3	**1.256**	0.75	0.32	0.84	0.36
Iron	NA	1	0.3	**9.259**	0.87	2.46	1.26	0.35
Lead	0.0338[3]	0.0013[3]	0.015	**0.01**	0.001	0.002	0.002	<0.001
Manganese	NA	NA	0.05	**1.718**	0.45	0.13	0.57	0.28
Zinc	0.067[3]	0.067[3]	2	**0.225**	0.14	0.01	0.12	0.06
Hardness	NA	NA	NA	NA	56	31	62	42
pH (s.u.)	NA	NA	NA	**2.1**	4.0	5.8	3.9	4.32
Flow (cfs)	NA	NA	NA	NA	0.065	6.94	0.14	0.426

Table 1-4. Selected Water Quality Data for Fisher Creek Monitoring Station SW-4

Parameter (mg/l)	Aquatic Life (acute)	Aquatic Life (chronic)	Human Health Standard (Iron & Manganese values are guidelines)	SW-4 (Total Recoverable)			
				Narrative Water Quality Standard[1]	Apr-07	Jun-07	Sep-07
Aluminum[2]	0.75	0.087	NA	**0.740**	<0.05	0.30	0.07
Cadmium	0.001054[3]	0.000162[3]	0.005	**0.001**	0.0002	<0.0001	0.0002
Copper	0.0073[3]	0.00516[3]	1.3	**0.172**	0.038	0.069	0.044
Iron	NA	1	0.3	**1.726**	0.02	0.27	0.05
Lead	0.0338[3]	0.0013[3]	0.015	**0.005**	<0.001	<0.001	<0.001
Manganese	NA	NA	0.05	**0.790**	0.014	0.020	0.033
Zinc	0.067[3]	0.067[3]	2	**0.660**	0.04	<0.01	0.02
Hardness	NA	NA	NA	NA	45	31	59
pH (s.u.)	NA	NA	NA	**5.241**	6.4	7.3	7.0
Flow (cfs)	NA	NA	NA	NA	0.58	46.70	0.88

Notes for Tables 1-3 and 1-4.

Shading/coloring indicates exceedance of respectively shaded/colored regulatory standard.

[1] Narrative Water Quality Standards apply to any point in affected stream segments and are included in the rule for temporary water quality standards. As with the temporary standards, narrative standards are calculated as the mean plus 2 standard deviations.

[2] Aluminum standard applies to dissolved concentrations in water with a pH between 6.5 to 9.0 s.u.

[3] Based on 50 mg/l hardness.

Table 1-5. Selected Water Quality Data for Fisher Creek Monitoring Station CFY-2

Parameter (mg/l)	Aquatic Life (acute)	Aquatic Life (chronic)	Human Health Standard (Iron & Manganese values are guidelines)	CFY-2 (Total Recoverable)			
				Temporary Water Quality Standard[1]	Apr-07	Jun-07	Sep-07
Aluminum[2]	0.75	0.087	NA	**0.470**	<0.05	0.14	<0.05
Cadmium	0.001054[3]	0.000162[3]	0.005	NA	<0.0001	<0.0001	<0.0001
Copper	0.0073[3]	0.00516[3]	1.3	**0.110**	0.005	0.040	0.008
Iron	NA	1	0.3	**0.750**	<0.01	0.13	0.01
Lead	0.0338[3]	0.0013[3]	0.015	**0.002**	<0.001	<0.001	<0.001
Manganese	NA	NA	0.05	**0.082**	<0.003	0.010	<0.003
Zinc	0.067[3]	0.067[3]	2	**0.044**	<0.01	<0.01	<0.01
Hardness	NA	NA	NA	NA	42	33	54
pH (s.u.)	NA	NA	NA	**5.7**	6.8	7.4	7.3
Flow (cfs)	NA	NA	NA	NA	0.84	43.4	0.92

Notes for Tables 1-5.

Shading/coloring indicates exceedance of respectively shaded/colored regulatory standard.

[1] Temporary Water Quality Standards are set in accordance to the rule adopted by the Board of Environmental Review. These standards apply to specific surface water sampling stations and shall not be exceeded more than 3% of the time.
[2] Aluminum standard applies to dissolved concentrations in water with a pH between 6.5 to 9.0 s.u.
[3] Based on 50 mg/l hardness.

1.3 PURPOSE AND OBJECTIVES

The purpose of this report is to estimate what surface water quality might have been in Daisy and Fisher Creeks prior to mining in the New World District. Because the area of interest has been disturbed by mining, it is not possible to directly measure the pre-mining conditions. A variety of methods have been proposed to estimate pre-mining water quality conditions but none provide certainty. Therefore, various methods are used in this report to infer the estimated pre-mining conditions. The first section summarizes a variety of qualitative evidence that indicates that surface water quality was acidic and metal rich prior to mining. The following sections present more quantitative evidence of what surface water quality conditions might have been. The methods used to develop this evidence include estimating pre-mining water-quality from ferricrete deposits, assessing existing water-quality in springs and seeps emanating from mineralized but unmined geographic areas, and using loading analyses to better understand the magnitude of metal loading to Daisy and Fisher Creek from known mining features.

2.0 QUALITATIVE EVIDENCE OF PRE-MINING ACIDIC, METAL-RICH SURFACE WATER QUALITY

Data presented in this section indicate, at least qualitatively, that pre-mining surface water quality likely was impacted by natural acid rock drainage and metal loading prior to mining activities.

2.1 MINERAL-DEPOSIT TYPE

Mineral deposits in the New World District occur principally in stratiform carbonate-hosted, massive sulfide/iron-oxide and skarn-replacement deposits (Kirk and Kirk, 2002, 2005), some of which are exposed at the surface. Although carbonate-hosted mineral deposits such as these generally have lower probability than other types of mineral deposits of producing adverse environmental effects (Plumlee et al., 1999), the majority of the rocks that comprise the deposits at New World are acid generating (Kirk and Kirk, 2005). Neutralization potential varies spatially in the district, and therefore some rocks are more likely to be acid generating. In particular, disseminated sulfide mineralization in the intrusive porphyry rocks and the massive-sulfide replacement deposits in limestones are strongly acid generating, but locally portions of the limestone-hosted replacement/skarn deposits are net neutralizing. Generally, the exposed and near surface portions of the McLaren, Como, and Fisher Mountain deposits are strongly acid generating. Similar mineralization occurs in the unmined Miller Creek deposit; however because this deposit does not outcrop and is below the regional groundwater table, sulfide oxidation likely is restricted and consequent acid production from this deposit may be limited. Plumlee et al. (1999) attributed the acidic metal-rich drainage waters at New World to the lack of neutralizing reactions between acid water and the calc-silicate alteration minerals in the skarns and the carbonate minerals that may remain in the original sedimentary host rocks. It is likely that this scenario of net acid generation of exposed massive sulfide replacement deposits and exposed disseminated sulfides in intrusive stocks would exist in the absence of mining or under pre-mining conditions.

2.2 STREAM SEDIMENTS

Several studies in historical mining districts have determined both the natural background level of metal contamination in streams as well as the additional mining-induced component by examining metal concentrations in stream sediments deposited before and after mining (Leenaers and Schouten, 1988; Macklin et al., 1994; Church et al., 2004).

A similar study conducted by Hren et al. (2001) in Fisher Creek examined copper and iron concentrations in fine-grained overbank stream sediments deposited before and after mining. The relative timing of sediment deposition was determined using a flood surface model developed during the study.

The study found that leachable iron and copper concentrations do not follow typical distance decay curves relative to the location of the source of loading (i.e., the Glengarry Adit). Instead, mean leachable copper concentrations in post-mining sediments increased with distance from the adit to a peak of about 2,000 ppm 3 to 4 km downstream. Leachable iron concentrations changed little with distance between 1 and 6.5 km from the adit and were statistically equal with little variation about the mean (i.e., around 30,000 ppm) although a peak concentration of about 48,000 ppm was measured 3 km below the adit.

Copper and iron concentrations in pre-mining sediments also had highest concentrations at 3 to 4 km downstream of the Glengarry Adit, but these concentrations decreased to lower levels farther downstream compared to post-mining sediments. Mean and peak copper concentrations measured in

pre-mining sediments between 3 and 4 km downstream of the Glengarry Adit were about 1,500 and 2,700 ppm respectively, very similar to concentrations measured in post-mining sediments in this same stretch of stream. The mean iron concentration of about 46,000 ppm is also similar to that of post-mining sediments in this reach. Hren et al. (2001) pointed out that while pre-mining sediments displayed a greater decrease in copper and iron concentrations at distances beyond 4 km, both pre- and post-mining sediments had similar mean concentrations of copper and iron (about 1,200 and 30,000 ppm, respectively) in the upper 3 km of the stream.

Hren et al. (2001) supported their conclusion that metal rich sediments, similar in copper and iron concentrations to those deposited post-mining, had been deposited prior to mining with radiocarbon dating of 860 and 8,220 year-old organic materials found in iron- and copper-rich layers at one of their study sites. In addition, they observed iron-rich sediments located beneath tree roots dated between 100 and 125 years.

2.3 FERRICRETE

Ferricrete is a common geologic deposit in both mined and unmined mineralized areas (Lovering, 1929; Pardee and Schrader, 1933; Miller and McHugh, 1994; Logsdon et al., 1996; Yager et al., 2003; Verplanck et al., 2007). Ferricrete forms when alluvial or colluvial material is cemented by the iron-precipitates that form as acidic water rich in ferric iron is neutralized, or as reduced (anoxic) water rich in ferrous iron is oxidized. Holocene ferricrete deposits in metal-mining districts have been widely recognized as indicators of ancient acid rock drainage (Bassett et al., 1992; Plumlee et al., 1995; Furniss et al., 1999; Yager et al., 2003; Wirt et al., 2007).

Prominent alluvial ferricrete deposits occur along the valley bottoms of Fisher and Daisy Creeks, and colluvial ferricrete deposits are found higher on the valley walls (Lovering, 1929; Furniss and Hinman, 1998). Alluvial ferricrete is exposed along Fisher and Daisy Creeks as 0.1- to 2-m thick lenses of iron-cemented gravels as much as 2 m above modern stream level. These ferricrete outcrops extend downstream along the first 1.2 km of Daisy Creek and the first 2 km of Fisher Creek (Fig. 1). Similar ferricretes are forming in the streambeds of the modern channels, suggesting that the ancient ferricretes were formed at the level of paleo-stream channels and have been preserved as terraces by incision. Logs, twigs, algae, moss, and Mt. Mazama ash are locally preserved within the ferricretes. The ages of the ferricrete deposits were established using ^{14}C-dating of co-deposited wood fragments. Based on the ages of over 20 samples, natural acidic drainage has occurred in upper Daisy and Fisher Creeks over the last 8,840 years (Furniss and Hinman, 1998; Furniss et al., 1999; Hren et al., 2001).

2.4 INFLOW FROM UNMINED AREAS

Detailed synoptic sampling studies were conducted during low flow in Fisher Creek in 1997 by Kimball et al. (1999) and in Daisy Creek in 1999 by Nimick and Cleasby (2001). These studies identified and quantified the sources of metal loading contributed by surface and subsurface inflows to these streams. Metal-rich and acidic inflows from areas not affected physically or hydrologically by mining were identified and are evidence of conditions likely to have existed prior to mining.

In Daisy Creek, Nimick and Cleasby (2001) found metal-rich subsurface inflows located upstream and downstream from the tributaries draining the McLaren Mine area. The existence of these flows indicates that bedrock both to the south and north of the McLaren Mine area is a source of acid rock drainage not related to mining. The smaller of these subsurface inflows was thought to be derived from the Chimney Rock area, near the north end of Henderson Mountain. The other inflow, which contributed a larger subsurface metal load, may be derived from Fisher Mountain; however, shallow

groundwater monitoring data (i.e., wells DCGW-103S, DCGW-106, DCGW-137, and MW-3) do not confirm the presence of acidic or metal-rich groundwater in this area.

Nimick and Cleasby (2001) also reported that Daisy Creek received a substantial copper load (10,100 ug/s) originating from a manganese bog located adjacent to the creek, and south of the McLaren Pit. This source of loading accounted for 20% of the dissolved copper load contributed to Daisy Creek in 1999 from surface and subsurface inflows, including those from the McLaren Mine. This bog is located along the Crown Butte fault, near the lowest point in the valley and just above where the fault intersects Daisy Creek. The Crown Butte fault offsets the McLaren massive-sulfide replacement deposit down-dropping the deposit some 280 feet on the west side of the fault. Historical mining occurred exclusively to the east of the fault plane on the up-thrown side of the fault. Based on tracer studies (EPA 1998), the Crown Butte fault is known to be a major conduit for water flow through mineralized rock. Tracers injected into a well located above the highwall of the McLaren pit were found over a mile and a half away in upper Miller Creek in a monitoring well (MW-5P) drilled into the Crown Butte Fault zone. Pumping tests (Maxim 2003) demonstrated that this fault zone is capable of transmitting large volumes of groundwater in the plane of the fault, but very little at right angles to the fault zone. Given these relationships, loading of copper and perhaps other metals has likely been occurring from this fault-controlled bog location since before mining started and flow along the fault has not likely been impacted significantly by historical mining.

In Fisher Creek, the metal-loading investigation conducted by Kimball et al. (1999) showed that only 32 percent of the copper load in Fisher Creek came from the Glengarry adit and that substantial metal loading occurred from other more diffuse, or non-point, sources in reaches not immediately adjacent to or affected by historical mines. For instance, loading occurred upstream of the Glengarry adit from natural weathering of sulfidic rocks. Similarly, ground-water inflow contributed metals to a reach of Fisher Creek upstream from the Gold Dust tributary. For example, inflows from seeps at 786 and 1,134 meters had pH values of 4.44 and 3.85, respectively, and dissolved copper concentrations of 323 and 375 µg/L, respectively. The postulated source of this diffuse loading is assumed to be ground-water that has flowed through the sulfide-rich Fisher Mountain Intrusive Complex (rhyodacite-porphyry) under parts of Fisher Mountain and Henderson Mountain.

2.5 COPPER BOGS

The area immediately downstream of the Glengarry adit was the location of a "copper bog" containing native copper described by Lovering (1929). Similar undisturbed "copper bogs" have been identified in the vicinity and have been determined to be fens fed by copper-rich ground water. Peat deposits in the fens have up to 2.2% copper (MacHardy-Mitman, 2002; Joe Gurrieri, U.S. Forest Service unpublished data).

The copper bog described by Lovering (1929) was located in alluvium just downstream from the abrupt change in gradient at the valley head. The copper bog deposits were at least 5 feet thick and were located near (downstream) but predate the Glengarry adit, which was driven in 1925 (Lovering, 1928). Lovering (1928) hypothesized that the copper deposited in the organic-rich layers of the bog was derived from pyritic copper ore that crops out about a half mile above the bog in the Como basin. He noted that the copper (and acid) would have been released by sulfide oxidation in the Como basin, but that the copper could only have reached the downstream bog if the surface water carrying the copper remained acidic. Once these solutions reached the bog, copper was precipitated by the abundant organic material contained in muds interbedded with gravel and slope wash (Lovering, 1928). Native copper was also observed in alluvium near the bog.

3.0 ESTIMATION OF PRE-MINING WATER QUALITY FROM FERRICRETE DEPOSITS

Holocene ferricrete deposits in metal-mining districts have been widely recognized as indicators of ancient acid rock drainage (Bassett et al., 1992; Plumlee et al., 1995; Furniss et al., 1999; Yager et al., 2003; Wirt et al., 2007). Furniss (1999) took the idea that ferricrete provides geologic evidence of pre-mining acidic conditions a step farther and suggested that the difference in trace metal content between the Fe-precipitates currently forming on a streambed and the terrace deposits of ferricrete along the adjacent valley floor might provide the basis for a method for distinguishing between natural acid rock drainage and anthropogenic acid mine drainage. Subsequently, Nimick et al. (2009) developed such a method. This method is based on empirical trace-metal relations between ancient ferricrete, modern Fe-precipitates, and stream water. The method uses the downstream spatial variation in geochemical characteristics of ferricrete and Fe-precipitates to estimate longitudinal profiles of pre-mining pH and dissolved copper concentrations during base-flow conditions in acidic streams affected by mining. Much of the work conducted by Nimick et al. (2009) to develop this method was conducted in Daisy and Fisher Creeks using the prominent outcrops of ancient alluvial ferricrete that were deposited prior to mining and that extend along the valley bottoms of both streams. A summary of that work is presented here.

3.1 METHOD

To use the method, stream-specific estimation equations are generated from relations between either pH or dissolved copper concentration in stream water and the Fe/Cu concentration ratio in Fe-precipitates presently forming in the stream. These Fe-precipitates include Fe-oxyhydroxides such as ferrihydrite, Fe-oxyhydroxysulfates such as schwertmannite and jarosite, and Fe-oxides such as goethite. Trace metals adsorb to or co-precipitate with the Fe-precipitates as they form. The equations and Fe/Cu ratios for pre-mining deposits of alluvial ferricrete then are used to reconstruct estimated pre-mining longitudinal profiles for pH and dissolved copper in the sampled streams.

Locations that were sampled along Daisy and Fisher Creeks by Nimick et al. (2009) are shown in **Figure 3-1**. Chemical data for samples of ferricrete, Fe-precipitates, and water are listed in **Table 3-1**. Plots showing the relations between pH or dissolved copper concentration in stream water and the Fe/Cu concentration ratio in Fe-precipitates are shown in **Figures 3-2d**, **3-2e**, **3-3d**, and **3-3e**. Estimated pre-mining values of pH are shown in Figures **3-2b** and **3-3b**. Estimated pre-mining values of copper concentration are shown in Figures **3-2c** and **3-3c**.

Distances along Fisher Creek had been measured previously by Kimball et al. (1999), and these distances, which started with zero in the southern headwater tributary (see **Figure 3-1**), were used. Distances along Daisy Creek were initially those measured by Nimick and Cleasby (2001). However, the trace of uppermost Daisy Creek used by Nimick et al. (2009) diverged from the Nimick and Cleasby (2001) trace at 481 m. At this location, the study reach followed a tributary that headed almost due north to the base of the McLaren mine. The uppermost sampling site in Daisy Creek was assigned 0 m, and consequently, sites along the Nimick and Cleasby (2001) trace downstream from 481 m had 295 m added to their distance.

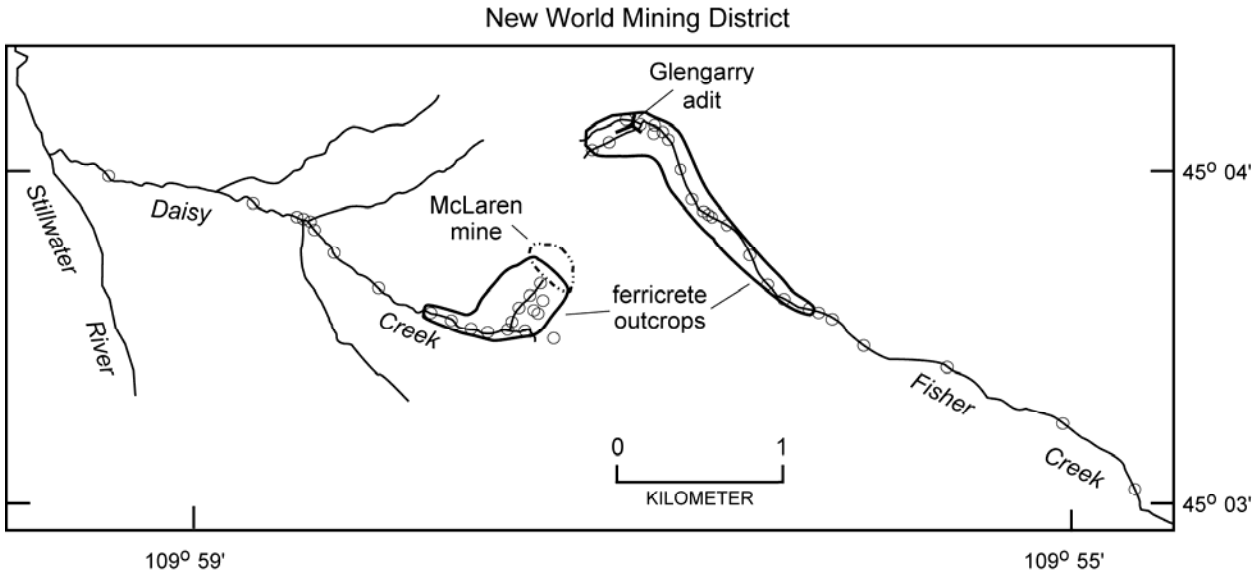


Figure 3-1. Map showing study reaches and locations of sampling sites (open circles) used by Nimick et al. (2009) in the New World mining district.

Table 3-1. Chemical data collected for ferricrete in 2002-04 and for Fe-precipitate and water samples in 2004 from Daisy Creek, Fisher Creek, Paymaster Creek, and Swift Gulch, Montana.

