Watershed Management Plan for the Upper Lefthand Creek Watershed, Boulder County, Colorado

Lefthand Watershed Oversight Group

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ABBREVIATIONS

AMD – acid mine drainage
ALD – anoxic limestone drain
ARD – acid rock drainage
BCHD – Boulder County Health Department
BMP – best management practice
CDEQ – Colorado Department of Environmental Quality
CDPHE – Colorado Department of Public Health and Environment
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CJM – Captain Jack Mill site
CR – county road
CWPF – Colorado Watershed Protection Fund
EPA – United States Environmental Protection Agency
JCWI – James Creek Watershed Initiative
LHDC – Left Hand Ditch Company
LHWD – Left Hand Water District
LiCl – lithium chloride
LWOG – Lefthand Watershed Oversight Group
LWTF – Lefthand Watershed Task Force
m - meter
NaCl – sodium chloride
NPDES - National Pollution Discharge Elimination System
NTU – nephelometric turbidity unit
OHV – off-highway vehicle
RGI – EPA Regional Geographic Initiative
SRB – sulfate-reducing bacteria
TMDL – total maximum daily load
TWGP – EPA Targeted Watershed Grants Program
USFS – United States Forest Service
USGS – United States Geological Survey
VCUP – Colorado Voluntary Cleanup Program

1 Introduction

Located in northwest Boulder County, Colorado, in the Front Range of the Rocky Mountains, the Lefthand Creek watershed (Figures 1 and 2) drains an area of approximately 220 km^2. Lefthand Creek, James Creek, and Little James Creek are the primary streams in the watershed, producing an average total discharge of 985 Ls^{-1}, about 25,000 acre-feet per year, where Lefthand Creek drains from the foothills onto the plains near Highway 36. Lefthand Creek serves as a key water supply—and the only winter water source—for the 18,000 residential customers of the Left Hand Water District. Additional water users include watershed residents, agricultural shareholders of the Left Hand Ditch Company, and Boulder County Parks and Open Space.

Diverse land use and land cover in the watershed include national forest land, residential, and recreational areas in the forested mountains and foothills in the western portion of the drainage, transitioning to agriculture and semi-urban areas in the eastern plains region of the watershed. Situated in the northern tip of the Colorado Mineral Belt, a highly mineralized region that stretches northeast from the San Juan Mountains, the Lefthand Creek watershed formerly hosted wide spread hardrock mining and milling operations. Beginning in the late 1850s, mineral extraction and processing occurred at hundreds of sites in the watershed (Cobb, 1988; EPA, 2003a). The most recent mining activity ceased in the mid-1990s, and no mines or mills currently operate in the watershed.

1.1 Stakeholder and Agency Interest in Watershed Issues

Decades of mining activities in the watershed left a legacy of heavy metal and acid contamination in surface and groundwaters, and few remaining parties responsible for cleanup of the sites. In 1999, the U.S. Environmental Protection Agency (EPA) approached the potentially impacted communities of Jamestown and Ward about the possibility of Superfund National Priorities List (NPL, or "Superfund") designation for mine-scarred lands in the watershed. The threat of Superfund listing spurred debates among watershed stakeholders including local residents, governments, and water users. Local newspapers highlighted the controversy, stressing the community resistance to Superfund listing (Westword, 2001). In response, the EPA funded the Boulder County Health Department (BCHD), through a grant to the Colorado Department of Environmental Quality (CDEQ), to create a community-based task force to explore alternatives to Superfund designation. The objectives of the group, known as the Lefthand Watershed Task Force (LWTF), were to assess watershed environmental and health data, determine if cleanup actions were necessary, evaluate cleanup options, and recommend preferred cleanup options. Serving as a liaison between community members and government agencies, the LWTF convened meetings between EPA and community stakeholders. The final output of the LWTF was a comprehensive report to the Boulder County Board of Health, submitted in March 2002 (LWTF, 2002). The report included the following recommendations:

- Formation of a watershed oversight group to serve as a hub for communications throughout the watershed;
- A systematic characterization of the watershed;

- Support of Superfund listing for the California Gulch area of upper Lefthand Creek;
- Support for remediation alternatives to Superfund for sites other than the California Gulch area.