		Ferricrete			Fe-precipitate			Water	
Site name	**Distance**	**Fe**	**Cu**	**Fe/Cu**	**Fe**	**Cu**	**Fe/Cu**	**Dissolved Cu**	**pH**
	(m)	(mg/kg)	(mg/kg)		(mg/kg)	(mg/kg)		(mg/L)	(su)
Daisy Creek[1]									
DCSW-104ab[2]	--[3]	--	--	--	37,400	339	110	3.80	4.65
270 (USGS 0)[2]	--	--	--	--	33,300	17,400	1.91	0.237	7.30
Dpit	0	519,000	1,830	284	--	--	--	--	--
Pit underdrain	112	--	--	--	--	--	--	14.7	3.03
D1A	213	304,000	1,600	190	--	--	--	--	--
D1	213	246,000	446	552	--	--	--	--	--
Apron spring 2[2]	265	--	--	--	40,300	86.0	469	27.5	2.62
Apron spring[2]	271	--	--	--	--	--	--	13.4	3.45
D2	417	214,000	702	305	35,000	41.0	854	15.6	3.01
DC ledge	444	377,000	802	470	--	--	--	--	--
D3	481	576,000	839	687	--	--	--	4.66	3.44
D3 replicate	--	506,000	970	522	--	--	--	--	--
D3A	545	446,000	3,390	132	--	--	--	--	--
D4	703	418,000	2,320	180	52,000	126	413	3.54	4.32
D4A	905	303,000	1,870	162	--	--	--	--	--
D5 (DC 2)	1,105	424,000	2,600	163	--	--	--	--	--
D6	1,600	--	--	--	56,700	479	118	2.81	4.78
4879	1,782	--	--	--	155,000	801	194	--	4.78
5475	1,964	--	--	--	106,000	691	153	2.54	4.77
5661	2,020	--	--	--	37,800	2,540	14.9	1.84	5.46
5770	2,054	--	--	--	97,200	10,300	9.44	0.149	7.03
D7	2,075	--	--	--	77,100	5,090	15.1	0.165	7.16
7324	2,527	--	--	--	--	--	--	0.023	7.65
D8 (DC 5)	3,320	--	--	--	88,900	17,100	5.20	0.019	7.51
D8 replicate	--	--	--	--	91,000	15,900	5.72	--	--
D10 blank	--	--	--	--	--	--	--	<0.003	--
Fisher Creek[1]									
FCT12 up[2]	--	--	--	--	70,800	549	129	1.13	4.12
FCT11 lower[2]	--	--	--	--	244,000	318	767	0.188	3.52
F1	0	535,000	362	1,478	--	--	--	--	--
F1 replicate	--	535,000	391	1,368	--	--	--	--	--
FCT-12	0	479,000	615	779	--	--	--	0.558	4.16
Glengarry adit	263	358,000	854	419	404,000	284	1,423	0.673	3.49
F2	567	366,000	5,070	72	--	--	--	--	--
F1A	570	405,000	5,970	68	--	--	--	--	--
F3	666	373,000	1,880	198	373,000	287	1,300	0.690	3.54
F3 replicate	--	211,000	1,040	203	--	--	--	0.687	--
F2B	681	311,000	2,030	153	--	--	--	--	--
F4	810	207,000	1,870	111	--	--	--	--	--
F4 replicate	--	232,000	2,050	113	--	--	--	--	--
SW3 weir	955	368,000	3,130	118	--	--	--	--	--
F4A	1,072	228,000	2,660	86	--	--	--	--	--

Table 3-1, continued. Chemical data collected for ferricrete in 2002-04 and for Fe-precipitate and water samples in 2004 from Daisy Creek, Fisher Creek, Paymaster Creek, and Swift Gulch, Montana.

		Ferricrete			Fe-precipitate			Water	
Site name	**Distance**	**Fe**	**Cu**	**Fe/Cu**	**Fe**	**Cu**	**Fe/Cu**	**Dissolved Cu**	**pH**
	(m)	(mg/kg)	(mg/kg)		(mg/kg)	(mg/kg)		(mg/L)	
Fisher Creek, continued									
F5	1,103	269,000	3,190	84	--	--	--	0.576	3.52
F5A	1,133	198,000	1,910	104	--	--	--	--	
F6	1,267	290,000	1,390	209	346,000	449	771	0.410	3.73
F6A	1,412	221,000	1,010	219	--	--	--	--	--
F6C	1,768	321,000	2,410	133	--	--	--	0.301	4.13
F6D	1,920	315,000	2,960	106	81,700	525	156	0.278	4.70
F7	2,042	290,000	3,750	77	96,200	832	116	0.270	5.02
F7 replicate	--	--	--	--	--	--	--	0.276	--
F7A	2,088	--	--	--	60,400	3,510	17.2	0.199	6.28
F7AA	2,134	--	--	--	55,900	6,480	8.6	0.201	6.05
F8	2,355	--	--	--	79,300	8,760	9.1	0.179	6.33
FC5	3,008	--	--	--	92,000	8,280	11.1	0.121	6.60
FC6	3,537	--	--	--	75,400	8,840	8.5	0.050	6.79
F9 (SW4)	4,065	--	--	--	79,600	10,600	7.5	0.024	7.00
Swift Gulch[4]									
F1	30	330,000	904	365	--	--	--	--	--
F3	61	445,000	250	1,780	--	--	--	--	--
F4	76	260,000	297	875	--	--	--	--	--
F5	91	338,000	131	2,580	--	--	--	--	--
F6	122	370,000	167	2,216	--	--	--	--	--
F7	427	295,000	131	2,252	--	--	--	--	--
M1	518	--	--	--	315,000	191	1,649	0.001	6.6
M2	579	--	--	--	410,000	111	3,694	0.005	6.0
F8/M3	610	388,000	44.4	8,739	426,000	37	11,514	0.006	5.1
F9/M4	671	191,000	141	1,355	430,000	35	12,286	0.011	3.6
F10/M5	747	389,000	33.5	11,612	418,000	25	16,720	0.005	4.0
F12/M6	823	338,000	97.1	3,481	412,000	22	18,727	0.006	3.9
M7	945	--	--	--	432,000	35	12,343	0.007	3.7
F13/M8	1,128	302,000	77.2	3,912	436,000	34	12,824	0.010	3.6
F15/M9	1,585	226,000	77.6	2,912	286,000	180	1,589	0.010	4.2
Paymaster Creek[5]									
12	0	362,000	80	4,525	322,000	77.7	4,144	0.004	4.04
10	335	512,000	176	2,909	368,000	61.3	6,003	0.008	3.83
9	496	530,000	36	14,722	349,000	49.4	7,065	0.007	3.80
5trib[2]	--	--	--	--	243,000	129	1,884	0.013	4.28
5	697	518,000	19	27,263	358,000	50.5	7,089	0.005	3.85
2	896	549,000	11	49,909	362,000	62.9	5,755	0.008	3.63
2fen	914	468,000	25	18,720	373,000	37.4	9,973	<0.003	3.44
2fen replicate	--	--	--	--	--	--	--	<0.003	--
blank	--	--	--	--	--	--	--	<0.003	--

[1] Ferricrete samples collected in 2002-03; Fe-precipitate and water samples collected in September 2004

[2] Site on tributary; data used to develop relation between Fe/Cu concentration ratio in Fe-precipitates and pH and dissolved copper concentration in water

[3] No data

[4] All samples collected in August and September 2004

[5] Ferricrete samples collected in 2002-03; Fe-precipitate and water samples collected in October 2004

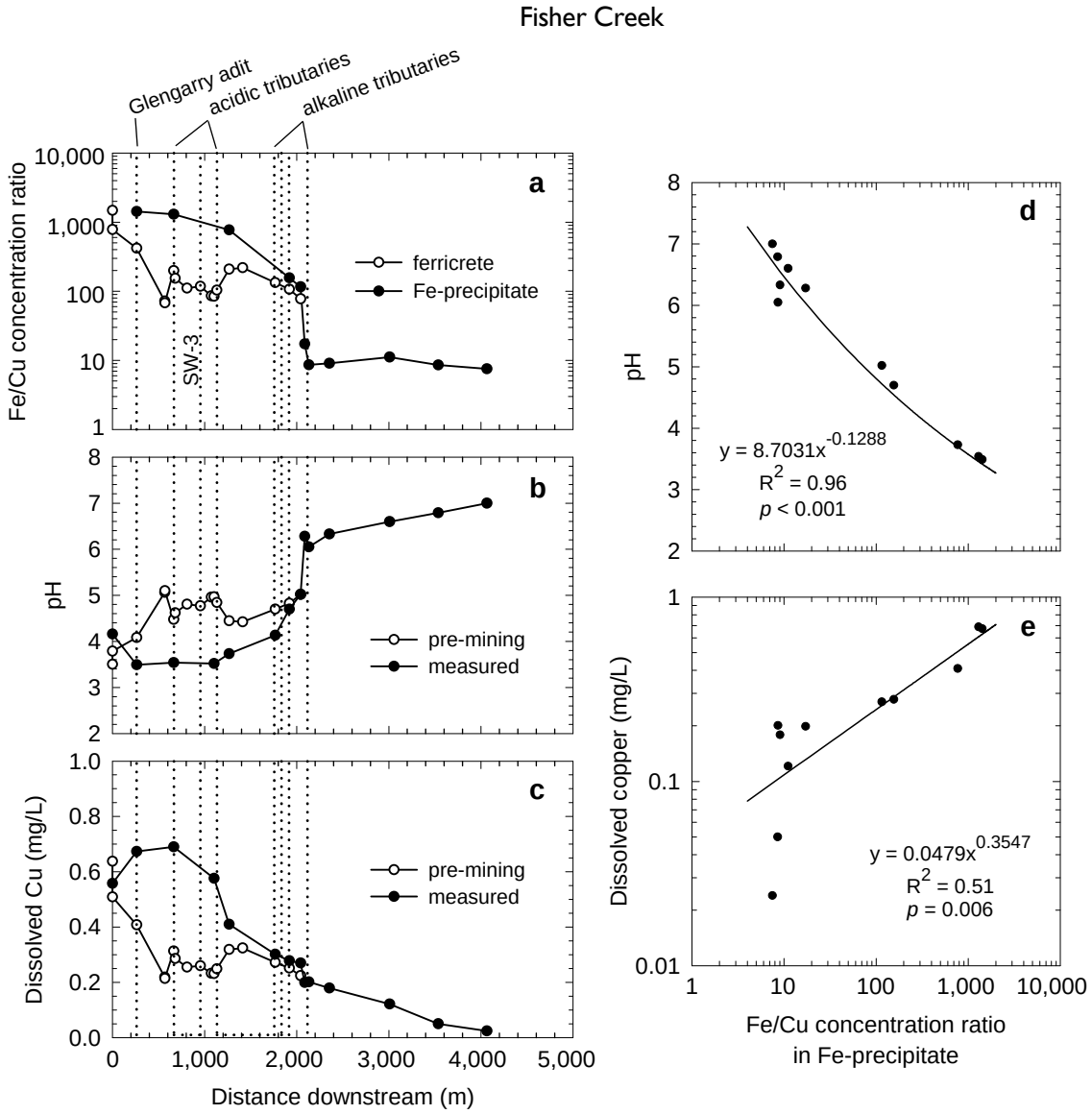


Figure 3-2. Downstream profiles of (a) Fe/Cu concentration ratio in ferricrete and Fe-precipitates, (b) estimated pre-mining and measured pH, and (c) estimated pre-mining and measured dissolved copper concentration. Estimation models for (d) pre-mining pH based on relation of measured pH and Fe/Cu ratio in Fe-precipitates, and (e) pre-mining dissolved copper concentration based on relation of measured dissolved copper concentration and Fe/Cu ratio in Fe-precipitates for Fisher Creek. Inflows noted in panels a-c were identified by the detailed synoptic sampling of Kimball et al. (1999).

Daisy Creek

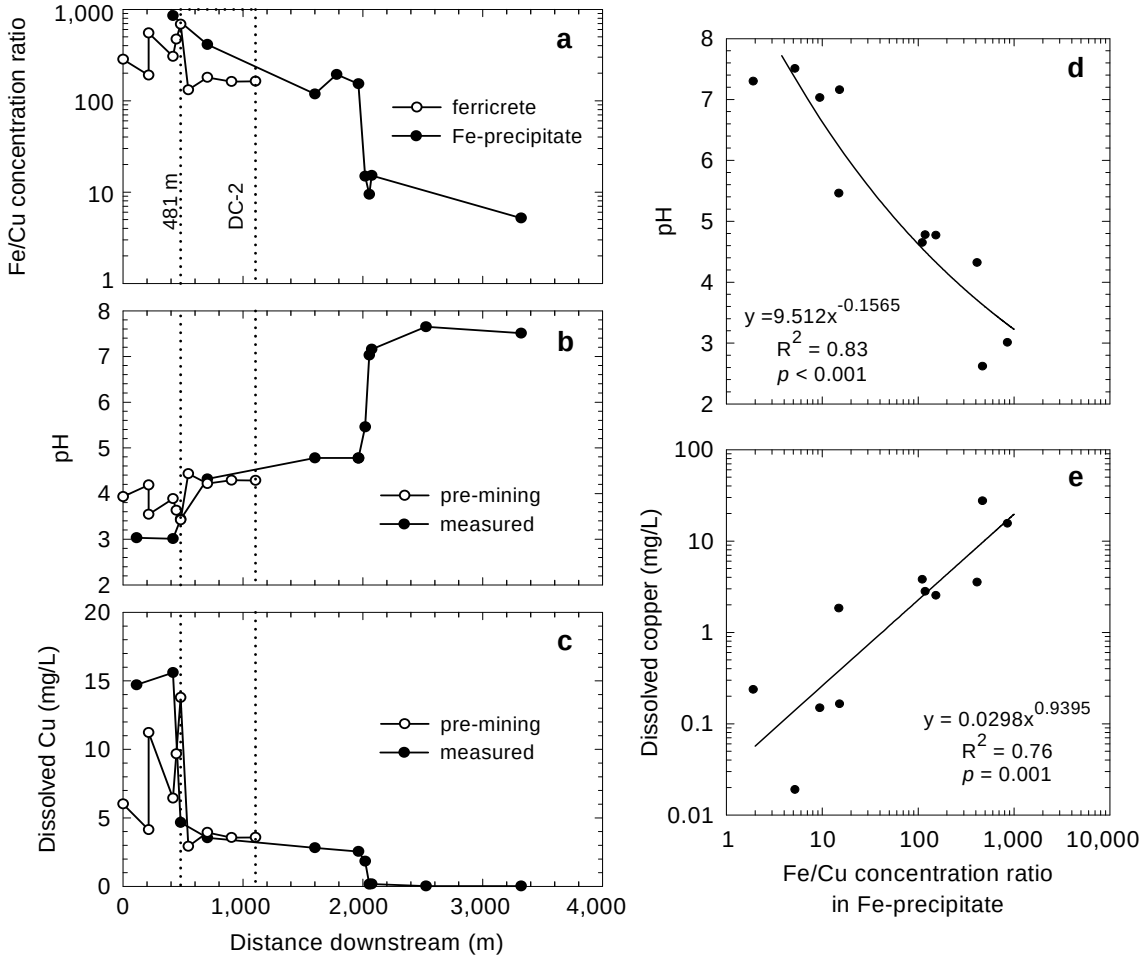


Figure 3-3. Downstream profiles of (a) Fe/Cu concentration ratio in ferricrete and Fe-precipitates, (b) estimated pre-mining and measured pH, and (c) estimated pre-mining and measured dissolved copper concentration. Estimation models for (d) pre-mining pH based on relation of measured pH and Fe/Cu ratio in Fe-precipitates, and (e) pre-mining dissolved copper concentration based on relation of measured dissolved copper concentration and Fe/Cu ratio in Fe-precipitates for Daisy Creek.

3.2 ESTIMATED PRE-MINING CONDITIONS IN FISHER CREEK

In order to better understand the estimated pre-mining geochemical conditions in upper Fisher Creek and how those conditions were affected by subsequent mining activities, a brief description of various natural and man-made features in the headwaters area of Fisher Creek are presented here.

The Glengarry Mining Company drove the Glengarry Adit beginning in 1925 (Lovering, 1929) and they collared the adit near the base of Lulu Pass in the headwaters of Fisher Creek (**Figure 3-4**). The adit was driven about 700 meters (2,300 feet) west-northwest towards Lulu Pass in an attempt to intercept mineralization previously mined at higher elevation (Spaulding Tunnels) near Lulu Pass. In the early 1930's a new internal southwest heading of the Glengarry Adit was driven some 183 meters (600 feet)

to come in under mineralization identified at the surface in the Como Basin (**Figure 3-4**). The Glengarry Mining Company drove the Como Raise to the surface, a distance of about 490 feet (150 meters), into the topographic feature called the Como Basin at the foot of the north flank of Fisher Mountain (**Figure 3-4)**. The upper 25 m (80 feet) of this raise passes through the Como stratabound massive sulfide replacement deposit hosted in the Meagher Limestone formation. The Como deposit , which is exposed at the surface at the southeast side of the basin, was subsequently defined by drilling by various companies, including Crown Butte Mines, to be a massive sulfide gold-silver-copper deposit. the deposit is as much as 27 m thick (100 feet) and about 180 m (600 feet) in diameter and contained approximately 707,000 metric tons of ore with an average copper concentration of 1.03%. The Como raise came to surface at a location that was near the center of the ore deposit and in an area of locally low elevation (sink). As a result of this geometry, a considerable amount of surface water, and shallow colluvial groundwater in contact with ore and residual soil in the Como Basin, flowed directly down the raise and out the portal of the Glengarry Adit. During most years under low flow conditions, the Glengarry Adit was the only upstream source of flow to Fisher Creek. Therefore, once the Como Raise was completed in the early 1930s, a significant amount of naturally contaminated water that once flowed in surface water channels out of the mineralized Como Basin was now directed to a new man-made discharge point at the Glengarry Adit portal and from there, directly into Fisher Creek. Presumably this occurred from 1930 until the Como Raise and Glengarry Mine were closed in 2005. With these relations in mind, the pre-mining geochemical conditions of Fisher Creek are evaluated below.

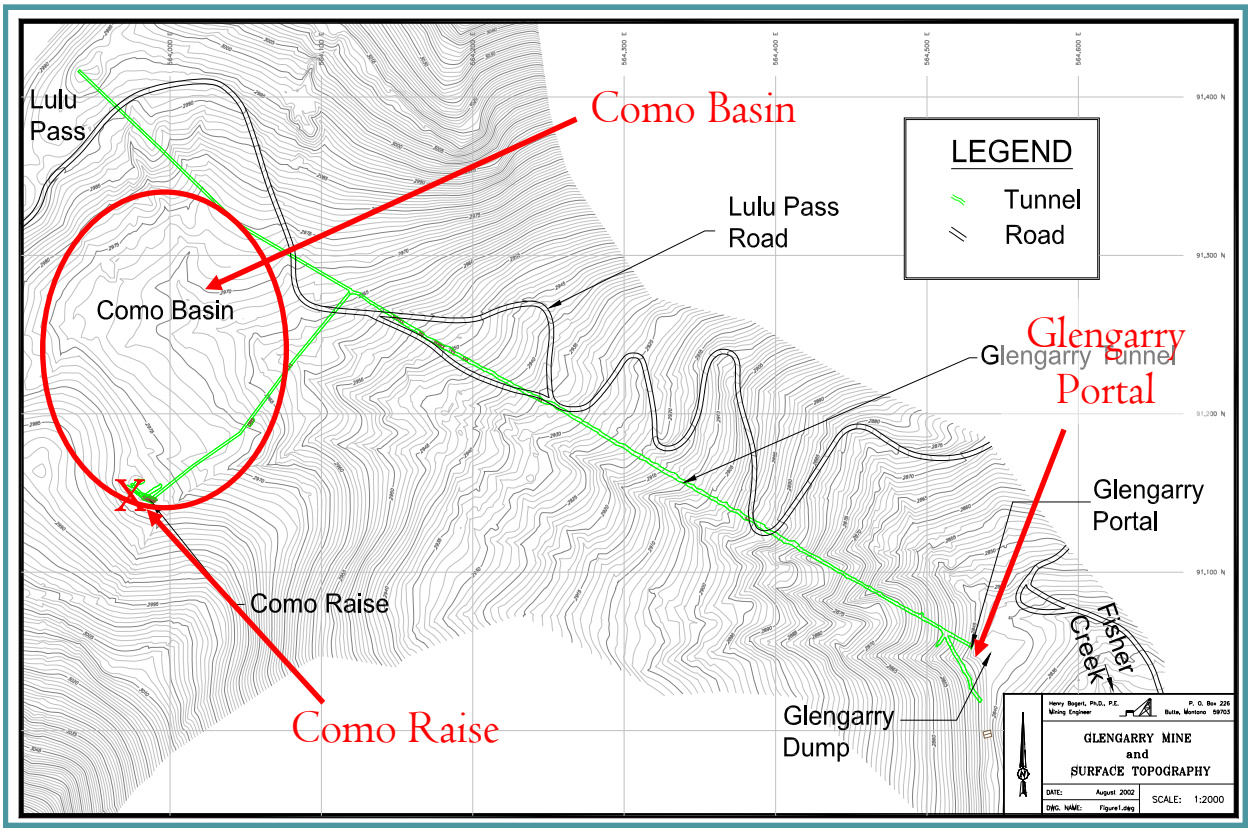


Figure 3-4. Surface topography and workings of the Glengarry Mine.

The profile of estimated pre-mining pH for Fisher Creek (**Figure 3-2b**) shows that in the headwaters upstream from the Glengarry adit, pre-mining pH (3.5-3.8 at 0 m) was similar to the pre-mining pH in

Daisy Creek (mean = 3.8) and more acidic than the measured pH (4.16) in the headwaters of Fisher Creek. Downstream through the reach affected by inflow from the Glengarry adit, the pre-mining and measured pH values diverged, with the pre-mining pH increasing to 5.1 at 567 m and the measured pH decreasing to 3.54 at 666 m. Between 666 and the end of the ferricrete deposits at 2,042 m, pre-mining pH was fairly constant (mean = 4.8; range 4.4-5.0). Measured pH (in 2004) through the upper part of this reach (666-1,103 m) was about 3.5, about 1 to 1.5 pH units lower than the pre-mining values. In September 2007 (after closure and stemming of the flow from the Glengarry adit in August 2005), measured pH at SW-3 (995 m) was 3.9, somewhat lower than the estimated pre-mining value of 4.8 for this site. Between 1,103 and 2,042 m, measured pH gradually increased to 5.02, which is the same as the estimated pre-mining value at 2,042 m (**Figure 3-2b**).

The profile of estimated pre-mining copper concentrations for Fisher Creek (**Figure 3-2c**) shows conditions without the influence of the inflow from the Glengarry adit (263 m), which was the primary mining-related source of metals to the stream (Kimball et al., 1999). Upstream from the Glengarry adit (at 0 m), estimated pre-mining copper concentrations (0.51-0.64 mg/L) were similar to the measured concentration (0.558 mg/L), indicating that the measured copper concentration likely represents natural background conditions. Between 0 and 570 m, the pre-mining concentration decreased to 0.21 mg/L while the measured concentration increased to 0.690 mg/L (at 666 m) owing primarily to the inflow from the Glengarry Adit at 263 m. The pre-mining concentration decrease in this reach suggests that copper was either being diluted by inflows from known groundwater seeps and springs in this area or being precipitated, or both. Between 666 and 1,412 m (**Figure. 3-2c**), the estimated pre-mining copper concentrations (0.23 to 0.33 mg/L) were constant to slightly increasing. Streamflow presumably was increasing in this reach as it does today (Kimball et al., 1999) indicating that inflows were adding copper to the stream. The increase at 666 and 681 m (**Figure 3-2c**) coincides with the location of a tributary (FC-2 in Figure 1 of Kimball et al., 1999) that contributed acid and copper. Similarly, the pre-mining increase at 1,267 and 1,412 m likely was caused by another acidic tributary (FCT-14 at 1,134 m) and diffuse ground-water inflows identified by the detailed synoptic sampling of Kimball et al. (1999) in this unmined reach. These results indicate that locations of metal-rich ground-water discharge to the stream may be the same today as they were thousands of years ago. At SW-3 (995 m), the September 2007 total recoverable copper concentration was 0.84 mg/L, somewhat higher than the estimated pre-mining dissolved concentration of 0.26 mg/L. Near the downstream end of the ferricrete deposits (1,768-2,042 m), the estimated pre-mining concentrations (0.22-0.27 mg/L) were almost the same as the measured concentrations (0.270-0.301 mg/L).

3.3 ESTIMATED PRE-MINING CONDITIONS IN DAISY CREEK

The profile of estimated pre-mining pH for Daisy Creek (**Figure 3-3b**) shows headwater values with a mean of 3.8 (range = 3.4-4.2 from 0 to 481 m). Measured pH in this reach was lower (mean = 3.16; range = 3.01-3.44). The pre-mining and measured pH profiles merge downstream from 481 m and maintain essentially the same value to the end of the ferricrete deposits at 1,105 m. The estimated pre-mining pH values were 4.2 to 4.4 between 545 and 1,105 m, similar to the one measured pH value (4.32 at 703 m) in this reach as well as the September 2007 pH value at DC-2 (1,105 m) of 4.1 (Table 1-1).

The profile of estimated pre-mining copper concentrations for Daisy Creek (**Figure 3-3c**) shows that the highest concentrations (mean = 8.5 mg/L; range = 4.1-14 mg/L) were just downstream from the McLaren mine in an area where an extensive ferricrete apron formed over glacial till between 0 and 481 m. The measured concentrations in this reach (mean = 11.7 mg/L; range = 4.66-15.6 mg/L) were, on average, almost 40% higher than the estimated pre-mining values. Farther downstream, the neutral ground-water inflows currently near the toe of the ferricrete apron likely existed in the past and, as occurs today, caused a decrease in copper concentration downstream from 481 m. The pre-mining

concentrations then remained at nearly the same level (2.9 to 3.9 mg/L) for the remaining part of the ferricrete deposits (545-1,105 m), and closely matched the measured concentrations of 3.54 at 703 m and 2.81 downstream from the ferricrete reach at 1,600 m. These values also were similar to the September 2007 value at DC-2 (1,105 m) of 3.58 mg/L (Table 1-1).

3.4 METHOD VALIDITY

Primary assumptions underlying the proposed method are that alluvial ferricretes and modern Fe-precipitates share a common origin, that the copper content of Fe-precipitates remains constant during and after conversion to ferricrete, and that geochemical factors other than pH and dissolved copper concentration play a lesser role in determining Fe/Cu ratios in Fe-precipitates. The validity and overall reasonableness of the method were evaluated by Nimick et al. (2009) in two ways. The first was by comparing measured and estimated paleo pH and Cu concentration data for a control stream (Paymaster Creek, 60 miles southwest of Great Falls, Montana; data in **Table 3.1**) that was unaffected by mining. In this catchment northwest of Helena, sulfide mineralization produces naturally acidic waters with elevated Cu concentrations. The profiles of paleo pH and copper concentration estimated from the ferricretes sampled along Paymaster Creek were essentially the same as those actually measured in the stream in 2004, thus suggesting that the method works.

A second check on the validity of the method was to determine whether inflows, particularly from areas where hydrologic or other effects of mining are absent, had a consistent effect on both the pre-mining and measured profiles of pH and copper concentration. These inflows could contribute either acidic and metal-rich water that would decrease pH and increase copper concentration in the stream or alkaline water that would cause neutralization and co-precipitation of iron and aqueous copper. Perhaps the most noteworthy example of this effect of inflows is the convergence of pre-mining and measured pH and copper concentration at the downstream end of the ferricrete deposits. For both Daisy Creek and Fisher Creek, the pre-mining and measured values converge to essentially the same value in these reaches. It is noteworthy that this convergence occurs even though the values at the downstream end of the ferricrete deposits were quite different in Daisy Creek (pH $\cong$ 4.3; Cu $\cong$ 3.6 mg/L) than in Fisher Creek (pH $\cong$ 5.0; Cu $\cong$ 0.3 mg/L). For Daisy Creek, alkaline inflows near 704 m (identified by Nimick and Cleasby, 2001) provide some neutralization (**Figure 3-3b**). For Fisher Creek, calcium-rich inflows between 1,756 and 2,116 m (identified by Kimball et al., 1999) cause the rapid neutralization of pH indicated in the middle of the measured pH profile (**Figure 3-2b**). These inflows, which drain carbonate terrain unaffected by mining, almost certainly existed prior to mining.

Other examples of the effect of inflows include acidic tributaries as shown in the pre-mining and measured profiles for Fisher Creek (**Figures 3-2b** and **3-2c**) at 666 and 1,134 m. The pre-mining profile shows decreased pH and increased copper concentration where these tributaries enter Fisher Creek. Similar effects (decreased pH and increased copper concentration) are not as evident in the measured record at these locations because the composition of the tributary water was similar to that in Fisher Creek, which in 2001was being degraded by the inflow from the upstream Glengarry adit.

3.5 ASSESSMENT OF MINING EFFECT AND IMPLICATIONS FOR RESTORATION EFFORTS

Mining appears to have adversely affected at least the upper 481 m of Daisy Creek. Dissolved copper concentrations were increased almost 40%, from a mean estimated pre-mining value of 8.5 mg/L to a mean measured value of 11.7 mg/L, and pH was decreased by about 0.6 pH units from a mean estimated pre-mining value of 3.8 (range = 3.4-4.2) to a mean measured value of 3.16 (range = 3.0-3.4) upstream from 481 m. Although conditions were not as acidic or metal-rich before mining, pH was low and

copper concentrations were high prior to mining. It should be noted here that mean copper concentrations in the upper reaches (481 m) of Daisy Creek under pre-mining estimated and post-mining measured conditions, 8.8 mg/L and 11.7 mg/L respectively, are both essentially 1000 times that allowed by B-1 aquatic life hardness adjusted standards for Daisy Creek at 0.0093 mg/L.

Mining appears to have adversely affected about 1.8 km of Fisher Creek between the Glengarry adit at 263 m downstream to 2,042 m. Dissolved copper concentrations increased as much as 230%, from the estimated pre-mining value of 0.21 to 0.690 mg/L in the reach between 570 and 666 m, and pH decreased by a pH unit or more after mining between 570 and 1,103 m. Thus, mining appears to have decreased pH and increased copper concentration to a greater degree in Fisher Creek than in Daisy Creek.

In Fisher Creek upstream from the Glengarry adit, the estimated pre-mining pH (3.5-3.8) is slightly lower than the measured value (4.16), indicating that the pre-mining condition was worse than the measured condition. This unique situation could have two possible explanations. The first is that sulfide oxidation may have lessened after the sampled ferricrete was deposited and resulted in improved water quality in this reach of Fisher Creek. The pre-mining pH for Fisher Creek upstream from the Glengarry adit is based on very old ferricrete (the one sample that has been dated from this upstream area is 5,650 ± 50 years old; unpublished data, G. Furniss). Thus, the difference in pH over this long time period could be reasonable because fresh surfaces of the abundant sulfidic rock that crops out in this Como Basin headwater area (Elliot et al., 1992) presumably would have been exposed after the retreat of the late Pleistocene mountain ice cap. Weathering of these surface materials may have produced more acid and copper during the earlier millennia of the Holocene than during later millennia, causing pH to increase slightly during the entire period. A second, more likely explanation is that mining activity caused the increase in pH. As described above, a raise extending vertically from the Glengarry adit to land surface daylights into and drains the sulfidic rock outcropping in this headwater area (**Figure 3-4**). Prior to mining, drainage from the sulfidic rocks likely would have flowed into headwater tributaries of Fisher Creek. After construction of the raise, the acid and metal load in this drainage water no longer would have flowed to upper Fisher Creek, but instead was diverted and discharged from the Glengarry Adit portal.

4.0 WATER QUALITY IN UNMINED AREAS

Surface water (i.e. discharges from seeps and springs, and flow in creeks) and groundwater resources in the New World District can be categorized into two groups; 1) those in mineralized areas and 2) those in non-mineralized areas. Mineralized areas are defined as areas associated with the four major Tertiary-age (Paleocene to Eocene) intrusive stocks of the district (**Figure 4-1**). Each of these areas is genetically, temporally, and spatially associated with widespread hydrothermal alteration and specific mineral deposits (veins, porphyries, replacements and breccia-hosted deposits). These intrusive stocks are, from north to south, the Scotch Bonnet diorite (dolerite), the Fisher Mountain rhyodacite porphyry, the Homestake quartz-dacite porphyry, and the Henderson Mountain quartz monzonite. Non-mineralized areas are defined as areas outside of and more distal to the altered intrusive stocks located in the central portion of the district and encompass areas underlain by Precambrian granitic rock, Paleozoic sedimentary rock or unconsolidated surficial materials such as Pleistocene glacial deposits and Holocene surficial deposits.

Crown Butte Mines Inc. (CBMI) conducted an inventory of all seeps and springs located within the New World Mining District as part of their Permit Application (Crown Butte Mines, Inc. 1990). In addition to mapping and describing these surface water features, CBMI collected analytical data (i.e. metal concentrations, pH, conductivity, etc) from selected seeps and springs during subsequent annual monitoring events (Hydrometrics 1992, 1993, 1994, 1995, 1996, and 1997). Additionally, Hydrometrics (1997) sampled seeps and tributaries of Fisher Creek located below the Como Basin, above the Glengarry Adit, as part of a natural acid rock drainage study. Routine groundwater quality monitoring has also occurred during baseline investigations and as part of response actions.

For this report, Tetra Tech reviewed the locations of each inventoried seep/spring/tributary and monitoring well to identify those that were topographically upgradient or upstream of mining disturbances, on opposite sides of surface water divides from mining disturbances, or otherwise located in the District in areas not impacted by historical mining. Field notes from the 1990 CBMI inventory were reviewed to confirm that the identified seeps/springs did not represent adit seepage and that they were not otherwise located in areas with visible mining-related disturbances. The locations of seeps/springs were cross referenced with a geological map for the District to determine the geologic unit from which each seep/spring originated. Well logs were reviewed to identify the geologic formation that each well was completed in. Finally, existing water quality data for these surface and groundwater monitoring stations were reviewed, and water quality data for non-disturbed areas of the District are used here as an analogue for pre-mining water quality conditions (**Table A-1** in **Appendix A**).

Water quality changes that were observed in a small ephemeral stream located northwest of Scotch Bonnet Mountain were useful for determining what natural water quality might have been like in this mineralized area. This stream was sampled in 2008 as part of a site investigation conducted in support of a land transaction (Tetra Tech 2008). The stream began at the toe of a melting snow drift and flowed along the side of a weathered rock outcrop that had been excavated as a prospect trench. The trench was shallow and in fractured material (**Photos 4-1** and **4-2**) that would not have been previously isolated from atmospheric weathering. Therefore, water quality in the stream downstream from the excavation is considered representative of natural run-off occurring in this area. Water samples were collected approximately 50 feet upstream (Bessie-US) and 10 feet downstream (Bessie-DS) of the trench. The results of this sampling are described in section 4.2 below.

The location of each group of seeps/springs/tributaries is described in **Table 4-1** and shown on **Figure 4-2**. Monitoring well locations are shown on **Figure 4-3.**

Photo 4-1. Location of Bessie US and Bessie DS surface water samples (looking west).

Photo 4-2. Location of Bessie US and Bessie DS surface water samples (looking north).

Table 4-1. Summary of seeps and springs from non-mined locations representative of pre-mining water quality.

Geology	Location	Seep / Spring Identification[1]
Non-Mineralized Areas		
Pleistocene glacial deposits	North of Crown Butte and Miller Mountain, west of Daisy Creek.	D-4 through D-13. D-50 through D-53. D-61 through D-65.
	North of Soda Butte Campground, south of New World waste repository.	AE-13, AE-15, AE-16.
Precambrian granitic	South and east of Sheep Mountain, north of Fisher Creek.	F-12 through F-20, F-34 through F-42.
	South of Fisher Creek, northeast of Henderson Mountain.	F-22 through F-25.
Holocene surficial deposits	East facing flank of Miller Mountain.	M-27 through M-29
Mineralized Areas		
Eocene rhyodacite porphyry of Lulu Pass	Northwest of Lulu Pass and Scotch Bonnet Mountain.	WR-3 through WR-11. Bessie-DS and Bessie-US.
Eocene rhyodacite porphyry of Henderson Mountain	Southwest facing flank of Henderson Mountain.	M-16 and M-17. M-19 through M-23. M-26.
	East facing flank of Henderson Mountain.	F-1
Complex of Fisher Mountain Area (breccia intruded by rhyodacite porphyry)	Fisher Mountain / Lulu Pass area.	F-4 through F-6. F-48, F-54, F-60, F-61 and FCT-11-1 through FCT-11-8 and FCT-16[2].

[1] Except for Bessie-DS and Bessie-US, all identifications are from CBMI (1990) Exhibit B-3 and;
[2] Hydrometrics (1997) Exhibit 1.

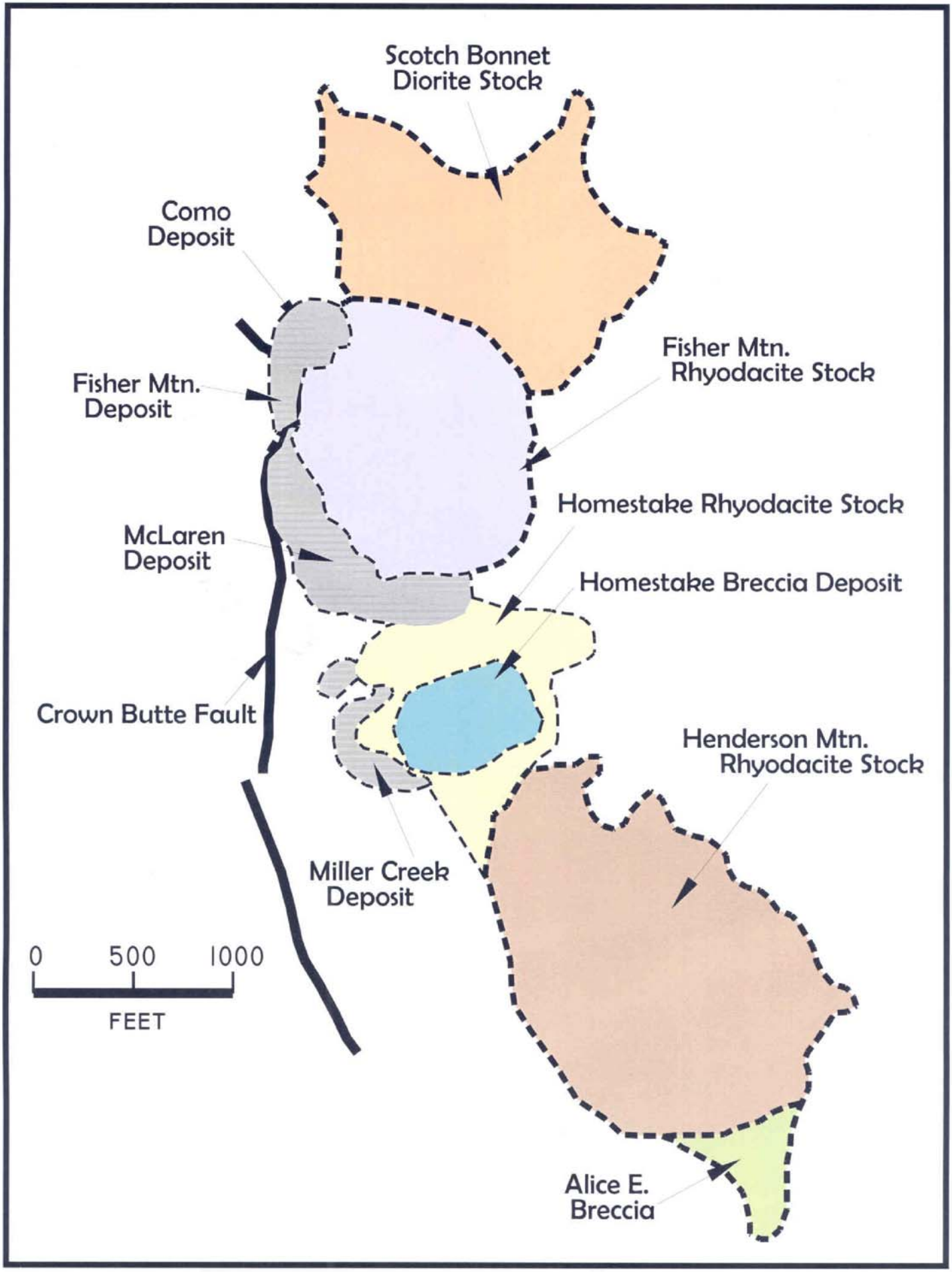
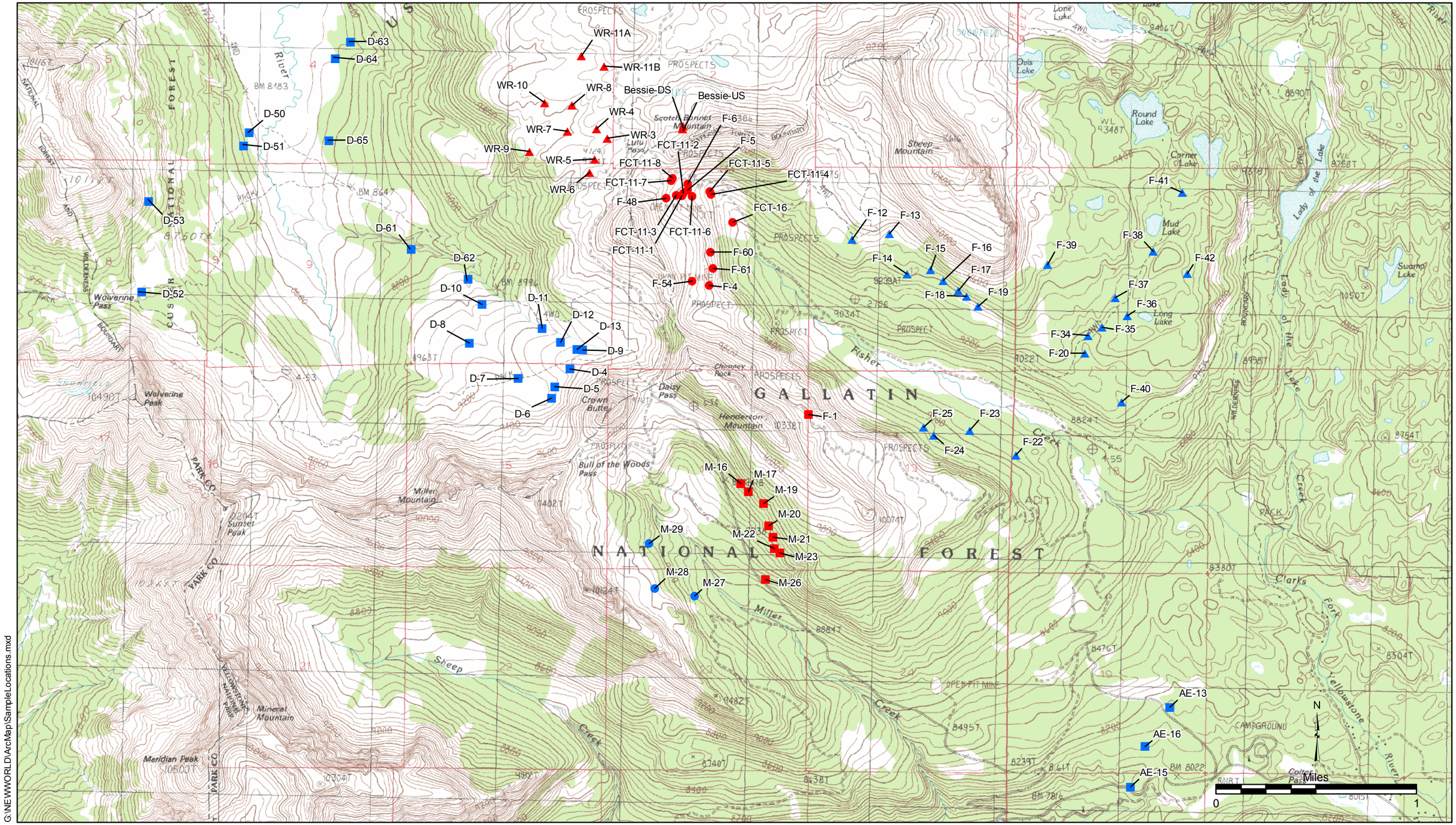