1.1.1 Recent Activities

In the years since the release of the report, watershed stakeholders and government agencies have taken actions toward the LWTF recommendations. The Lefthand Watershed Oversight Group (LWOG), the authors of this Watershed Plan, formed a Board of Directors representing diverse watershed interests and incorporating as a non-profit organization in 2004.

Additionally, multiple efforts are underway to improve the water quality of the Lefthand Creek watershed. The EPA assigned Superfund designation to the Captain Jack Mine and Mill site in the California Gulch segment of Lefthand Creek in September 2003, and the Colorado Department of Public Health and Environment (CDPHE) is now heading up remediation planning for that site. A voluntary cleanup funded by Honeywell International, Inc. is underway at the Burlington Mine located along the Little James and Balarat Creeks west of Jamestown. The U.S. Forest Service (USFS) is planning reclamation activities at the Fairday Mine site on James Creek west of Jamestown, and at the Golden Age site just east of Jamestown. Currently, the Slide Mine near Rowena is being considered for Colorado's Voluntary Cleanup Program (VCUP).

1.1.2 Watershed Oversight Group Profile

1.1.2.1 Mission and Objectives

As described in LWOG's bylaws, the group's mission is to assess, protect, and restore the quality of the Lefthand Creek watershed, and to serve as a hub of communication about watershed issues through the fostering of stakeholder collaboration.

In pursuit of this mission, the LWOG members endeavor to meet the following objectives:

- Facilitate cooperative water quality assessment and the exchange of information in order to identify and address water quality concerns in a proactive manner.
- Identify and prioritize existing and potential water quality problems in the Lefthand Creek watershed.
- Facilitate the remediation of sites that have a negative impact on the water quality of Lefthand Creek or its tributaries.
- Communicate water quality and watershed-related information to increases public awareness of watershed issues.
- Secure funding for watershed activities through local, state, and federal grants and other sources.
- Build an effective watershed protection program that fosters open communication and cooperation among stakeholders, with strong public and financial support based on documented accomplishment of its objectives.

All methods employed by LWOG to achieve these goals will embody the spirit of cooperation and community involvement on which the group is founded. In particular, LWOG emphasizes voluntary participation, education and outreach, and coordination with other organizations, entities, agencies, and stakeholders involved in watershed activities.

1.1.2.2 Organization

The Board of Directors oversees the activities of LWOG. This board consists of a minimum of five and a maximum of nine members. At all times, the board will include a representative from each of the following entities/agencies: the Town of Ward, the Town of Jamestown, the Left Hand Water District (LHWD), Boulder County Parks and Open Space, and the James Creek Watershed Initiative (JCWI). Such entity/agency representatives may be elected officials, employees of such entities/agencies, or appointees of such entities/agencies.

In addition to the board, a watershed coordinator plays a lead role in organizing LWOG activities. Meetings are open to the public, and a variety of individuals, including watershed residents, University of Colorado researchers, employees of local environmental consulting firms, representatives of local government, agency officials, and other interested stakeholders, regularly contribute their time and expertise to the organization.

1.1.3 Watershed Management Partners

Partnerships with local, state, and federal agencies and organizations are essential for the successful management of watershed activities and the communication of those activities to the watershed community. Federal agencies including the EPA and USFS, as well as the CDPHE on the state level, play important roles in setting environmental guidelines, data collection, and implementation and funding of cleanup activities. Local government involvement from the Boulder County Health Department, Boulder County Parks and Open Space, and the towns of Ward and Jamestown provides an avenue for communication to the community of individuals who live in or near the watershed. Participation from local businesses and institutions, including the LHWD, the University of Colorado, and local environmental consulting companies provides valuable professional expertise and local knowledge in scientific and legal areas. Table 1 lists the LWOG's key partners and their roles, as well as potential partners and resources that LWOG may engage in the future.

1.1.3.1 The James Creek Watershed Initiative (JCWI)

Key LWOG partners are also members of the JCWI. The James Creek watershed lies completely within the larger Lefthand Creek watershed; therefore, LWOG and JCWI share particular water quality concerns including sedimentation, nutrient, and metal loading. Additionally, the willingness of JCWI members to share the experiences of their group, which has been incorporated for nine years, has bolstered LWOG's efforts to organize and secure funding.