Figure 4-1 Geologic map of the New World deposits, showing intrusives and contact/replacement zones of mineralization



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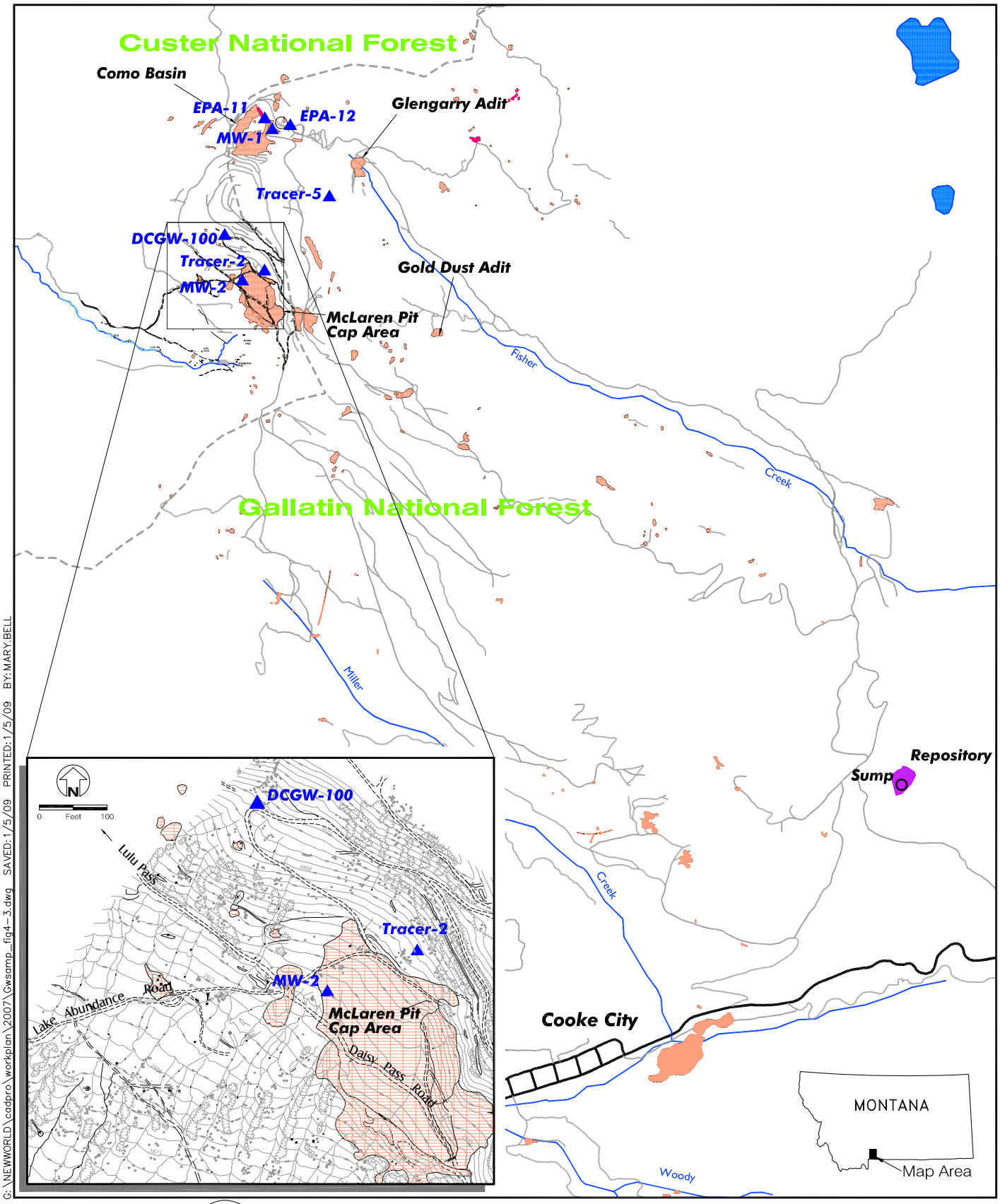
December 2008

Geology Type

- Mineralized Complex of Fisher Mountain Area (breccia intruded by rhyodacite porphyry)
- Mineralized Eocene rhyodacite porphyry of Henderson Mountain
- Mineralized Eocene rhyodacite porphyry of Lulu Pass
- Non-mineralized Holocene surfical deposits
- Non-mineralized Pleistocene glacial deposits
- Non-mineralized Precambrian granitic

Figure 4-2
Seeps and Springs of the New World District not Impacted by Mine Activities



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7561506.110

Monitoring Wells Upgradient
of Mining Disturbances
New World Mining District
Response and Restoration Project
Cooke City Area, Montana
FIGURE 4-3

Data Source: Unimproved roads and surface water sample locations from Gallatin National Forest Interagency Spatial Analysis Center. Cartographic feature files obtained from Montana State Library, Natural Resource Information System.

The following sections describe water quality from each group of seeps/springs/tributaries and also from monitoring wells.

4.1 SURFACE WATER QUALITY FROM NON-MINERALIZED AREAS

Seeps and springs from non-mineralized areas flow into Miller and Daisy Creeks from the west and influence water quality in both creeks (**Figure 4.2**). These seeps and springs originate from both Pleistocene glacial deposits and Holocene surficial deposits that typically had neutral pH values and low sulfate and metal concentrations that were often below analytical detection limits (**Table 4-2**).

Seeps and springs originating in Precambrian granitic rock have an average pH of 6.4, somewhat lower compared to the pH values of Pleistocene (7.3) and Holocene (7.0) seeps/springs. In particular, a line of springs (F-12, -13, 14, -15, and -16) located along an approximately 4,000-foot distance on the southwest facing flank of Sheep Mountain (**Figure 4.2**) had pH values ranging between 5.5 and 6.5. The pH of this line of springs, including F-17 and F-18, increased with increasing distance eastward along the unmined flank of the mountain suggesting that more highly acidic water entered Fisher Creek from east-bank sources near the head of the drainage, compared to downstream locations prior to mining.

Metal concentrations in seeps and springs originating in Precambrian granitic rock tended to have low and often non-detectable metals concentrations although spring F-17 had the maximum concentrations of both iron (0.67 mg/L) and manganese (0.12 mg/L) measured in any non-mineralized seep/spring sample.

4.2 SURFACE WATER QUALITY FROM MINERALIZED AREAS

Seeps and springs in mineralized areas all originate in Eocene rhyodacite porphyry rock that is further classified by geographic location as reported in **Table 4-3**.

Springs in the Lulu Pass Eocene rhyodacite porphyry are located on the west side of Lulu pass in the Daisy Creek drainage north of the historically mined McLaren Pit area. This mineralized geologic unit underlies about 27% of the area draining into Daisy Creek above its confluence with the Stillwater River. Springs originating in this unit have an average pH of 7.8 and elevated concentrations of some metals (**Table 4-3**). Average concentrations of copper (0.06 mg/L), iron (0.80 mg/L), lead (0.009 mg/L), and manganese (0.08 mg/L) all exceed DEQ-7 aquatic life or secondary standards for these constituents.

Comparison of data for BESSIE-US and BESSIE-DS samples, also collected from the Lulu Pass rhyodacite porphyry, show the influence of metal loading as snowmelt upgradient of a rock outcrop flows along the edge of the outcrop and past a shallow exploration cut (**Table 4-4**). Metal concentrations were low or below detection limits in upstream water which had only contacted the rock outcrop for a short distance (BESSIE-US). Downstream, after flowing along the base of the outcrop for a distance of about 60 feet, metals concentrations were considerably greater (BESSIE-DS). Concentrations of aluminum, cadmium, copper, iron, and manganese measured in the BESSIE-DS sample were about the same as the average concentrations calculated for all seep and spring samples collected in the Lulu Pass area suggesting that similar metal release mechanisms are occurring across the area as they would have prior to mining in the district.

Table 4-2. Summary of water quality in surface water from non-mineralized areas.

Area Geology	Statistic	pH	Conductivity	Sulfate	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
		S.U.[1]	umhos/cm	Total Recoverable Concentrations in Milligrams per Liter							
Pleistocene Glacial Deposits	n[2]	22	15	10	8	8	8	8	8	8	8.00
	Minimum	6.1	71	1	All Below Detection (<0.1)	All Below Detection (<0.001)	All Below Detection (<0.01)	<0.03	All Below Detection (<0.01)	All Below Detection (<0.02)	0.01
	Mean[3]	7.3	152	31				0.06			0.10
	Maximum	8.5	275	151				0.16			0.70
Precambrian Granitic	n	23	19	18	12	14	14	14	10	14	13
	Minimum	4.8	16	<1	<0.1	All Below Detection (<0.001)	<0.01	<0.03	<0.01	<0.02	<0.01
	Mean	6.4	90	21	<0.1		<0.01	0.10	0.01	0.03	0.02
	Maximum	7.2	182.0	93	0.1		0.01	0.67	0.02	0.12	0.08
Holocene Surficial Deposits	n	4	4	0	0	1	1	1	0	1	1
	Minimum	6.6	53	--	--	<0.001	0.04	<0.03	--	<0.02	<0.01
	Mean	7.0	80								
	Maximum	7.3	134								
DEQ-7 Standard	Human Health	6.5 to 8.5	No Standard	250	No Standard	0.005	1.3	0.3	0.015	0.05	2.0
	Acute[4]				0.750[5]	0.0010	0.0073	No Standard	0.034	No Standard	0.067
	Chronic[4]				0.087[5]	0.0002	0.0052	1.0	0.0013		0.067

[1] S.U. = Field pH reported in standard units
[2] n = number of samples
[3] Half the reporting limit value was used to calculate means in instances where analytical data were below reporting limits.
[4] Acute and chronic aquatic life standards calculated for waters having hardness of 50 mg/L and are provided for reference only.
[5] Aluminum standards are based on dissolved concentrations and only applicable to waters with pH between 6.5 and 9. Values provided for reference only.

Table 4-3. Summary of water quality in surface water from mineralized areas.

Area Geology	Statistic	pH	Conductivity	Sulfate	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
		S.U.[1]	umhos/cm	Total Recoverable Concentrations in Milligrams per Liter							
Eocene rhyodacite porphyry of Lulu Pass	n[2]	12	9	4	3	5	5	5	3	5	5
	Minimum	6.4	58	4	0.1	<0.001	<0.01	<0.02	<0.001	<0.02	<0.01
	Mean[3]	7.8	87	12	0.1	<0.001	0.06	0.80	0.009	0.08	0.03
	Maximum	8.6	111	36	0.12	0.002	0.23	3.18	0.022	0.26	0.09
Eocene rhyodacite porphyry of Henderson Mountain	n	10	9	2	1	2	2	2	1	2	1
	Minimum	5.8	40	7	<0.1	Both Below Detection (<0.001)	<0.001	<0.03	<0.002	Both Below Detection (<0.02)	0.01
	Mean	6.8	74	17			0.02	0.04			
	Maximum	7.0	100	27			0.03	0.07			
Fisher Mountain Complex (breccia intruded by rhyodacite porphyry)	n	20	24	24	22	15	25	25	11	14	31
	Minimum	3.3	12	4	0.05	<0.0001	<0.001	<0.01	<0.003	0.01	<0.01
	Mean	4.5	101	35	1.52	0.0004	0.52	0.76	<0.003	0.18	0.05
	Maximum	7.2	311	114	6.00	0.001	2.31	11.10	0.003	0.53	0.24
DEQ-7 Standard	Human Health	6.5 to 8.5	No Standard	250	No Standard	0.005	1.3	0.3	0.015	0.05	2.0
	Acute[4]				0.750[5]	0.0010	0.0073	No Standard	0.034	No Standard	0.067
	Chronic[4]				0.087[5]	0.0002	0.0052	1.0	0.0013		0.067

[1] S.U. = Field pH reported in standard units
[2] n = number of samples
[3] Half the reporting limit value was used to calculate means in instances where analytical data were below reporting limits.
[4] Acute and chronic aquatic life standards calculated for waters having hardness of 50 mg/L and are provided for reference only.
[5] Aluminum standards are based on dissolved concentrations and only applicable to waters with pH between 6.5 and 9. Values provided for reference only.

Seeps and springs originating in the rhyodacite porphyry of Henderson Mountain between Miller Creek and the lower portion of Fisher Creek (**Figure 4.2**), had a lower average pH (6.8) compared to the Lulu Pass area (**Table 4-3**). Metal concentrations appear low and similar to those measured from non-mineralized areas, however the sample size is very small (i.e. one or two samples). The rhyodacite porphyry rock of Henderson Mountain underlies about 7% of the area draining into Fisher Creek above its confluence with the Clarks Fork of the Yellowstone River.

Seeps and springs originating from the Fisher Mountain Complex located at the headwaters of Fisher Creek (**Figure 4.2**), have considerably lower pH values and elevated metal concentrations compared to all other inventoried seeps/springs (**Table 4-3**). Of the 13 individual seeps/springs inventoried in this area, only one (F-5) had near-neutral pH values (i.e. 6.7 and 7.2) while the remaining sample pH values ranged between 3.3 and 5.4 with an average of 4.5. Average metal concentrations were elevated relative to DEQ-7 aquatic life or secondary surface water quality standards for aluminum, cadmium, copper, iron, and manganese as reported in **Table 4-3**.

The Fisher Mountain Complex contains disseminated sulfide mineralization ranging from 1 to 4% throughout. The Complex underlies about 4% of the entire area draining into Fisher Creek and about 45% of the area draining into Fisher Creek above the Glengarry Adit. About 2% of the area draining into Daisy Creek is underlain by the Fisher Mountain Complex. In addition to the McLaren and Como sediment-hosted massive-sulfide deposits associated with the Fisher Mountain Complex (**Figure 4-1),** minor amounts of other mineralized rock types are present in the Daisy and Fisher Creek drainages. These rock types include the Homestake Breccia, which accounts for 1% of the rock underlying the Fisher Creek Drainage, and Quartz "Eye" rhyodacite which accounts for 1% in Fisher Creek and 1 percent in Daisy Creek.

Table 4-4. Comparison of water quality from samples collected upstream (BESSIE-US) and downstream (BESSIE-DS) of rock outcrop in Lulu Pass area.

Sample Identification	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
	Total Recoverable Concentrations in Milligrams per Liter						
BESSIE-US	<0.05	<0.0001	0.003	0.04	<0.001	0.003	<0.01
BESSIE-DS	0.12	0.0005	0.068	0.68	0.022	0.11	0.09

4.3 GROUNDWATER QUALITY UPGRADIENT OF MINING DISTURBANCE

Groundwater has been monitored from wells installed upgradient from mining disturbances at the heads of both Daisy and Fisher Creek drainages. These data (**Table A-2** in **Appendix A**) are summarized by drainage in **Tables 4-5** and **4-6**. In the Daisy Creek drainage, these wells consist of DCGW-100 completed in a mineralized section of the Meagher Limestone, and Tracer 2 completed in the Fisher Mountain Complex, both located topographically above (upgradient) the McLaren Pit. A third well MW-2 is located at the northwest corner of the pit and is completed in mineralized Wolsey Shale beneath the pit bottom (**Figure 4-3**). In the Fisher Creek drainage, four wells are located above mining disturbance in the Como Basin: EPA-11 completed in an intrusive dike within the Fisher Mountain Complex, Tracer 5 in the Fisher Mountain Complex, EPA-12 in the Scotch Bonnet Diorite, and MW-1 completed in mineralized Wolsey Shale (**Figure 4-3**).

Table 4-5. Summary of groundwater quality wells upgradient of mining disturbance in the Daisy Creek drainage.

Well (Completion Formation)	Statistic	pH	Conductivity	Sulfate	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
		S.U.[1]	umhos/cm	Dissolved Concentrations in Milligrams per Liter							
DCGW-100 (Meagher Limestone)	n[2]	11	11	5	4	5	5	5	4	4	4
	Minimum	6.2	533	148	< 0.05	< 0.0001	0.001	0.01	All below detection (< 0.001)	0.41	0.01
	Mean[3]	6.9	689	177	< 0.05	0.0003	0.012	0.17		0.74	0.03
	Maximum	7.6	1410	218	0.06	0.0004	0.020	0.32		1.06	0.05
MW-2 (Wolsey Shale)	n	25	23	17	17	17	17	17	17	17	17
	Minimum	3.4	610	372	32.6	< 0.001	0.001	23	< 0.002	0.62	0.21
	Mean	3.9	785	469	41	0.002	0.27	97	0.01	0.99	0.37
	Maximum	4.7	1163	586	51	0.006	0.91	121	0.03	1.30	0.91
Tracer 2 (Fisher Mountain Complex)	n	14	14	10	10	10	10	10	10	10	10
	Minimum	3.1	445	365	41	0.0005	2.73	59.2	< 0.001	0.36	0.14
	Mean	3.7	675	467	54	0.0009	4.19	69.0	0.001	0.42	0.16
	Maximum	4.2	874	607	69	0.0012	8.62	88.2	0.002	0.52	0.21

[1] S.U. = Field pH reported in standard units

[2] n = number of samples

[3] Half the reporting limit value was used to calculate means in instances where analytical data were below reporting limits.

Table 4-6. Summary of groundwater quality wells upgradient of mining disturbance in the Fisher Creek drainage.

Well (Completion Formation)	Statistic	pH	Conductivity	Sulfate	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
		S.U.[1]	umhos/cm	Dissolved Concentrations in Milligrams per Liter							
EPA-11 (Intrusive dike in Fisher Mountain Complex)	n[2]	15	15	9	9	9	9	9	9	9	9
	Minimum	4.0	1.877	995	0.67	0.0018	< 0.001	197	0.02	8.59	0.65
	Mean[3]	5.1	1522	1211	3.9	0.0064	0.33	280	0.15	13.7	1.07
	Maximum	5.6	2070	1470	6.9	0.012	0.75	347	0.34	19.1	1.61
EPA-12 (Scotch Bonnet Diorite)	n	17	17	10	10	10	10	10	10	10	10
	Minimum	5.6	285	134	< 0.05	All below detection (< 0.0001)	All below detection (< 0.005)	27.30	All below detection (< 0.001)	1.35	0.03
	Mean	6.3	387	154	< 0.1			31.72		1.61	0.05
	Maximum	7.2	671	180	< 0.1			37.10		2.04	0.08
MW-1 (Wolsey Shale)	n	22	21	17	17	17	17	17	16	17	17
	Minimum	3.2	20	117	< 0.1	< 0.001	< 0.01	11.5	< 0.002	0.99	0.05
	Mean	4.1	652	336	1.2	0.0013	0.35	45.0	0.017	3.41	0.20
	Maximum	5.0	1449	730	4.4	0.0025	1.48	108	0.018	6.76	0.25
Tracer 5 (Fisher Mountain Complex)	n	9	9	10	10	10	10	10	10	10	10
	Minimum	3.1	5.95	206	18.2	<0.0001	0.62	39.7	0.003	0.66	0.04
	Mean	3.8	489	279	24.4	0.0016	3.54	56.0	0.005	0.99	0.31
	Maximum	4.6	667	369	33.7	0.0026	9.33	76.6	0.006	1.37	0.43

[1] S.U. = Field pH reported in standard units

[2] n = number of samples

[3] Half the reporting limit value was used to calculate means in instances where analytical data were below reporting limits.

Groundwater quality from each of these wells shows signs of degradation from naturally occurring mineralization. Wolsey Shale wells in both Daisy (i.e., MW-2) and Fisher (i.e., MW-1) Creek drainages have low pH ranging from 3.2 to 5.0 and dissolved metal concentrations that exceed DEQ-7 surface water quality standards despite those standards being based on total recoverable concentrations. The same is true for Fisher Mountain Complex wells Tracer 2 and Tracer 5 with pH ranging from 3.1 to 4.6 and elevated metals concentrations. Aluminum and iron concentrations are greater in the Daisy Creek wells compared to Fisher Creek wells while the opposite is true for manganese concentrations.

Groundwater from the intrusive dike monitored by EPA-11 had a greater average pH (5.1) compared to the other Fisher Mountain Complex wells. EPA-11 had considerably greater mean concentrations of sulfate (1211 mg/L), cadmium (0.0064 mg/L), iron (280 mg/L), lead (0.15 mg/L), manganese (13.7 mg/L), and zinc (1.07 mg/L) compared to all other wells discussed in this section.

Groundwater monitored in the upgradient mineralized section of the Meagher Limestone by DCGW-100 and in the Scotch Bonnet Diorite by EPA-12 has better water quality than the Wolsey Shale and Fisher Mountain Complex Wells. Groundwater in these wells has near-neutral pH, and metal concentrations that are low and often below detection limits. However, manganese concentrations in both wells are elevated, ranging from 0.41 to 19.1 mg/L, and iron concentrations measured from EPA-12 range between 27 and 37 mg/L.

5.0 POTENTIAL WATER QUALITY IMPROVEMENT THROUGH ADDITIONAL RECLAMATION

Routine monitoring of Daisy and Fisher Creeks has been conducted since 1989. Monitoring of mining-related water sources including adit flows and waste rock seeps has also been conducted. These data were used in loading analyses to better understand the magnitude of metal loading to Daisy and Fisher Creeks from known mining features identified in the 2006 Draft Adit Discharge Engineering Evaluation / Cost Analysis (EE/CA) (Tetra Tech 2006).

These same data can be used to estimate water quality in the absence of mining disturbance by subtracting metal loads contributed by the known mine related sources from the loads in Daisy and Fisher Creeks and then using streamflow data to convert the adjusted loads to concentrations. One limitation of this method is that it cannot account for metal loads potentially contributed by metal-rich streambed sediments derived from mining activity or instream geochemical reactions. The remainder of this section discusses results of this analysis for Daisy Creek and then for Fisher Creek. Data used in this analysis are presented in **Table A-3** in **Appendix A**.

5.1 DAISY CREEK

Mining-related sources of metal loading currently impacting water quality in the Daisy Creek drainage are limited to the McLaren Adit and any contribution to metals loading that occurs in response to seasonal flushing of backfilled waste in the the McLaren Pit. Loading from the McLaren Pit was greatly reduced as evidenced by considerable improvements in water quality measured in Daisy Creek following installation of the cap in September 2003 (section 1.2.1). However, it is not possible to quantify the current amount of loading that occurs in response to annual flushing by rising groundwater during spring snowmelt. Loads of aluminum, cadmium, copper, iron, lead, manganese, and zinc measured at DC-2, the furthest upstream monitoring station, decreased between 24 and 60% depending on constituent and flow conditions in response to pit capping (Tetra Tech 2006). For this reason, examination of loading to Daisy Creek relies on data collected after installation of the pit cap.

Another source of metal loading to Daisy Creek is the McLaren Pit underdrain system. This system consists of three underdrain pipes that were installed during pit recontouring work to capture spring water originating from bedrock sources at the base of the pit highwall and to transport it through the waste rock backfill in non-perforated pipes. These groundwater springs were observed prior to recontouring of the pit and they discharge groundwater from upgradient unmined areas. However, they are included in the following load analysis as a source as they contribute the greatest metal loads to Daisy Creek compared to any other observable source and therefore provide an element of conservatism to the resulting estimates of pre-mining water quality in Daisy Creek.

At the time of this writing, data collected after June 2006 were not yet integrated with those presented in the 2006 Draft EE/CA (Tetra Tech 2006). The following discussion relies only on data presented in the EE/CA, but conclusions based on these data are not expected to change considerably with inclusion of the more recent monitoring data.

Metal loads in water from the McLaren Adit and the three underdrains (i.e. DCSW-101, -102, and -103) are compared to Daisy Creek loads during high flow (**Table 5-1)** and low flow conditions (**Table 5-2)**. The relative contribution of metal loading from the McLaren Adit to Daisy Creek accounts for less than 1% of the load of aluminum, cadmium, copper, lead, manganese, and zinc during both high and low flow conditions at Daisy Creek monitoring station DC-2.

During low flow conditions, when the combined flow from the adit and underdrains account for 14% of the total flow in Daisy Creek at station DC-2, about 18% of the loads of aluminum, cadmium, and manganese at DC-2 are contributed by the underdrains. About 7% of the lead load at DC-2 is from the underdrains while 25.6% and 30.8% of the zinc and copper loads, respectively, are contributed by the underdrains (**Table 5-1**). Data in **Table 5-1** show that the load of iron in the combined flow from the underdrains and adit is 167% that at DC-2 indicating that attenuation of iron occurs along the flow path before entering Daisy Creek. For this reason it is unclear what the underdrain / adit contribution to the total iron load is at DC-2 and therefore iron concentrations are not examined further in this section.

Total metal loads at DC-2 are much greater under high flow conditions compared to low flow conditions (**Table 5-2**). The relative contributions of aluminum, lead, and manganese loads to DC-2 from underdrains and the adit are similar to those under low flow conditions despite a much smaller contribution to total flow (2%) from these sources. The cadmium load from the underdrains doubles and considerable increases in the copper and zinc loads from the underdrains also occur under high flow conditions primarily due to the increase in flow.

Table 5-1
Relative Contribution of Metals Loading from McLaren Adit and McLaren Pit Subsurface Drains at Daisy Creek Station DC-2 After Capping the McLaren Pit (Low Flow)

Station Number	Aluminum		Cadmium		Copper		Iron	
	Load[1] kg/month	Percent Contribution at DC-2	Load kg/month	Percent Contribution at DC-2	Load kg/month	Percent Contribution at DC-2	Load kg/month	Percent Contribution at DC-2
DCSW-101	10.6	8.3	0.004	9.1	4.84	14.7	65.3	81.6
DCSW-102	1.8	1.4	0.001	2.3	1.04	3.2	8.5	10.6
DCSW-103	11.3	8.9	0.003	6.8	4.26	12.9	46.2	57.8
McLaren Adit	0.06	0.05	0.00003	0.1	0.014	0.04	13.3	16.6
Total Contribution[2]	23.8	18.6	0.008	18.3	10.15	30.8	133	167
DC-2	127		0.044		33		80	
	Lead		Manganese		Zinc		Flow (gallons per minute)	
	Load kg/month	Percent Contribution at DC-2	Load kg/month	Percent Contribution at DC-2	Load Kg/month	Percent Contribution at DC-2		
DCSW-101	0.002	5.0	1.3	5.9	0.69	12.2	2.2	
DCSW-102	0.0001	0.0	0.3	1.4	0.14	2.5	0.45	
DCSW-103	0.0003	0.0	1.8	8.2	0.6	10.6	0.90	
McLaren Adit	0.0003	0.8	0.655	3.0	0.019	0.3	5.6	
Total Contribution[2]	0.0027	6.8	4.055	18.4	1.449	25.6	9.15	
DC-2	0.04		22.0		5.65		63	

Notes: 1 DC-2 and subsurface drain loads are September 2006 data; McLaren Adit loads are averages of data collected after plugging adit borehole. Concentration data are provided in Appendix A.
2 Total Contribution is the total combined load from McLaren Adit, DSCW-101, 102, and 103.
kg/month = kilograms per month

Table 5-2
Relative Contribution of Metals Loading from McLaren Adit and McLaren Pit Subsurface Drains at Daisy Creek Station DC-2 After Capping the McLaren Pit (High Flow)

Station Number	Aluminum		Cadmium		Copper		Iron	
	Load[1] kg/month	Percent Contribution at DC-2	Load kg/month	Percent Contribution at DC-2	Load kg/month	Percent Contribution at DC-2	Load kg/month	Percent Contribution at DC-2
DCSW-101	88	7.4	0.0277	14.6	45.58	17.3	354.5	27.5
DCSW-102	79	6.6	0.036	18.9	44.81	17.0	327	25.4
DCSW-103	24	2.0	0.007	3.7	10.6	4.0	127.4	9.9
McLaren Adit	0.06	0.005	0.00003	0.02	0.014	0.005	13.3	1.0
Total Contribution[2]	191	16.1	0.071	37.2	101.0	38.4	822.2	63.8
DC-2	1189		0.19		263		1288	
Station Number	**Lead**		**Manganese**		**Zinc**		**Flow (gallons per minute)**	
	Load kg/month	**Percent Contribution at DC-2**	**Load kg/month**	**Percent Contribution at DC-2**	**Load kg/month**	**Percent Contribution at DC-2**		
DCSW-101	0.041	5.13	9.3	7.2	5.06	13.3	20.6	
DCSW-102	0.005	0.63	11.5	8.8	6.44	16.9	14.8	
DCSW-103	0.001	0.13	3.8	2.9	1.3	3.4	1.8	
McLaren Adit	0.0003	0.04	0.655	0.5	0.019	0.1	5.6	
Total Contribution[2]	0.0473	5.91	25.255	19.4	12.82	33.7	42.8	
DC-2	0.8		130		38		2329	

Notes: 1 DC-2 and subsurface drain loads are June 2006 data; McLaren Adit loads are averages of data collected after plugging adit borehole. Concentration data are provided in Appendix A.

2 Total Contribution is the total combined load from McLaren Adit, DSCW-101, 102, and 103.

kg/month = kilograms per month

Table 5-3 shows the total recoverable metal concentrations at DC-2 calculated by subtracting metal loads in underdrain and adit flows from the total loads at DC-2 and then converting the resulting loads to units of concentration based on the total flow measured at DC-2 minus flow contributed by the underdrains and adit as shown in **Equation 5-1**.

Equation 5-1.

$$\mathbf{X} \times \frac{1000\text{ g}}{1\text{ kg}} \times \frac{1000\text{ mg}}{1\text{ g}} \times \frac{1\text{ month}}{30\text{ days}} \times \frac{1\text{ day}}{24\text{ hrs}} \times \frac{1\text{ hour}}{60\text{ min}} \times \left(\mathbf{Y} \right)^{-1} \times \frac{1\text{ gallon}}{3.78\text{ L}} = \mathbf{Z}$$

Where:

X = Total load at DC-2 – combined underdrain / adit load (kg / month)
Y = Total flow at DC-2 – combined underdrain / adit flow (gallons / minute)
Z = Resulting concentrations at DC-2 (mg/L)

By subtracting underdrain and adit flow from the total flow at DC-2, **Equation 5-1** assumes that this water did not enter Daisy Creek at all under pre-mining conditions. It is however possible that this water did enter the creek as subsurface or surface flow. **Equation 5-1** can be revised to include this water as a component of Daisy Creek flow, albeit with zero contribution to metal loads, by using the actual flow measured at DC-2. The results of this revised calculation are also included in **Table 5-3**.

Table 5-3
Calculated Pre-mining Water quality at DC-2 without loading from McLaren Pit underdrains or adit.

Scenario	Aluminum	Cadmium	Copper	Lead	Manganese	Zinc
	Total Recoverable Concentrations in Milligrams Per Liter					
Low Flow Conditions (Sept. 2006)						
Actual Measured Concentration at DC-2	12.4	0.0043	3.17	0.004	2.14	0.55
Pre-Mining Estimate (No Flow)[1]	11.7	0.0041	2.60	0.004	2.04	0.48
Alternate Pre-Mining Estimate (Diluting Flow)[2]	10.0	0.0035	2.22	0.004	1.74	0.41
High Flow Conditions (June 2006)						
Actual Measured Concentration at DC-2	3.12	0.0005	0.69	0.002	0.34	0.1
Pre-Mining Estimate (No Flow)[1]	2.67	0.0003	0.43	0.002	0.28	0.1
Alternate Pre-Mining Estimate (Diluting Flow)[2]	2.62	0.0003	0.43	0.002	0.28	0.1
DEQ-7 Standards						
Human Health	No Standard	0.005	1.3	0.015	0.05	2.0
Acute[3]	0.750[4]	0.0021	0.014	0.082	No Standard	0.12
Chronic[3]	0.087[4]	0.0003	0.0093	0.0032		0.12

[1] Assumes that no flow from McLaren underdrains or adit reaches Daisy Creek at DC-2.
[2] Assumes that McLaren underdrain and adit flow does reach Daisy Creek at DC-2 but that this flow delivers no metal load.
[3] Acute and chronic aquatic life standards calculated for waters having hardness of 100 mg/L and are provided for reference only.
[4] Aluminum standards are based on dissolved concentrations and only applicable to waters with pH between 6.5 and 9. Values provided for reference only.

Data reported in **Table 5-3** show that concentrations of most metals at DC-2 would be expected to decrease if McLaren Adit and underdrain flows were either prevented from entering Daisy Creek or if the metal loads in these sources were somehow removed. However, in no case would the expected

decrease result in compliance with existing DEQ-7 standards for constituents that are currently in exceedence. Furthermore, lead concentrations would not be expected to decrease under high or low flow conditions and zinc would not be expected to decrease during high flow conditions. If data for either of the pre-mining scenarios in **Table 5-3** are accurate, the data indicate that the current water quality in Daisy Creek is similar to pre-mining conditions.

5.2 FISHER CREEK

Numerous adit discharge locations in the Fisher Creek drainage have been monitored. The Glengarry, Glengarry Mill site, Sheep Mountain #1, and the Lower Tredennic adits are all located near the headwaters of Fisher Creek upstream of monitoring station SW-3. The Gold Dust Adit is located further downstream above SW-4 while seepage from the Henderson Mountain Dump #7 occurs above the confluence of Fisher Creek with Clark's Fork of the Yellowstone River (CFY-2) (Tetra Tech 2006).

The Glengarry Adit, which used to contribute as much as 65% of certain metals to Fisher Creek (Amacher 1998; Kimball et. al. 1999), was plugged in October 2004 resulting in a dramatic reduction in flow from the adit. Reclamation work was conducted in the Gold Dust adit in 2004, 2005, and 2006. For these reasons the loading analysis presented in the Draft EE/CA (Tetra Tech 2006) relied on data for Fisher Creek collected during low flow events between October 2004 and October 2006 while Glengarry and Gold Dust Adit data were from September 2006. Data for other mine-related sources were the average for the entire period of record however it should be noted that flows from both the Sheep Mountain #1 Adit and the Lower Tredennic Adit infiltrate into the ground a short distance from the adit portals and do not directly enter surface water. Additionally, the flow from the Glengarry Mill-site Adit was greatly reduced in September 2008 and there is no direct discharge to surface water.

Loading data reported in both **Table 5-4** and in **Figure 5-1** show that the relative contribution to metal loads in Fisher Creek from any of the identified mine features is very small, in most cases accounting for less than 1% of the total load. Additionally, cadmium, lead, and zinc loads in Fisher Creek increased between stations SW-3 and SW-4 (**Table 5-4**) by an amount greater than that in seepage from the Gold Dust Adit, suggesting that cumulative loading of these elements occurs from natural sources located below station SW-3.

In most cases reductions to Fisher Creek metal concentrations calculated by subtracting mine related metal loads are undetectable because mine related features contribute so little to most metal loads. This is particularly true for stations SW-4 and CFY-2 where mine related contributions to loading are not great enough to overcome bias introduced by rounding error, resulting in calculated pre-mining concentrations that are slightly greater than those actually measured in Fisher Creek. For this reason, such calculations were made only for monitoring station SW-3 (**Table 5-5**).

As was the case for Daisy Creek, the data in **Table 5-5** show that removing the load contributed to Fisher Creek by mine adits would result in very small changes to Fisher Creek metal concentrations. These changes would not result in compliance with any DEQ-7 standards that are not currently met. Data in **Table 5-5** shows increased concentrations of aluminum, copper, manganese, and zinc under the "no flow" from adits scenario indicating that the load of these metals in adit seepage is sufficiently low that the adit flow dilutes the concentration of these metals in Fisher Creek at SW-3.

TABLE 5-4
PERCENT CONTRIBUTION OF ADIT METALS LOADING TO FISHER CREEK

Station	Aluminum				Cadmium				Copper			
	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2
Glengarry (F-8A)	0.006	0.02			0.000004	0.04			0.003	0.03		
Glengarry Millsite (F-8B)	0.16	0.51			0.0001	1.00			0.05	0.45		
Sheep Mtn. #1 (FCSI-99-1)	0.014	0.04			0.00003	0.32			0.002	0.02		
L. Tredennic (FCSI-96-5)	0.008	0.02			0.00003	0.28			0.0007	0.01		
SW-3	31	100			0.01	100			11.2	100		
Gold Dust (F-28)	0.03		0.44		0.00003		0.14		0.0003		0.006	
SW-4	7.5		100		0.02		100		4.6		100	
Henderson Mtn. (AE-17)	0.05			0.73	0.00005			0.57	0.009			0.57
CFY-2	6.2			100	0.009			100	1.6			100

	Iron				Lead				Manganese			
	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2
Glengarry (F-8A)	0.2	1.1			0.00004	0.14			0.03	0.35		
Glengarry Millsite (F-8B)	2.1	11.4			0.0004	1.38			0.2	2.9		
Sheep Mtn. #1 (FCSI-99-1)	0.05	0.25			0.001	3.85			0.003	0.04		
L. Tredennic (FCSI-96-5)	0.03	0.17			0.0002	0.69			0.02	0.29		
SW-3	19	100			0.03	100			7.3	100		
Gold Dust (F-28)	0.35		4.91		0.0006		1.1		0.07		3.88	
SW-4	7.0		100		0.05		100		1.9		100	
Henderson Mtn. (AE-17)	0.6			22.3	0.001			1.1	0.03			4.8
CFY-2	2.9			100	0.05			100	0.7			100

	Zinc				Flow (gallons per minute)
	Load kg/month	% Contribution at SW-3	% Contribution at SW-4	% Contribution at CFY-2	
Glengarry (F-8A)	0.003	0.13			0.54
Glengarry Millsite (F-8B)	0.02	1.03			7.68
Sheep Mtn. #1 (FCSI-99-1)	0.004	0.19			3.40
L. Tredennic (FCSI-96-5)	0.006	0.31			2.56
SW-3	2	100			101.13
Gold Dust (F-28)	0.02		0.48		3.40
SW-4	4.6		100		612.17
Henderson Mtn. (AE-17)	0.02			0.66	1.02
CFY-2	3.3			100	667.90

Notes: 1 Data for Fisher Creek monitoring stations SW-3, SW-4, and CFY-2 are the average low flow measured from Oct 04 through Oct 06.
2 Glengarry and Gold Dust loads calculated using data collected in June or September 2006; remaining adit data is average for period of record reported by Maxim 2006. Concentration data provided are in Appendix A.
kg/month = kilograms per month

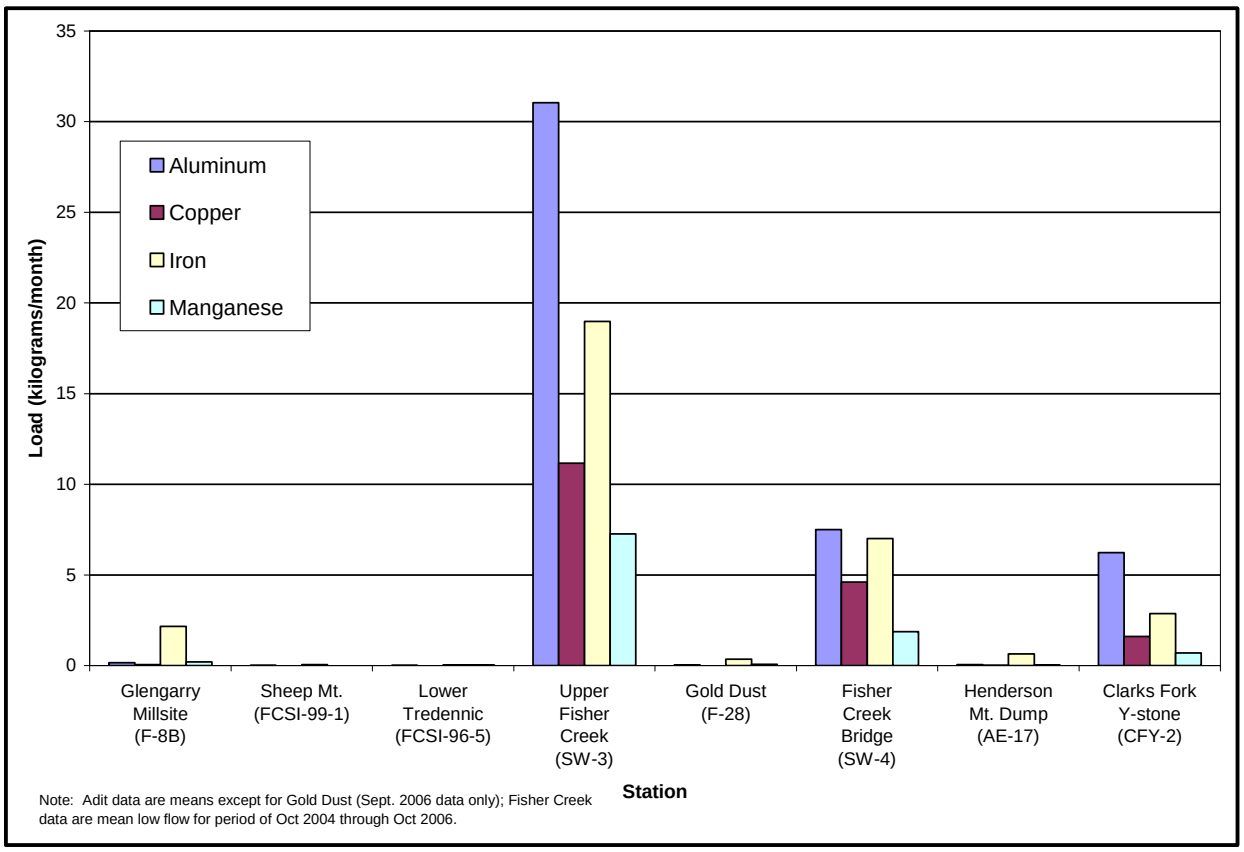

Figure 5-1. Metal loads in Fisher Creek drainage.

Table 5-5
Calculated Pre-mining Water quality in Fisher Creek without loading from adits or waste rock piles.

Scenario	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
	Total Recoverable Concentrations in Milligrams Per Liter						
Actual Measured Concentration at SW-3	2.06	0.0007	0.73	1.17	0.002	0.48	0.13
Pre-Mining Estimate (No Flow)[1]	2.17	0.0007	0.78	1.17	0.002	0.50	0.14
Alternate Pre-Mining Estimate (Diluting Flow)[2]	1.87	0.0006	0.67	1.01	0.002	0.43	0.12
DEQ-7 Standards							
Human Health	No Standard	0.005	1.3	0.30	0.015	0.05	2.0
Acute[3]	0.750[4]	0.0021	0.014	No Standard	0.082	No Standard	0.12
Chronic[3]	0.087[4]	0.0003	0.0093	1.0	0.0032		0.12

[1] Assumes that no flow from McLaren underdrains or adit reaches Daisy Creek at DC-2.
[2] Assumes that McLaren underdrain and adit flow does reach Daisy Creek at DC-2 but that this flow delivers no metal load.
[3] Acute and chronic aquatic life standards calculated for waters having hardness of 100 mg/L and are provided for reference only.
[4] Aluminum standards are based on dissolved concentrations and only applicable to waters with pH between 6.5 and 9. Values provided for reference only.