1.1.3.1.1 JCWI Mission and Organization

The organization is a grassroots community based organization located in Jamestown, Colorado, whose mission is to engage the community in protecting and restoring the waters of James Creek and the forest ecosystem surrounding it. The organization was founded by Mark Williams in 1997 as a Masters Degree project at the University of Denver. Start-up funding was provided by an EPA Regional Geographic Initiative grant, under the umbrella of the Town of Jamestown. In 2000, the JCWI received its 501(c)(3) status as a non-profit organization and currently has 205 members.

The following are the goals of JCWI:

- Maintain the quality of aquatic and riparian habitats and in turn the quality of Jamestown's surface water supply through adaptive ecosystem management.
- Prevent any degradation of James Creek as a result of shortsightedness, inattentiveness or lack of education.
- Facilitate cooperative efforts among multiple agencies for planning and implementation of policies in the James Creek watershed.
- Educate and involve stakeholders in watershed issues.
- Gather water quality data.

1.1.3.1.2 JCWI Projects

- Established a baseline water quality monitoring of six sites on James Creek as part of the Rivers of Colorado Water Watch Program (1997 – present).
- Revised the town of Jamestown's Flood Hazard Mitigation Plan and received grant funding for a floodway project in Jamestown from the Colorado Water Conservation Board (1998).
- Worked in collaboration with the Forest Service and Wildlands Restoration Volunteers to restore hillsides and wetlands at the Fair Day Meadow (1999 – 2000).
- Removed three truckloads of trash from Little James Creek with the help of Americorps volunteers (2000).
- Completed *James Creek: State of the Watershed Report 2000* (JCWI, 2000).
- Assisted the town of Jamestown in revising the town's Watershed District Ordinance to create a five-mile buffer zone along James Creek upstream from the Town's water treatment plant to protect Jamestown's water supply (2000-2001).
- Organized a turbidity study in partnership with the University of Colorado to study the problem of turbidity in James Creek (1998 - 2001).
- Completed a field source analysis report that identified sources of sediment loading onto James Creek along the County Road 102J corridor (2003).
- Obtained funding from the State of Colorado's S319 Non-point Source Grant Program for the James Creek Restoration Project and restored road and stream banks along a 3-mile riparian corridor (2000 - 2005).
- Organized a local Forest Watch group and trained as Forest Service volunteers to help monitor resource impacts of recreation users (2002).

- Worked in partnership with the Forest Service, Wildlands Restoration Volunteers and area residents on the Owens Flats Restoration Project (2002).
- Distributed over 1400 ponderosa pine seedlings to victims of the 2003 Overland Fire to reforest their private land (2004 – 2005).
- Organized volunteers to spread 170 bales of straw in the Overland Fire burn area to prevent further flooding in Jamestown (2005).

1.1.3.1.3 JCWI Partnership Strategy

The Lefthand and James Creek watershed groups share water quality concerns including sedimentation, nutrient, and metal loading. JCWI has shared their experiences of their group, which has bolstered LWOG's efforts to organize and secure funding. By working together the two watershed groups can take on the bigger picture of addressing water quality issues for water users downstream.

1.2 Overview of the Watershed Plan

1.2.1 Watershed Plan Objectives

In 2003, the CDPHE granted funds to LWOG through the Clean Water Act §319 Non-Point Source program. The funds allowed LWOG to hire a group coordinator, organize a board of directors, incorporate as a 501(c)(3) nonprofit organization, develop a newsletter and website, host public meetings, and serve as a communication liaison between various agency, community, and government stakeholders in the watershed. Additionally, the §319 funding provided for the development of this report—a compendium of data, site prioritization lists, best management practice (BMP) recommendations, reclamation cost estimates, and final watershed management and planning recommendations. The intent of this Watershed Plan is to enable LWOG to provide educated, data-based recommendations regarding watershed management to local landowners, water users, water rights owners, government officials at the local, state, and federal level, agency representatives including the EPA, and USFS, and other interested stakeholders. This Watershed Plan is intended to be a galvanizing tool to bring together diverse watershed stakeholders towards meeting the objectives of LWOG, as described in section 1.2.1.1, Mission and Objectives.