6.0 SUMMARY AND CONCLUSION

Water quality in the upper reaches of Daisy and Fisher Creeks do not meet the definition of B-1 under the State of Montana Water Quality Act (§§ 75-5-101 et seq., Montana Code Annotated {MCA}). Specifically, these waters are currently not suitable for certain B-1 uses (i.e. growth and propagation of salmonid fishes) due to elevated concentrations of some metals, particularly copper, iron, and manganese although concentrations of cadmium, lead, and zinc are sometimes also detected above DEQ-7 water quality standards.

Data presented in Section 2 of this report indicate that Daisy and Fisher Creeks had acidic pH values, elevated metal concentrations, and transported metal rich sediments prior to any mining activity in the New World District. Metal-rich acidic subsurface water sources not related to mining and currently discharging to Daisy and Fisher Creeks have also been identified. These data suggest naturally occurring pollutant concentrations could prevent the attainment of B-1 uses in the upper reaches of Daisy and Fisher Creeks.

Multiple methods were used to quantify metal concentrations and pH values that may have existed in Daisy and Fisher Creek headwaters prior to mining. These include stream-specific estimation equations based on ferricrete deposits and iron precipitate data (Section 3), and evaluation of surface and groundwater quality data for sources located outside the area of influence of mining (Section 4). Additionally, a loading analysis was conducted to evaluate whether elimination of known sources of potentially human caused pollution would be sufficient to meet the definition of B-1 waters (Section 5).

Results of ferricrete / iron precipitate-based calculations and data for seeps/springs and groundwater monitoring stations chosen as analogs for pre-mining water quality are in agreement that the headwaters of Daisy and Fisher Creeks had acidic pH values and concentrations of metals above DEQ-7 standards for surface water quality prior to mining in the New World District.

6.1 DAISY CREEK

Pre-mining mean pH values and copper concentrations in the upper 481 meters of Daisy Creek were estimated to be, respectively, 3.8 and 8.5 mg/L (range 4.1 to 14 mg/L) based on calculations from the ferricrete study. These data are quite similar to those for well Tracer 2 [mean pH of 3.7 and mean dissolved copper concentration of 4.19 mg/L (range 2.73 to 8.62 mg/L]. Tracer 2 is completed in the Fisher Mountain Complex up the hydrologic gradient from historically mined portions of the McLaren Pit and as such is considered representative of pre-mining or undisturbed conditions. Monitoring well MW-2, which is completed in the mineralized Wolsey Shale beneath the McLaren Pit, also had a mean pH of 3.9 but had a lower mean copper concentration (0.27 mg/L) despite greater concentrations of cadmium, lead, iron, manganese, and zinc than in Tracer 2. Considering the close agreement with calculated estimates of pre-mine water quality data measured from Tracer 2 appear to provide a reasonable estimate of pre-mining surface water quality in the vicinity of the McLaren Pit at the head of Daisy Creek.

At locations below 481 meters from the head of Daisy Creek, downstream of the McLaren Pit, pre-mining estimates of water quality (pH range 4.2 to 4.4 and copper concentration range 2.9 to 3.9) were calculated and are similar to currently measured concentrations at DC-2. This downstream improvement in water quality is due to neutral groundwater inflows near the edge of the ferricrete apron located below the McLaren Pit. The chemistry of these diluting inflows may be represented by water quality measured in Meagher Limestone well DCGW-100 and also by seeps and springs of the Eocene rhyodacite porphyry of Lulu Pass (including surface run-off samples Bessie-US and Bessie-DS)

which underlies about 27% of the area draining into Daisy Creek above its confluence with the Stillwater River. Water quality from these locations had near-neutral pH and metal concentrations that were considerably lower than those from the uppermost headwaters of Daisy Creek yet still exceeded DEQ-7 acute and / or chronic standards for aquatic life.

These data all support the hypothesis that natural mineralization in the Fisher Mountain Intrusive Complex and in the vicinity of the exposed McLaren massive sulfide deposit was a major source of pre-mining acidity and metal release prior to mining. While inflows located north of the McLaren Pit improve Daisy Creek water quality through dilution, metal concentrations in these inflows are too high to meet B-1 definitions either on their own or upon mixing with surface water in Daisy Creek.

The loading analysis presented in Section 5 indicates that if seepage from the McLaren Adit and the pit underdrain system was eliminated, metal concentrations would not improve sufficiently to meet DEQ-7 standards.

6.2 FISHER CREEK

Pre-mining pH values for the reach of Fisher Creek upstream of the Glengarry Adit are estimated to be between 3.5 and 3.8 (similar to Daisy Creek) based on ferricrete / iron precipitate calculations. These data are similar to that for monitoring well Tracer 5 (pH range 3.1 to 4.6, mean 3.8) which is completed in the Fisher Mountain Complex in the Como Basin. Calculated estimates are less than the mean pH measured in seeps and springs originating from the Fisher Mountain Complex (4.5) or in monitoring well MW-1 completed in mineralized Wolsey Shale in the Como Basin (4.1) however this could be attributed to reasons explained in Section 3.5.

Estimated pre-mining copper concentrations above the Glengarry Adit were calculated to range between 0.5 to 0.64 mg/L. These concentrations bracket the mean of 0.52 mg/L for seeps and springs originating in the Fisher Mountain Complex which underlies about 45% of the area draining into Fisher Creek above the Glengarry Adit. The calculated pre-mining copper concentration is much lower than the mean dissolved copper concentration measured at Tracer 5 (3.54 mg/L) but is similar to that measured in groundwater from an intrusive dike monitored by EPA-11 (0.33 mg/L).

In September 2007 (after closure of the Glengarry adit), measured pH at SW-3 (995 m) was 3.9, somewhat lower than the pre-mining value of 4.8 estimated from the ferricrete study for this site. At SW-3, the September 2007 total recoverable copper concentration was 0.84 mg/L, somewhat higher than the estimated pre-mining value of 0.26 mg/L.

As was the case prior to mining, naturally occurring acidic and metal-rich inflows contribute metals to Fisher Creek below the Glengarry Adit. These natural sources of loading contribute a greater proportion of the total metal load in Fisher Creek compared to mine related sources. The loading analysis presented in Section 5 indicates that if seepage from all known mine related sources was eliminated, metal concentrations in Fisher Creek would not improve to meet DEQ-7 standards.

6.3 IMPLICATIONS FOR WATER QUALITY IMPROVEMENT

Data presented in this report strongly indicate that acidic metal-rich surface water existed in Daisy Creek above the Stillwater River, and in Fisher Creek above Clark's Fork of the Yellowstone River prior to mining activity in the New World Mining District. Based on comparison of data for non-impacted surface and groundwater sources with results of empirically based calculations, pre-mining water quality at the headwaters of Daisy Creek appears to be reasonably represented by water quality measured in

monitoring well Tracer 2 while monitoring data for seeps and springs originating in the Fisher Mountain Complex in the Como Basin represent natural conditions in Fisher Creek above the Glengarry Adit.

Mining activity has resulted in increased metal concentrations in Daisy and Fisher Creeks compared to pre-mining conditions. For copper, and potentially other metals, these impacts are suspected to have been more pronounced in Fisher Creek compared to Daisy Creek based on work by Nimick et al. (2009). However, review of water quality data for surface and groundwater monitored upgradient of mining activity shows that these sources of inflow to each creek typically exceed DEQ-7 surface water quality standards for one or more metals. Loading analyses show even complete removal of all known mine related water sources, including McLaren Pit underdrain flow, would not improve water quality relative to DEQ-7 standards.

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APPENDIX A-1
SEEP DATA

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	pH (field)	pH(lab)	EH	SC(Field)	SC(lab)	Flow	Flow units	TDS flag	TDS	TSS flag	TSS	Ca flag	Ca	Mg flag	Mg	Na flag	Na
Pleistocene Glacial Deposits	North of Crown Butte and Miller Mountain, west of Daisy Creek	D-4	9/12/1989	7.3			219.0		1	gpm										
		D-5	9/12/1989	7.5					5	gpm										
		D-6	9/12/1989	8.0	8.3		201.0		12	L/min										
		D-6	8/3/1990	6.5	8.3	24.0			60	L/min										
		D-7	9/12/1989	8.5			94.8		2	L/min										
		D-8	9/12/1989	7.9			155.0		5	L/min										
		D-9	9/12/1989	8.5			125.0		5	L/min										
		D-10	9/13/1989	8.3																
		D-11	9/13/1989	7.5	6.6		71.0		½	L/min										
		D-12	9/13/1989						10	L/min										
		D-13	9/13/1989		7.5		124.0		0.5	L/min										
		D-13	8/3/1990	6.7		23.0			2	L/min										
		D-50	7/19/1990	7.6			275.0		3	gpm										
		D-51	7/19/1990	7.6					0.5	gpm										
		D-52	7/19/1990	6.7	8.2		113.0		3	cfs						14.0		4.0		3.0
		D-53	7/19/1990	8.1					8	gpm										
		D-61	7/20/1990	6.9	8.2		107.0		30	gpm						32.0		3.0	<	1.0
		D-62	7/20/1990	7.1	8.1		144.0		2.5	cfs						22.0		5.0	<	1.0
		D-63	7/18/1990	6.7	7.8				3	cfs						10.0		5.0	<	1.0
		D-64	7/18/1990	6.1	7.7		92.0		0.5	cfs						17.0		2.0	<	1.0
		D-65	7/18/1990	7.1	7.9		156.0		0.5	cfs						30.0		2.0	<	1.0
	Between Waste Repository and Soda Butte Campground	AE-13	7/17/1990	7.1	8.3		205.0		0.5	cfs						39.0		6.0		1.0
		AE-15	7/18/1990	6.4	8.3		212.0		40	gpm										
		AE-16	7/18/1990	7.1					5	gpm										
Holocene Surficial Deposits	East flank of Miller Mountain	M-27	9/1/1989	7.0	8.0		53.0		14	L/min										
		M-27	8/9/1990	6.6	7.6	9.0	134.0		25	L/min										
		M-28	9/1/1989	7.0			57.0		10	L/min										
		M-29	9/1/1989	7.3			75.0		60	gpm										

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	pH (field)	pH(lab)	EH	SC(Field)	SC(lab)	Flow	Flow units	TDS flag	TDS	TSS flag	TSS	Ca flag	Ca	Mg flag	Mg	Na flag	Na
Precambrian Granitic	South and east of Sheep Mountain, north of Fisher Creek	F-12	9/19/1989	5.5	7.3		76.0		23	L/min										
		F-13	9/19/1989	6.0	7.8		114.0		180	L/min										
		F-14	9/19/1989	6.1			72.0		1	L/min						21.0		3.0		1.0
		F-15	9/19/1989	6.3	8.3		182.0		30	L/min						38.0		5.0		1.0
		F-16	9/19/1989	6.5			97.0		1	L/min										
		F-17	9/19/1989	6.8			135.0		32	L/min						16.0		9.0		1.0
		F-18	9/19/1989	7.0			139.0		30	L/min										
		F-19	9/19/1989						3	L/min										
		F-20	9/19/1989	6.9	7.7		80.0		0.25	cfs		62.5		3.0		16.5		3.0	<	1.0
		F-20	7/13/1990	6.9	7.9		99.0	100.0	2075	gpm		54.0								
		F-20	7/18/1990	6.8	8.0				3	cfs						16.0		3.0	<	1.0
		F-34	7/18/1990	5.6	7.8				4	gpm										
		F-35	7/18/1990						5	gpm										
		F-36	7/18/1990	5.9					6	gpm										
		F-37	7/18/1990	6.7	7.2		112.0		30	L/min						2.0	<	1.0	<	1.0
		F-38	7/18/1990						3	gpm										
		F-39	7/18/1990	6.0	8.0		112.0		5	cfs						17.0		3.0	<	1.0
		F-40	7/18/1990	6.9	7.7		98.0		3.5	cfs						15.0		3.0		1.0
		F-41	7/18/1990	5.6	7.0		16.0	19.0	135	gpm		12.0				2.0	<	1.0	<	1.0
		F-42	7/18/1990	4.8	6.1		17.0		0.5	gpm						2.0	<	1.0	<	1.0
	South of Fisher Creek, northeast of Henderson Mountain	F-22	9/20/1989	7.1			43.0		0.1	L/min										
		F-23	9/20/1989	6.8	7.2		80.0		8	L/min										
		F-23	8/8/1990	6.4	6.9	1.0	110.0		5	L/min						16.0	3		<	1.0
		F-24	9/20/1989	7.0			79.0		15	L/min										
		F-25	9/20/1989	7.2	7.1	1.0	58.0		65	gpm										
		F-25	8/8/1990	6.5	6.7															

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	pH (field)	pH(lab)	EH	SC(Field)	SC(lab)	Flow	Flow units	TDS flag	TDS	TSS flag	TSS	Ca flag	Ca	Mg flag	Mg	Na flag	Na
Eocene Rhyodacite Porphyry of Henderson Mountain	Southwest facing flank of Henderson Mountain	M-16	9/1/1989	7.0	7.8		99.0		1.5	L/min										
		M-17	9/1/1989	7.0			88.0		4.2	L/min										
		M-19	9/1/1989	7.0	7.4		68.0		1.3	L/min										
		M-20	9/1/1989	7.0			72.0		1.7	L/min										
		M-20	8/9/1990	5.8	6.3	18.0			3	L/min										
		M-21	9/1/1989						1.5	L/min										
		M-22	9/1/1989	7.0			54.0		1.2	L/min										
		M-23	9/1/1989	7.0	6.1		40.0		0.75	L/min										
		M-26	9/1/1989	7.0			52.0		0.5	L/min										
	East facing flank of Henderson Mountain	F-1	9/17/1989	6.4			96.0		½	L/min										
		F-1	7/21/1995	6.8	7.1		100.0	137.0	219							26.0		2.0	<	1.0
Complex of Fisher Mountain	Fisher Mountain and Lulu Pass area	F-4	9/18/1989	3.6	3.7		95.0		20	L/min		38.5	<	4		3.3		1.0	<	1.0
		F-4	8/7/1990	3.8	4.1	152.0	98.0									3.0	<	1.0	<	1.0
		F-4	8/23/1990	3.93	4.1		105.0		4	gpm		59.0				3.0	<	1.0	<	1.0
		F-4	7/11/1991	4.5	4.5		51.0		22.6	gpm		39.0	<	2.0		1.0	<	1.0	<	1.0
		F-4	9/26/1991	3.7	3.8		125.0		0.93	gpm		60.0	<	4.0		4.0		2.0	<	1.0
		F-4	7/14/1995	4.3	4.2		36.0					20.0	<	10.0	<	1.0	<	1.0	<	1.0
		F-4	8/6/1996	3.7	3.8		95.0	90.0	25	gpm		72.0	<	10.0		2.0	<	1.0	<	1.0
		F-5	9/18/1989	6.7	3.7		98.0		6	L/min										
		F-5	8/7/1990	7.2	5.9	6.0			30	L/min						1.0	<	1.0	<	1.0
		F-6	9/18/1989	3.4	3.9		73.0		7	L/min										
		F-6	8/7/1990		4.2				3	L/min										
		F-48	8/7/1996	5.1	4.8		12.0	12.0	15	gpm	<	10.0	<	10		1.0	<	1.0	<	1.0
		F-54	8/6/1996	3.7	3.9		30.0	37.0	8	gpm		20.0	<	10	<	1.0	<	1.0	<	1.0
		F-60	8/8/1996		4.1		55.0	63.0	12	gpm		57.0	<	10		1.0	<	1.0		1.0
		F-61	8/8/1996		3.5		311.0	252.0	0.5	gpm		140.0	<	10		4.0		2.0		4.0
		FCT-11-1	8/7/1996	4.3	5.0		307.0	28.0	27.8	gpm		16.0	<	10		2.0	<	1.0	<	1.0
		FCT-11-1	9/12/1996	4.5	3.7		43.0	40.0	6.73	gpm		28.0	<	10		3.0	<	1.0	<	1.0
		FCT-11-2	8/7/1996	3.3	3.3		281.0	303.0				139.0		136		13.0		2.0	<	1.0
		FCT-11-6	8/7/1996	4.9	5.3		32.0	28.0	0.007	gpm		25.0	<	10		3.0	<	1.0	<	1.0
		FCT-11-7	8/8/1996		5.5		64.0	69.0	50	gpm		50.0	<	10		8.0		1.0	<	1.0
		FCT-11-7	9/12/1996	5.4	5.5		64.5	70.0	3.14	gpm		49.0	<	10		7.0		2.0	<	1.0
		FCT-11-8	8/8/1996		5.9		53.0	63.0	19.74	gpm		35.0	<	10		4.0		2.0	<	1.0
		FCT-11-8	9/12/1996	4.5	4.2		64.8	74.0	4.5	gpm		41.0	<	10		4.0		2.0	<	1.0
		FCT-16	7/12/1996	4.5	3.9		72.5	70.0	0.14	cfs		29.0		9		2.0	<	1.0		2.0
		FCT-16	8/8/1996		4.1		151.0	95.0	0.022	cfs		88.0	<	10		3.0	<	1.0		3.0
		FCT-16	9/11/1996	4.5	4.1		102.0	115.0	0.001	cfs		86.0	<	10		3.0		1.0		4.0

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	pH (field)	pH(lab)	EH	SC(Field)	SC(lab)	Flow	Flow units	TDS flag	TDS	TSS flag	TSS	Ca flag	Ca	Mg flag	Mg	Na flag	Na
Eocene Rhyodacite Porphyry of Lulu Pass	Northwest of Lulu Pass and Scotch Bonnet Mountain	WR-3	9/21/1989	6.4			58.0		1	L/min										
		WR-4	9/21/1989	6.7	7.8		97.0		4	L/min										
		WR-5	9/21/1989	7.6	6.8		79.0		12	L/min										
		WR-6	9/21/1989	8.6			84.0		3	L/min										
		WR-6	9/25/1991	7.8	7.3															
		WR-7	9/21/1989	8.5	7.8		72.0		½	L/min										
		WR-7	9/25/1991	8.5	7.6															
		WR-8	9/21/1989	8.1	7.5		111.0		20	L/min										
		WR-9	9/21/1989	8.3			109.0		5.5	L/min										
		WR-9	9/25/1991	8.0	6.9															
		WR-10	9/21/1989	7.5			76.0		Trickle											
		WR-11	9/21/1989	7.7	7.4		95.0		8	L/min						13.0		9.0	<	1.0
		BESSIE-US	8/19/2008																	
		BESSIE-DS	8/19/2008																	

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Alkalinity flag	Alkalinity	Acidity flag	Acidity	HCO3 flag	HCO3	CO3	SO4 flag	SO4	Cl flag	Cl	AL (DIS) flag	AL (DIS)	AL (TRC) flag	AL (TRC)	As (DIS) flag	As (DIS)
Pleistocene Glacial Deposits	North of Crown Butte and Miller Mountain, west of Daisy Creek	D-4	9/12/1989																	
		D-5	9/12/1989																	
		D-6	9/12/1989		122.0		0.0					151.0								
		D-6	8/3/1990		118.0		0.0					122.0					<	0.10		
		D-7	9/12/1989																	
		D-8	9/12/1989																	
		D-9	9/12/1989																	
		D-10	9/13/1989																	
		D-11	9/13/1989				0.0													
		D-12	9/13/1989																	
		D-13	9/13/1989		90.0		0.0					16.0								
		D-13	8/3/1990																	
		D-50	7/19/1990																	
		D-51	7/19/1990																	
		D-52	7/19/1990		55.0		0.0		68.0	0.0		1.0	<	1.00			<	0.10		
		D-53	7/19/1990																	
		D-61	7/20/1990		87.0		0.0		106.0	0.0		1.0	<	1.00			<	0.10		
		D-62	7/20/1990		63.0		0.0		77.0	0.0		9.0	<	1.00			<	0.10		
		D-63	7/18/1990		40.0		0.0		48.0	0.0		4.0	<	1.00			<	0.10		
		D-64	7/18/1990		46.0		0.0		56.0	0.0		2.0	<	1.00			<	0.10		
		D-65	7/18/1990		81.0		0.0		99.0	0.0		2.0	<	1.00			<	0.10		
	Between Waste Repository and Soda Butte Campground	AE-13	7/17/1990		109.0		0.0		133.0	0.0		10.0	<	1.00			<	0.10		
		AE-15	7/18/1990																	
		AE-16	7/18/1990																	
Holocene Surficial Deposits	East flank of Miller Mountain	M-27	9/1/1989		62.0															
		M-27	8/9/1990		58.0		46.0													
		M-28	9/1/1989																	
		M-29	9/1/1989																	

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Alkalinity flag	Alkalinity	Acidity flag	Acidity	HCO3 flag	HCO3	CO3	SO4 flag	SO4	Cl flag	Cl	AL (DIS) flag	AL (DIS)	AL (TRC) flag	AL (TRC)	As (DIS) flag	As (DIS)
Precambrian Granitic	South and east of Sheep Mountain, north of Fisher Creek	F-12	9/19/1989		15.0		0.0					28.0								
		F-13	9/19/1989		71.0		0.0					50.0								
		F-14	9/19/1989		49.0		0.0		60.0	0.0		15.0	<	1.00			<	0.10		
		F-15	9/19/1989		98.0		0.0		120.0	0.0		11.0	<	1.00			<	0.10		
		F-16	9/19/1989																	
		F-17	9/19/1989		46.0				56.0	0.0		32.0		1.00	<	0.10	<	0.10	<	0.005
		F-18	9/19/1989																	
		F-19	9/19/1989																	
		F-20	9/19/1989		42.3		0.0		51.5	0.0		40.0		2.50			<	0.10		
		F-20	7/13/1990		43.0							93.0					<	0.10		
		F-20	7/18/1990		44.0		0.0		54.0	0.0		12.0	<	1.00			<	0.10		
		F-34	7/18/1990		10.0							1.0								
		F-35	7/18/1990																	
		F-36	7/18/1990																	
		F-37	7/18/1990		7.0		0.0		9.0	0.0		1.0	<	1.00			<	0.10		
		F-38	7/18/1990																	
		F-39	7/18/1990		43.0		0.0		53.0	0.0		13.0	<	1.00			<	0.10		
		F-40	7/18/1990		41.0		0.0		50.0	0.0		11.0	<	1.00			<	0.10		
		F-41	7/18/1990		7.0		0.0		9.0	0.0	<	1.0	<	1.00			<	0.10		
		F-42	7/18/1990		9.0		0.0		11.0	0.0		1.0	<	1.00			<	0.10		
	South of Fisher Creek, northeast of Henderson Mountain	F-22	9/20/1989																	
		F-23	9/20/1989		44.0		0.0					16.0						0.10		
		F-23	8/8/1990		31.0				38.0	0.0		19.0	<	1.00						
		F-24	9/20/1989																	
		F-25	9/20/1989		16.0		0.0					17.0								
		F-25	8/8/1990		18.0							20.0								

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Alkalinity flag	Alkalinity	Acidity flag	Acidity	HCO3 flag	HCO3	CO3	SO4 flag	SO4	Cl flag	Cl	AL (DIS) flag	AL (DIS)	AL (TRC) flag	AL (TRC)	As (DIS) flag	As (DIS)
Eocene Rhyodacite Porphyry of Henderson Mountain	Southwest facing flank of Henderson Mountain	M-16	9/1/1989				0.0													
		M-17	9/1/1989																	
		M-19	9/1/1989		34.0		0.0													
		M-20	9/1/1989																	
		M-20	8/9/1990		5.0							27.0								
		M-21	9/1/1989																	
		M-22	9/1/1989																	
		M-23	9/1/1989																	
		M-26	9/1/1989																	
	East facing flank of Henderson Mountain	F-1	9/17/1989																	
		F-1	7/21/1995		66.0				80.0	0.0		7.0	<	1.00	<	0.10	<	0.10	<	0.001
Complex of Fisher Mountain	Fisher Mountain and Lulu Pass area	F-4	9/18/1989	<	0.0		30.7	<	1.0	0.0		37.5	<	1.00		1.85		1.77	<	0.005
		F-4	8/7/1990	<	1.0		18.7	<	1.0	0.0		31.0	<	1.00		1.40		1.40	<	0.005
		F-4	8/23/1990	<	1.0		22.2	<	1.0	0.0		35.0	<	1.00		1.50			<	0.005
		F-4	7/11/1991	<	1.0		8.0	<	1.0	0.0		11.0		1.00				0.90		
		F-4	9/26/1991	<	1.0		20.0	<	1.0	0.0		32.0		1.00		2.30		2.40	<	0.005
		F-4	7/14/1995		0.0		3.0		0.0	0.0		12.0		1.00		0.50		0.40	<	0.001
		F-4	8/6/1996		0.0		21.0		0.0	0.0		46.0				1.90		1.90		
		F-5	9/18/1989		0.0		46.0					47.0								
		F-5	8/7/1990		3.0				4.0	0.0		4.0	<	1.00	<	0.10	<	0.10	<	0.005
		F-6	9/18/1989		0.0		44.5					37.3								
		F-6	8/7/1990		0.0		33.0					46.0								
		F-48	8/7/1996		2.0	<	1.0		2.0	0.0		6.0			<	0.10	<	0.10		
		F-54	8/6/1996		0.0		8.0		0.0	0.0		24.0						0.60		
		F-60	8/8/1996		0.0		7.0		0.0	0.0		31.0				1.70		1.70		
		F-61	8/8/1996		0.0		60.0		0.0	0.0		104.0						6.00		
		FCT-11-1	8/7/1996	<	1.0	<	1.0		0.0	0.0		10.0				0.30		0.30		
		FCT-11-1	9/12/1996		0.0		7.0		0.0	0.0		17.0	<	1.00		0.50		0.60		
		FCT-11-2	8/7/1996		0.0		51.0		0.0	0.0		114.0				4.10		5.60		
		FCT-11-6	8/7/1996		1.0	<	1.0		2.0	0.0		12.0				0.10	<	0.10		
		FCT-11-7	8/8/1996		10.0	<	1.0		13.0	0.0	22.0				<	0.10	<	0.10		
		FCT-11-7	9/12/1996		8.0	<	1.0		10.0	0.0	20.0		<	1.00	<	0.10		0.10		
		FCT-11-8	8/8/1996	<	1.0		7.0		0.0	0.0		21.0				0.60		0.70		
		FCT-11-8	9/12/1996		0.0		12.0		0.0	0.0		33.0	<	1.00		1.40		1.60		
		FCT-16	7/12/1996		0.0		15.0		0.0	0.0		23.0	<	1.00		1.60		1.60		
		FCT-16	8/8/1996		0.0		25.0		0.0	0.0		50.0				2.40		2.50		
		FCT-16	9/11/1996		0.0		28.0		0.0	0.0		54.0	<	1.00		3.00		3.10		

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Alkalinity flag	Alkalinity	Acidity flag	Acidity	HCO3 flag	HCO3	CO3	SO4 flag	SO4	Cl flag	Cl	AL (DIS) flag	AL (DIS)	AL (TRC) flag	AL (TRC)	As (DIS) flag	As (DIS)
Eocene Rhyodacite Porphyry of Lulu Pass	Northwest of Lulu Pass and Scotch Bonnet Mountain	WR-3	9/21/1989																	
		WR-4	9/21/1989		96.0		0.0					4.0								
		WR-5	9/21/1989		9.0		0.0					36.0								
		WR-6	9/21/1989																	
		WR-6	9/25/1991																	
		WR-7	9/21/1989																	
		WR-7	9/25/1991																	
		WR-8	9/21/1989		88.0							5.0								
		WR-9	9/21/1989																	
		WR-9	9/25/1991																	
		WR-10	9/21/1989																	
		WR-11	9/21/1989		66.0		0.0		80.0	0.0		5.0	<	1.00	<	0.10	<	0.10	<	0.005
		BESSIE-US	8/19/2008														<	0.05		
		BESSIE-DS	8/19/2008															0.12		

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	As (TRC) flag	As (TRC)	Cd (DIS) flag	Cd (DIS)	Cd (TRC) flag	Cd (TRC)	Cu (DIS) flag	Cu (DIS)	Cu (TRC) flag	Cu (TRC)	Fe (DIS) flag	Fe (DIS)	Fe (TRC) flag	Fe (TRC)	Pb (DIS) flag	Pb (DIS)	
Pleistocene Glacial Deposits	North of Crown Butte and Miller Mountain, west of Daisy Creek	D-4	9/12/1989																	
		D-5	9/12/1989																	
		D-6	9/12/1989																	
		D-6	8/3/1990	<	0.005			<	0.001			<	0.01			<	0.03			
		D-7	9/12/1989																	
		D-8	9/12/1989																	
		D-9	9/12/1989																	
		D-10	9/13/1989																	
		D-11	9/13/1989																	
		D-12	9/13/1989																	
		D-13	9/13/1989																	
		D-13	8/3/1990																	
		D-50	7/19/1990																	
		D-51	7/19/1990																	
		D-52	7/19/1990	<	0.005			<	0.001			<	0.01				0.08			
		D-53	7/19/1990																	
		D-61	7/20/1990	<	0.005			<	0.001			<	0.01			<	0.03			
		D-62	7/20/1990	<	0.005			<	0.001			<	0.01			<	0.03			
		D-63	7/18/1990	<	0.005			<	0.001			<	0.01				0.16			
		D-64	7/18/1990	<	0.005			<	0.001			<	0.01				0.07			
		D-65	7/18/1990	<	0.005			<	0.001			<	0.01				0.09			
	Between Waste Repository and Soda Butte Campground	AE-13	7/17/1990	<	0.005			<	0.001			<	0.01				0.05			
		AE-15	7/18/1990																	
		AE-16	7/18/1990																	
Holocene Surficial Deposits	East flank of Miller Mountain	M-27	9/1/1989																	
		M-27	8/9/1990	<	0.005			<	0.001				0.04			<	0.03			
		M-28	9/1/1989																	
		M-29	9/1/1989																	

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	As (TRC) flag	As (TRC)	Cd (DIS) flag	Cd (DIS)	Cd (TRC) flag	Cd (TRC)	Cu (DIS) flag	Cu (DIS)	Cu (TRC) flag	Cu (TRC)	Fe (DIS) flag	Fe (DIS)	Fe (TRC) flag	Fe (TRC)	Pb (DIS) flag	Pb (DIS)	
Precambrian Granitic	South and east of Sheep Mountain, north of Fisher Creek	F-12	9/19/1989																	
		F-13	9/19/1989	<	0.005			<	0.001			<	0.01				0.06			
		F-14	9/19/1989	<	0.005			<	0.001			<	0.01				0.01			
		F-15	9/19/1989																	
		F-16	9/19/1989																	
		F-17	9/19/1989	<	0.005	<	0.001	<	0.001	<	0.01		0.01	<	0.03		0.67	<	0.01	
		F-18	9/19/1989																	
		F-19	9/19/1989																	
		F-20	9/19/1989	<	0.005			<	0.001			<	0.01			<	0.03			
		F-20	7/13/1990	<	0.005			<	0.001			<	0.01			<	0.03			
		F-20	7/18/1990	<	0.005			<	0.001			<	0.01			<	0.03			
		F-34	7/18/1990																	
		F-35	7/18/1990																	
		F-36	7/18/1990																	
		F-37	7/18/1990	<	0.005			<	0.001			<	0.01			<	0.03			
		F-38	7/18/1990																	
		F-39	7/18/1990	<	0.005			<	0.001			<	0.01				0.12			
		F-40	7/18/1990	<	0.005			<	0.001			<	0.01				0.04			
		F-41	7/18/1990	<	0.005			<	0.001			<	0.01				0.06			
		F-42	7/18/1990	<	0.005			<	0.001			<	0.01			<	0.03			
	South of Fisher Creek, northeast of Henderson Mountain	F-22	9/20/1989																	
		F-23	9/20/1989	<	0.005			<	0.001			<	0.01				0.24			
		F-23	8/8/1990																	
		F-24	9/20/1989																	
		F-25	9/20/1989	<	0.005			<	0.001				0.01				0.08			
		F-25	8/8/1990	<	0.005			<	0.001			<	0.01				0.06			

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	As (TRC) flag	As (TRC)	Cd (DIS) flag	Cd (DIS)	Cd (TRC) flag	Cd (TRC)	Cu (DIS) flag	Cu (DIS)	Cu (TRC) flag	Cu (TRC)	Fe (DIS) flag	Fe (DIS)	Fe (TRC) flag	Fe (TRC)	Pb (DIS) flag	Pb (DIS)	
Eocene Rhyodacite Porphyry of Henderson Mountain	Southwest facing flank of Henderson Mountain	M-16	9/1/1989																	
		M-17	9/1/1989																	
		M-19	9/1/1989																	
		M-20	9/1/1989																	
		M-20	8/9/1990	<	0.005			<	0.001				0.03			<	0.03			
		M-21	9/1/1989																	
		M-22	9/1/1989																	
		M-23	9/1/1989																	
		M-26	9/1/1989																	
	East facing flank of Henderson Mountain	F-1	9/17/1989																	
		F-1	7/21/1995	<	0.001	<	0.0001	<	0.0001	<	0.001	<	0.001	<	0.03		0.07	<	0.002	
Complex of Fisher Mountain	Fisher Mountain and Lulu Pass area	F-4	9/18/1989	<	0.005		0.000	<	0.001		0.41		0.40		0.28		0.34	<	0.01	
		F-4	8/7/1990	<	0.005	<	0.001		0.001		0.34		0.34		0.21		0.25	<	0.01	
		F-4	8/23/1990			<	0.001				0.30				0.26			<	0.01	
		F-4	7/11/1991	<	0.005				0.0002				0.23				0.27			
		F-4	9/26/1991	<	0.005		0.0004		0.0010		0.39		0.44		0.24		0.38	<	0.002	
		F-4	7/14/1995	<	0.001		0.0001		0.0001		0.132		0.116		0.09		0.09	<	0.002	
		F-4	8/6/1996								0.384		0.401		0.44		0.46			
		F-5	9/18/1989	<	0.005			<	0.001				0.70				0.59			
		F-5	8/7/1990	<	0.005	<	0.001	<	0.001	<	0.01	<	0.01	<	0.03	<	0.03	<	0.01	
		F-6	9/18/1989	<	0.005			<	0.002				0.36				0.26			
		F-6	8/7/1990	<	0.005			<	0.001				0.76				0.66			
		F-48	8/7/1996							<	0.001	<	0.001	<	0.01		0.01			
		F-54	8/6/1996										0.12			<	0.01			
		F-60	8/8/1996								1.22		1.32		0.05		0.04			
		F-61	8/8/1996										2.31				3.62			
		FCT-11-1	8/7/1996								0.003		0.003		0.01	<	0.01			
		FCT-11-1	9/12/1996				0.0002		0.0001		0.004		0.003		0.02		0.01	<	0.003	
		FCT-11-2	8/7/1996								0.97		1.02		2.40		11.10			
		FCT-11-6	8/7/1996								0.002		0.003	<	0.01	<	0.01			
		FCT-11-7	8/8/1996			<	0.0001	<	0.0001		0.006		0.01	<	0.01		0.21			
		FCT-11-7	9/12/1996			<	0.0001	<	0.0001		0.015		0.02	<	0.01		0.05	<	0.003	
		FCT-11-8	8/8/1996								0.397		0.429		0.25		0.47			
		FCT-11-8	9/12/1996			<	0.0001	<	0.0001		0.608		0.644		0.02		0.04	<	0.003	
		FCT-16	7/12/1996				0.0003		0.0003		0.83		0.84	<	0.01	<	0.01	<	0.003	
		FCT-16	8/8/1996								1.14		1.20		0.02	<	0.01			
		FCT-16	9/11/1996				0.0006		0.0007		1.34		1.40		0.03		0.04	<	0.003	

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	As (TRC) flag	As (TRC)	Cd (DIS) flag	Cd (DIS)	Cd (TRC) flag	Cd (TRC)	Cu (DIS) flag	Cu (DIS)	Cu (TRC) flag	Cu (TRC)	Fe (DIS) flag	Fe (DIS)	Fe (TRC) flag	Fe (TRC)	Pb (DIS) flag	Pb (DIS)	
Eocene Rhyodacite Porphyry of Lulu Pass	Northwest of Lulu Pass and Scotch Bonnet Mountain	WR-3	9/21/1989																	
		WR-4	9/21/1989																	
		WR-5	9/21/1989	<	0.005				0.002				0.23				3.18			
		WR-6	9/21/1989																	
		WR-6	9/25/1991																	
		WR-7	9/21/1989																	
		WR-7	9/25/1991																	
		WR-8	9/21/1989	<	0.005			<	0.001			<	0.01				0.08			
		WR-9	9/21/1989																	
		WR-9	9/25/1991																	
		WR-10	9/21/1989																	
		WR-11	9/21/1989	<	0.005	<	0.001	<	0.001	<	0.01	<	0.01	<	0.03	<	0.03	<	0.01	
		BESSIE-US	8/19/2008					<	0.0001				0.003				0.04			
		BESSIE-DS	8/19/2008						0.0005				0.068				0.68			

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Pb (TRC) flag	Pb (TRC)	Mn (DIS) flag	Mn (DIS)	Mn (TRC) flag	Mn (TRC)	Hg (DIS) flag	Hg (DIS)	Hg (TRC) flag	Hg (TRC)	Ag (DIS) flag	Ag (DIS)	Ag (TRC) flag	Ag (TRC)	Zn (DIS) flag	Zn (DIS)	Zn (TRC) flag	Zn (TRC)
Pleistocene Glacial Deposits	North of Crown Butte and Miller Mountain, west of Daisy Creek	D-4	9/12/1989																		
		D-5	9/12/1989																		
		D-6	9/12/1989																		
		D-6	8/3/1990	<	0.01			<	0.02			<	0.001			<	0.005			<	0.01
		D-7	9/12/1989																		
		D-8	9/12/1989																		
		D-9	9/12/1989																		
		D-10	9/13/1989																		
		D-11	9/13/1989																		
		D-12	9/13/1989																		
		D-13	9/13/1989																		
		D-13	8/3/1990																		
		D-50	7/19/1990																		
		D-51	7/19/1990																		
		D-52	7/19/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.01
		D-53	7/19/1990																		
		D-61	7/20/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.05
		D-62	7/20/1990	<	0.01			<	0.02			<	0.001			<	0.005			<	0.01
		D-63	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.02
		D-64	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.02
		D-65	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.70
	Between Waste Repository and Soda Butte Campground	AE-13	7/17/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.02
		AE-15	7/18/1990																		
		AE-16	7/18/1990																		
Holocene Surficial Deposits	East flank of Miller Mountain	M-27	9/1/1989																		
		M-27	8/9/1990					<	0.02											<	0.01
		M-28	9/1/1989																		
		M-29	9/1/1989																		

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Pb (TRC) flag	Pb (TRC)	Mn (DIS) flag	Mn (DIS)	Mn (TRC) flag	Mn (TRC)	Hg (DIS) flag	Hg (DIS)	Hg (TRC) flag	Hg (TRC)	Ag (DIS) flag	Ag (DIS)	Ag (TRC) flag	Ag (TRC)	Zn (DIS) flag	Zn (DIS)	Zn (TRC) flag	Zn (TRC)
Precambrian Granitic	South and east of Sheep Mountain, north of Fisher Creek	F-12	9/19/1989																		
		F-13	9/19/1989					<	0.02												0.01
		F-14	9/19/1989		0.01			<	0.02			<	0.001			<	0.005				0.02
		F-15	9/19/1989																		
		F-16	9/19/1989																		
		F-17	9/19/1989	<	0.01		0.11		0.12	<	0.001	<	0.001	<	0.005	<	0.005		0.05		0.04
		F-18	9/19/1989																		
		F-19	9/19/1989																		
		F-20	9/19/1989		0.02			<	0.02			<	0.001			<	0.005				0.08
		F-20	7/13/1990					<	0.02											<	0.01
		F-20	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.01
		F-34	7/18/1990																		
		F-35	7/18/1990																		
		F-36	7/18/1990																		
		F-37	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.02
		F-38	7/18/1990																		
		F-39	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.01
		F-40	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.01
		F-41	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005			<	0.01
		F-42	7/18/1990	<	0.01			<	0.02			<	0.001			<	0.005				0.02
	South of Fisher Creek, northeast of Henderson Mountain	F-22	9/20/1989																		
		F-23	9/20/1989	<	0.01				0.03			<	0.001			<	0.005				0.01
		F-23	8/8/1990																		
		F-24	9/20/1989																		
		F-25	9/20/1989					<	0.02											<	0.01
		F-25	8/8/1990					<	0.02									<	0.01		

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Pb (TRC) flag	Pb (TRC)	Mn (DIS) flag	Mn (DIS)	Mn (TRC) flag	Mn (TRC)	Hg (DIS) flag	Hg (DIS)	Hg (TRC) flag	Hg (TRC)	Ag (DIS) flag	Ag (DIS)	Ag (TRC) flag	Ag (TRC)	Zn (DIS) flag	Zn (DIS)	Zn (TRC) flag	Zn (TRC)
Eocene Rhyodacite Porphyry of Henderson Mountain	Southwest facing flank of Henderson Mountain	M-16	9/1/1989																		
		M-17	9/1/1989																		
		M-19	9/1/1989																		
		M-20	9/1/1989																		
		M-20	8/9/1990					<	0.02												0.01
		M-21	9/1/1989																		
		M-22	9/1/1989																		
		M-23	9/1/1989																		
		M-26	9/1/1989																		
	East facing flank of Henderson Mountain	F-1	9/17/1989																		
		F-1	7/21/1995	<	0.002	<	0.01	<	0.01												
Complex of Fisher Mountain	Fisher Mountain and Lulu Pass area	F-4	9/18/1989	<	0.01		0.29		0.28	<	0.001	<	0.001		0.003		0.001		0.09		0.09
		F-4	8/7/1990	<	0.01		0.20		0.21	<	0.001	<	0.001	<	0.005	<	0.050		0.07		0.07
		F-4	8/23/1990				0.21			<	0.001			<	0.005				0.07		
		F-4	7/11/1991	<	0.002				0.09			<	0.0001			<	0.0005				0.02
		F-4	9/26/1991	<	0.002		0.31		0.29	<	0.0001	<	0.0001		0.0007		0.0012		0.09		0.10
		F-4	7/14/1995	<	0.002		0.05		0.05					<	0.0005	<	0.0005		0.033		0.028
		F-4	8/6/1996																0.080		0.060
		F-5	9/18/1989						0.25												0.06
		F-5	8/7/1990	<	0.01	<	0.02	<	0.02	<	0.001	<	0.001	<	0.005	<	0.005		0.02	<	0.01
		F-6	9/18/1989						0.38												0.07
		F-6	8/7/1990						0.53												0.08
		F-48	8/7/1996															<	0.01		0.01
		F-54	8/6/1996																	<	0.01
		F-60	8/8/1996																0.03		0.02
		F-61	8/8/1996																		0.24
		FCT-11-1	8/7/1996																0.04		0.02
		FCT-11-1	9/12/1996	<	0.003		0.058		0.054										0.03		0.04
		FCT-11-2	8/7/1996																0.10		0.11
		FCT-11-6	8/7/1996																0.03		0.04
		FCT-11-7	8/8/1996																0.02		0.02
		FCT-11-7	9/12/1996	<	0.003		0.009		0.01										0.04		0.04
		FCT-11-8	8/8/1996																0.02		0.02
		FCT-11-8	9/12/1996	<	0.003		0.11		0.11										0.03		0.04
		FCT-16	7/12/1996	<	0.003		0.091		0.091										0.03		0.03
		FCT-16	8/8/1996																0.05		0.04
		FCT-16	9/11/1996		0.003		0.208		0.209										0.06		0.05

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

Table A-1. Analytical data for seeps and springs not impacted by mine activity.