1.2.2 Watershed Plan Components and Structure

In order to fulfill the requirements outlined in the 2004 Nonpoint Source Program and Grants Guidance Guidelines for States and Territories (Federal Register, 2003b) for development of watershed-based plans, this Watershed Plan will include the following components:

- An identification of the contamination and sources that need to be controlled to achieve load reductions (Sections 4 through 6).
- A description of the non-point source management measures that will need to be implemented to achieve the estimated load reductions (Section 7).
- A discussion of the funding sources and authorities that will be relied upon to implement the plan (Section 8).

- An information/education component that will enhance public understanding of watershed projects (Section 9).
- A schedule for implementing the non-point source management measures identified in the plan (Section 10).
- A description of interim, measurable milestones for determining whether management measures or other control actions are being implemented (Section 10).
- A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards (Section 11).
- A monitoring component to evaluate the effectiveness of the watershed management efforts over time (Section 11).

1.2.3 Updates to the Watershed Plan

A strong effort has been made on the part of LWOG to incorporate and base recommendations on the most accurate and current water quality data and other statistics; however, as new data is collected and reclamation activities begin to alter water quality conditions in the watershed, the recommendations of the watershed group will likely evolve. This Watershed Plan is intended to be a working document. Data and other information, including reports on the successes and failures of reclamation and monitoring projects, should be added to the plan as it becomes available. LWOG should strive to update this report annually, or as new data and resources become available. Updates should touch on the following key pieces of information:

- Descriptions of water quality-related activities undertaken within the watershed.
- Water quality changes resulting from those activities, including quantitative information regarding changes in contaminant load contributions.
- Updates to LWOG's list of priority sites based on completed or in-progress projects.
- Changes to recommended BMPs, as they are applied, and their successes and failures are evaluated.
- Updates regarding funding opportunities as new opportunities become available and former opportunities are exhausted.

By continually expanding the available database and revising BMPs based on experience and up-to-date information, LWOG will be best able to recommend efficient and effective watershed management strategies.

2 General Watershed Information

2.1 Location

Part of the St. Vrain Creek basin (HUC 10190005), the Lefthand Creek watershed (Figures 1 and 2) lies in north central Colorado on the eastern slope of the Rocky Mountain Front Range, northwest of the City of Boulder. Lefthand Creek, James Creek, and Little James Creek are the primary streams in the watershed; these three streams are fed by numerous intermittent tributary channels. The streams drain approximately 220 km^2 (about 54,400 acres) of land area, ranging in elevation from nearly 4,300 m at the Continental Divide to about 1,500 m on the eastern plains. The basin discharges an average of about 36,000,000 m^3 annually, but in wet years such as 1995 it may discharge nearly 50,000,000 m^3.

Lefthand Creek originates in glacial and snow melt waters at an elevation of approximately 4,200 m in the Indian Peaks Wilderness area near the Continental Divide, approximately 5 km west of Highway 72 and the town of Ward, Colorado. About 5 km below its headwaters, in an area locally known as California Gulch, Lefthand Creek flows through portions of the Ward mining district, including the Captain Jack Mine and Mill Superfund site. Lefthand Creek empties onto the plains at an elevation of about 1,400 m nearly 40 km downstream of its headwaters. Farther downstream, near the town of Longmont, Lefthand Creek drains into St. Vrain Creek, which in turn feeds the South Platte River.

James Creek, the largest tributary to Lefthand Creek, drains an area of approximately 48 km^2. This sub-watershed is covered entirely by alpine and sub-alpine forest. Elevations in the James Creek watershed range from approximately 3,000 m at the headwaters in the Indian Peaks Wilderness Area to 2,000 m at the confluence with Lefthand Creek approximately 5 km south of Jamestown. A diversion of the South St. Vrain Creek, which drains glacial-melt lakes near the continental divide, contributes nearly all of the flow of James Creek during parts of the year (Figure 6) (CDWR, 2002; Colorado River Watch, 2004). Snowmelt in the South St. Vrain Creek headwaters feeds high James Creek flows. James Creek and its tributaries drain heavily mined slopes, including areas known as the Jamestown and Golden Age mining districts.