Geology	Location	Station Name	Date	Pb (TRC) flag	Pb (TRC)	Mn (DIS) flag	Mn (DIS)	Mn (TRC) flag	Mn (TRC)	Hg (DIS) flag	Hg (DIS)	Hg (TRC) flag	Hg (TRC)	Ag (DIS) flag	Ag (DIS)	Ag (TRC) flag	Ag (TRC)	Zn (DIS) flag	Zn (DIS)	Zn (TRC) flag	Zn (TRC)
Eocene Rhyodacite Porphyry of Lulu Pass	Northwest of Lulu Pass and Scotch Bonnet Mountain	WR-3	9/21/1989																		
		WR-4	9/21/1989																		
		WR-5	9/21/1989						0.26												0.03
		WR-6	9/21/1989																		
		WR-6	9/25/1991																		
		WR-7	9/21/1989																		
		WR-7	9/25/1991																		
		WR-8	9/21/1989					<	0.02												0.01
		WR-9	9/21/1989																		
		WR-9	9/25/1991																		
		WR-10	9/21/1989																		
		WR-11	9/21/1989	<	0.01	<	0.02	<	0.02	<	0.001	<	0.001	<	0.005	<	0.005	<	0.01	<	0.01
		BESSIE-US	8/19/2008	<	0.001				0.003											<	0.01
		BESSIE-DS	8/19/2008		0.022				0.11												0.09

Concentrations in mg/L.
SC = Specific conductivity in umhos/cm
pH in standard units

APPENDIX A-2
WELL DATA

Table A-2. Groundwater quality data for wells not influenced by mine activity.

Fisher Creek Drainage Wells

Identification	Sample Date	pH (Field)	SC (Field)	SO4	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
EPA-11	7/27/1999	5.6	2.23	1470	5.2	0.0093	0.53	307	0.32	15.3	1.41
EPA-11	7/13/2000	4.72	1963	1410	6.7	0.012	0.75	347	0.34	16.6	1.61
EPA-11	6/27/2001	5.45	2070	1310	6.9	0.0097	0.73	322	0.2	18.6	1.48
EPA-11	7/10/2002	5.18	1864	1300	6.4	0.0076	0.46	344	0.15	19.1	1.03
EPA-11	7/15/2003	5.21	1910	1040	4.34	0.0057	0.3	261	0.14	14.6	1.08
EPA-11	7/30/2003	5.57	1616								
EPA-11	8/26/2003	5.41	1825								
EPA-11	9/8/2003	5.37	1807								
EPA-11	9/30/2003	5.64	1624								
EPA-11	7/19/2004	4.82	1.877	1010	1.24	0.0018	0.11	197	0.035	9.35	0.69
EPA-11	7/7/2005	4.96	1847	1250	2.37	0.0061	0.04	298	0.082	11.5	0.96
EPA-11	9/26/2005	4.77	1617								
EPA-11	7/18/2006	4.94	1679	1110	1.07	0.0032	0.005	233	0.035	10.1	0.75
EPA-11	7/17/2007	5.24	1740								
EPA-11	9/25/2007	4	1269	995	0.67	0.0019	< 0.001	208	0.022	8.59	0.65
EPA-12	5/11/1999	7.2	285	156	< 0.1	< 0.0001	< 0.001	29.7	< 0.001	1.48	0.04
EPA-12	7/26/1999	6.49	460	152	< 0.1	< 0.0001	< 0.001	27.3	< 0.001	1.45	0.07
EPA-12	7/13/2000	6.44	400	146	< 0.1	< 0.0001	< 0.005	31.7	< 0.001	1.35	0.04
EPA-12	6/27/2001	6.7	357	154	< 0.1	< 0.0001	< 0.001	31.4	< 0.001	1.65	0.05
EPA-12	7/11/2002	5.95	357	147	< 0.1	< 0.0001	< 0.001	35.3	< 0.001	1.69	0.04
EPA-12	7/15/2003	6.6	392	134	< 0.05	< 0.0001	< 0.001	30.5	< 0.001	1.62	0.03
EPA-12	7/30/2003	5.6	327								
EPA-12	8/13/2003	5.88	301								
EPA-12	8/26/2003	5.68	671								
EPA-12	9/8/2003	5.69	326								
EPA-12	9/30/2003	5.91	344								
EPA-12	7/28/2004	6.2	290	144	< 0.05	< 0.0001	< 0.001	30.4	< 0.001	1.59	0.08
EPA-12	7/7/2005	6.58	358	161	< 0.05	< 0.0001	< 0.002	29.5	< 0.001	1.39	0.06
EPA-12	9/26/2005	6.26	357								
EPA-12	7/18/2006	6.46	400	180	< 0.05	< 0.0001	< 0.001	34.3	< 0.001	1.88	0.05
EPA-12	7/17/2007	6.38	510								
EPA-12	9/25/2007	6.5	446	170	< 0.05	< 0.0001	< 0.001	37.1	< 0.001	2.04	0.06

Metal concentrations are disolved in mg/L
SC = specific conductivity in mhos/cm
pH in standard units

Fisher Creek Drainage Wells

Identification	Sample Date	pH (Field)	SC (Field)	SO4	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
MW-1	9/29/1989	6.96		117	< 0.1	0.003	< 0.01	20.7	< 0.01	1.14	0.22
MW-1	7/24/1990	4.7	544	243	0.7	0.002	0.13	24.2	0.092	2.51	0.52
MW-1	8/21/1990	4.7	463	197	0.5	< 0.001	0.05	22.2	0.04	1.98	0.22
MW-1	10/11/1990			124	0.5	< 0.001	< 0.01	11.5	0.03	0.99	0.05
MW-1	6/6/1991										
MW-1	7/11/1991	4.68	776	422	2.3	0.0025	2.58	47.4		5.77	0.25
MW-1	8/13/1991										
MW-1	10/1/1991	5.96	403	248	0.8	0.0041	0.13	28.4	< 0.002	3.25	0.48
MW-1	8/23/1995	4.5	20	282	1.2	0.0005	0.105	38.3	0.009	2.85	0.124
MW-1	5/10/1999	4.94	75	601	1.9	0.0025	0.29	85.6	0.01	6.76	0.25
MW-1	7/27/1999	3.86	886	354	1.4	0.0007	0.33	45	0.008	3.42	0.17
MW-1	7/13/2000	3.25	819	328	1.2	0.0005	0.24	42.8	0.014	2.92	0.1
MW-1	6/27/2001	3.18	1449	730	4.4	0.0019	1.48	108	0.018	5.62	0.2
MW-1	7/11/2002	3.22	856	372	1.6	0.0004	0.22	51.2	0.012	3.3	0.13
MW-1	7/15/2003	3.53	861	302	1.36	0.0005	0.15	38.7	0.011	3.08	0.09
MW-1	7/30/2003	3.28	762								
MW-1	8/13/2003	3.46	638								
MW-1	8/26/2003	3.27	583								
MW-1	9/8/2003	3.33	547								
MW-1	9/30/2003	3.3	664								
MW-1	7/28/2004	3.4	650	337	1.13	0.0003	0.093	37.1	0.006	2.76	0.24
MW-1	7/7/2005	4.01	537	237	0.68	0.0003	0.053	34	0.005	2.82	0.08
MW-1	9/26/2005	3.81	578								
MW-1	7/18/2006	5.02	749	409	0.36	0.0002	0.008	60	0.003	4.46	0.11
MW-1	7/23/2007	4.88	823	412	0.32	0.0002	0.01	70.4	0.002	4.32	0.11
Tracer 5	8/30/1997			244	21.7	0.001	0.83	44.9	< 0.01	0.66	0.23
Tracer 5	7/26/1999	4.18	5.95	285	25.1	0.0018	5.84	55	0.003	0.93	0.43
Tracer 5	7/13/2000	3.84	533	255	19.6	0.0016	4.3	54.9	0.005	0.8	0.32
Tracer 5	6/27/2001	4.12	432.1	206	18.2	0.0016	9.33	39.7	0.006	0.75	0.31
Tracer 5	7/10/2002	3.89	527	271	26	0.0023	3.6	61.1	0.006	1.16	0.39
Tracer 5	7/7/2003	3.13	480	222	18.7	0.0015	5.42	41	0.003	0.78	0.26
Tracer 5	7/19/2004	3.56	566	312	25	0.0017	2.84	54.7	0.003	0.97	0.4
Tracer 5	7/7/2005	3.59	559	279	24.1	< 0.0001	1.38	57.1	0.006	1.37	0.04
TRACER 5	7/12/2006	3.52	667	369	33.7	0.0022	1.19	75.4	0.004	1.16	0.38
TRACER 5	7/24/2007	4.6	633	346	31.7	0.0026	0.62	76.6	0.006	1.36	0.35

Metal concentrations are disolved in mg/L
SC = specific conductivity in mhos/cm
pH in standard units

Daisy Creek Drainage Wells

Identification	Sample Date	pH (Field)	SC (Field)	SO4	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
DCGW-100	8/1/2003	6.95	976								
DCGW-100	8/11/2003	6.82	661								
DCGW-100	8/19/2003	6.75	589	218	< 0.05	< 0.0001	< 0.001	0.01	< 0.001	0.41	< 0.01
DCGW-100	8/27/2003	6.8	565								
DCGW-100	9/9/2003	7.13	533								
DCGW-100	9/30/2003	6.68	547								
DCGW-100	8/10/2004	7.59	589	157		0.0003	0.008	0.22			
DCGW-100	7/25/2005	6.2	1410	173	0.06	0.0004	0.02	0.09	< 0.001	1.06	0.05
DCGW-100	9/28/2005	6.64	543								
DCGW-100	7/26/2006	6.99	606	187	< 0.05	0.0003	0.017	0.22	< 0.001	0.94	0.04
DCGW-100	7/24/2007	7.03	556	148	< 0.05	0.0002	0.012	0.32	< 0.001	0.55	0.02
Tracer 2	8/20/1997	3.94	739	527	49.8	< 0.001	8.62	59.2	< 0.01	0.52	0.14
Tracer 2	7/29/1999	4.1	445	365	55	0.0006	4.05	64.1	0.001	0.4	0.17
Tracer 2	7/11/2000	3.91	726.3	429	40.6	0.0005	3.1	64.8	0.001	0.37	0.16
Tracer 2	6/29/2001	3.66	732	418	51.5	0.0008	4.1	64.3	< 0.001	0.44	0.16
Tracer 2	7/8/2002	3.61	759	436	54.3	0.001	5.22	71.6	0.002	0.41	0.15
Tracer 2	7/17/2003	3.65	543	385	50.4	0.0009	3.31	59.7	< 0.001	0.41	0.14
Tracer 2	8/1/2003	3.45	476								
Tracer 2	8/11/2003	3.31	570								
Tracer 2	8/27/2003	3.08	567								
Tracer 2	9/8/2003	3.25	613								
Tracer 2	9/30/2003	3.53	786								
Tracer 2	7/21/2004	3.73	760	434	51.5	0.0009	2.73	63.5	< 0.001	0.42	0.17
Tracer 2	7/12/2005	3.96	874	502	54.3	0.001	3.5	68.9	< 0.001	0.36	0.21
TRACER 2	7/12/2006	4.2	861	566	63.8	0.0012	3.64	85.9	< 0.001	0.46	0.17
TRACER 2	7/19/2007			607	68.8	0.0012	3.6	88.2	< 0.001	0.45	0.17

Metal concentrations are disolved in mg/L
SC = specific conductivity in mhos/cm
pH in standard units

Daisy Creek Drainage Wells

Identification	Sample Date	pH (Field)	SC (Field)	SO4	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
MW-2	9/28/1989	4.24		467	41.6	0.006	0.88	114	0.02	1.16	0.79
MW-2	8/1/1990	3.94	841	529	44.6	< 0.001	0.64	106	0.03	0.63	0.65
MW-2	8/21/1990	3.97	865	487	45.3	< 0.001	0.24	103	0.03	0.62	0.54
MW-2	10/11/1990	3.63		514	46.7	0.002	0.01	93.7	< 0.01	0.75	0.33
MW-2	6/6/1991										
MW-2	7/11/1991	4.57	840	586	51	0.0019	0.4	121	0.008	1.09	0.45
MW-2	8/13/1991		827								
MW-2	10/1/1991	3.46	610	554	49	0.0048	0.91	23	0.005	1.02	0.91
MW-2	8/22/1995	4.3	792	493	49	0.0006	0.15	120	< 0.002	1.15	0.248
MW-2	5/12/1999	3.95	789	502	34.4	0.0017	0.011	92.2	0.008	1.09	0.24
MW-2	7/27/1999	4.03	766	416	36	0.0012	0.011	94.5	0.004	1.04	0.31
MW-2	7/11/2000	4.24	762.2	433	32.6	0.0009	0.01	100	0.007	1.03	0.27
MW-2	6/28/2001	4.31	797	425	37.9	0.0015	0.006	107	0.009	1.3	0.26
MW-2	7/9/2002	3.44	785	378	43.5	0.0014	0.007	113	0.008	1.19	0.23
MW-2	7/17/2003	3.81	751	372	37.4	0.0013	0.001	90.6	0.009	1.1	0.24
MW-2	8/1/2003	3.76	632								
MW-2	8/13/2003	3.79	1163								
MW-2	8/27/2003	3.7	732								
MW-2	9/8/2003	3.57	752								
MW-2	9/30/2003	3.86	760								
MW-2	7/28/2004	3.53	789	392	37.4	0.0013	0.42	91.9	0.01	1	0.23
MW-2	8/11/2004	3.6	778								
MW-2	9/28/2004	3.6	731								
MW-2	7/12/2005	3.84	767	474	35.7	0.0013	0.22	89.1	0.01	0.84	0.22
MW-2	9/26/2005	3.5	761								
MW-2	7/18/2006	3.88	754	462	34.6	0.0013	0.42	92.6	0.009	0.96	0.21
MW-2	7/23/2007	4.67		484	36.4	0.0015	0.32	98.6	0.01	0.94	0.21

Metal concentrations are disolved in mg/L
SC = specific conductivity in mhos/cm
pH in standard units

APPENDIX A-3
LOADING DATA

Table A-3. Analytical data for surface water and adit monitoring stations used in load calculations.

Station	Sample Date	Flow (gpm)	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
Daisy Creek Drainage Stations									
D-18 (McLaren Adit)	10/1/2003	3.59	0.1	<0.0001	0.025	19.1	<0.001	0.96	0.05
D-18 (McLaren Adit)	7/29/2004	7.30	--	--	--	--	--	--	--
D-18 (McLaren Adit)	8/10/2004	7.63	--	--	--	--	--	--	--
D-18 (McLaren Adit)	9/23/2004	4.70	0.08	<0.0001	0.018	20	<0.001	0.97	0.01
D-18 (McLaren Adit)	9/23/2005	4.90	--	--	--	--	--	--	--
DC-2	6/27/2006	2329.43	3.12	0.0005	0.69	3.38	0.002	0.34	0.1
DC-2	9/27/2006	62.84	12.4	0.0043	3.17	7.78	0.004	2.14	0.55
DCSW-101	6/27/2006	20.65	26.1	0.0082	13.5	105	0.012	2.74	1.50
DCSW-101	9/27/2006	2.24	29.0	0.010	13.2	178	0.005	3.41	1.87
DCSW-102	6/27/2006	14.8	32.5	0.015	18.5	135	0.002	4.76	2.66
DCSW-102	9/27/2006	0.45	24.2	0.012	14.2	116	0.002	4.04	1.97
DCSW-103	6/27/2006	1.80	81.1	0.024	36.1	434	0.002	13.1	4.44
DCSW-103	9/27/2006	0.90	77.3	0.022	29.0	315	0.002	12.5	4.07
Fisher Creek Drainage Stations									
AE-17 (Henderson Mtn Dump)	8/8/1990	Too low to gage	0.05	0.0005	0.01	0.67	0.005	0.12	0.04
AE-17 (Henderson Mtn Dump)	8/9/1993	Too low to gage		0.00128	0.0234	1.61	0.00568	0.102	0.0366
AE-17 (Henderson Mtn Dump)	8/6/1999	Too low to gage	--	--	--	--	--	--	--
AE-17 (Henderson Mtn Dump)	7/7/2001	Too low to gage	--	--	--	--	--	--	--
AE-17 (Henderson Mtn Dump)	7/23/2002	0.10	0.05	0.001	0.013	0.87	<0.001	0.08	0.11
AE-17 (Henderson Mtn Dump)	7/15/2003	5.03	0.11	0.0001	0.022	1.54	0.0015	0.08	0.05
AE-17 (Henderson Mtn Dump)	7/27/2004	2.00	--	--	--	--	--	--	--
CFY-2	10/5/2004	1943	0.08	0.0001	0.02	0.04	<0.001	0.01	0.03
CFY-2	10/5/2004	242	<0.05	<0.0001	0.004	0.01	<0.001	<0.003	<0.01
CFY-2	4/5/2005	346	<0.05	<0.0001	0.009	0.01	<0.001	<0.003	0.01
CFY-2	6/28/2005	413	<0.05	<0.0001	0.008	<0.01	<0.001	<0.003	<0.01
CFY-2	10/11/2005	390	<0.05	<0.0001	0.007	<0.01	<0.001	<0.003	0.09

Metal concentrations are total recoverable in mg/L.

Table A-3. Analytical data for surface water and adit monitoring stations used in load calculations.

Station	Sample Date	Flow (gpm)	Aluminum	Cadmium	Copper	Iron	Lead	Manganese	Zinc
Fisher Creek Drainage Stations									
F-8A (Glengarry Adit)	6/28/2006	0.54	0.07	<0.0001	0.038	2.32	0.0005	0.29	0.03
F-8B (Glengarry Millsite Adit)	9/18/1989	26.93	--	--	--	--	--	--	--
F-8B (Glengarry Millsite Adit)	8/7/1990	0.81	--	<0.0001	0.11	7.45	--	1	0.12
F-8B (Glengarry Millsite Adit)	8/9/1993	1.00	--	0.00128	0.121	14.2	0.00245	1.02	0.127
F-8B (Glengarry Millsite Adit)	8/18/1996	5.00	--	--	--	--	--	--	--
F-8B (Glengarry Millsite Adit)	7/1/2003	3.00	0.32	0.0001	0.24	6.46	0.001	0.66	0.05
F-8B (Glengarry Millsite Adit)	7/29/2004	5.00	--	--	--	--	--	--	--
F-28 (Gold Dust Adit)	9/26/2006	3.59	0.06	<0.0001	<0.001	0.62	0.001	0.13	0.04
FCSI-99-1 (Sheep Mtn #1 Adit)	8/5/1999	10.00	--	--	--	--	--	--	--
FCSI-99-1 (Sheep Mtn #1 Adit)	7/5/2001	0.45	0.4	0.0002	0.035	1.01	0.015	0.069	0.05
FCSI-99-1 (Sheep Mtn #1 Adit)	7/23/2002	0.50	0.05	0.0009	0.01	0.06	0.004	<0.003	0.07
FCSI-99-1 (Sheep Mtn #1 Adit)	7/15/2003	2.00	<0.05	<0.0001	0.005	0.19	0.007	0.01	<0.01
FCSI-99-1 (Sheep Mtn #1 Adit)	7/28/2004	4.00	--	--	--	--	--	--	--
FCSI-96-5 (Lower Tredennic Adit)	8/18/1996	5.00	--	--	--	--	--	--	--
FCSI-96-5 (Lower Tredennic Adit)	7/5/2001	1.80	0.05	0.0002	0.004	0.12	0.001	0.074	0.04
FCSI-96-5 (Lower Tredennic Adit)	7/16/2003	0.60	<0.05	0.0001	0.003	0.15	0.0015	0.12	0.02
FCSI-96-5 (Lower Tredennic Adit)	7/28/2004	4.00	--	--	--	--	--	--	--
FCSI-96-5 (Lower Tredennic Adit)	9/22/2004	1.40	<0.05	0.0001	0.003	0.21	0.001	0.13	0.02
SW-3	10/5/2004	157.00	1.52	0.0005	0.6	0.87	0.002	0.29	0.08
SW-3	4/5/2005	36.00	1.75	0.0009	0.8	0.9	0.002	0.49	0.18
SW-3	8/29/2005	171.00	1.36	0.0006	0.59	1.36	0.002	0.42	0.13
SW-3	10/11/2005	139.00	2.31	0.0007	0.73	0.9	0.002	0.52	0.12
SW-3	4/26/2006	31.00	2.61	0.0009	0.87	1.1	0.001	0.54	0.15
SW-3	9/26/2006	72.00	2.81	0.0008	0.79	1.89	0.002	0.59	0.14
SW-4	10/5/2004	1441	0.12	0.0002	0.05	0.06	<0.001	0.029	0.02
SW-4	4/5/2005	314	<0.05	0.0002	0.033	0.01	<0.001	0.008	0.08
SW-4	10/11/2005	727	<0.05	0.0002	0.05	0.16	<0.001	0.005	0.03
SW-4	4/26/2006	278	<0.05	0.0002	0.043	0.02	<0.001	0.005	0.04
SW-4	9/26/2006	296	0.08	0.0002	0.034	0.01	<0.001	0.026	0.18

Metal concentrations are total recoverable in mg/L.