A tributary to James Creek, Little James Creek drains a sub-watershed area of approximately 15 km^2. Alpine and sub-alpine forests cover the sub-watershed. Little James Creek flows near numerous sites of former hardrock mining and mineral processing. The State of Colorado included Little James Creek on the 1998 303(d) list of impaired streams with a high ranking. The CDPHE Water Quality Control Division developed Total Maximum Daily Load (TMDL) guidelines for the Little James Creek for cadmium, zinc, iron, manganese, and pH (WQCD, 2002).

2.2 Geology, Soils, and Geomorphology

Pre-Cambrian metamorphic and granitic rocks dominate the geology of the mountainous portions of the watershed, including intrusive stocks and dikes and glacial deposits near the upper watershed. The glacial deposits that run alongside and west of Highway 72 are mostly glacial morainal material rather than glacial outwash, and can reach up to 15 meters thick in some locations. The crystalline rocks within the watershed contain several minerals in extractable quantities, including gold, fluorite, lead, silver, uranium, tungsten, and copper. These minerals were deposited with intrusions of molten igneous rocks during periods of mountain uplift. Soils in the watershed are fairly thin and are identified by the Soil Conservation Service as Cryboralfs-Rock outcrop association.

The Lefthand Creek watershed covers portions of two distinct physiographic regions: the Southern Rocky Mountain province and the Colorado Piedmont section of the Great Plains province (Worcester, 1920). Foothills separate these distinct topographical features. Glaciation, stream erosion and deposition, wind erosion, and atmospheric weathering formed and continue to alter the watershed topography. The watershed features gentle slopes concentrated near the upper reaches of the watershed and steep canyon reaches near the watershed mouth. Although some glacial deposits are present near the upper watershed, the canyons in the middle and lower portions of the watershed have a V-shaped morphology, formed by water flow rather than glacial ice. Mass movements do not appear to be a significant geomorphic process within this watershed.

2.3 Land Cover

Land cover in the Lefthand Creek watershed consists of a mix of forested land (70%), residential land (15%), and agricultural land (1%). Roughly 10-14% of the remaining land cover is unspecific areas, such as roads.

2.4 Biological Assessment of Species

There have been reports of bald eagle nests within the watershed, as well as occasional sightings of bald and golden eagles. Known bald eagle nesting sites in the region outside of the watershed include cliffs near Balarat Hill and lower Lefthand Canyon. The watershed ecosystem once supported the boreal toad, a sensitive amphibian. The toad has not been seen in the watershed since 1968 (Colorado Natural Heritage Program, 1996). Large mammals sited in the area include black bears, elk, mule deer, mountain lions and bobcats.

The vegetation in the project area is considered lower montane zone consisting of open forest with broad-crowned ponderosa pine, Douglas fir, and aspen. There are no old growth forests. Riparian vegetation generally consists of cottonwood, willow and pine, with some forbs and grasses.

Boulder County identifies most of the western, mountainous portion of the watershed as Walker Mountain Environmental Conservation Area—land for which the County encourages conservation or preservation. The County also marks Porphory Mountain near Jamestown, Grassy Top Mountain near Ward, and the Buckingham Park hogbacks on Lefthand Creek as natural landmarks, and identifies Lefthand Creek and the lower reach of James Creek as stream habitat connectors (Boulder County, 1995a). The County also identifies an area along Lefthand Creek just east of Olde Stage Road as the Lefthand Pallisades Critical Wildlife Habitat (Boulder County 1995b).

2.5 Climate

The climate of the majority of the Lefthand Creek watershed is typical of temperate, semiarid, high plains areas, though the upper reach of the watershed is higher-elevation alpine climate. The four seasons are distinct; rainfall and humidity are generally low, and sunshine is abundant. Due to the extreme elevation differences within the watershed, weather conditions often vary over small areas. The mean annual precipitation for the watershed ranges from 50 cm in the lower reaches to 64 cm in the higher reaches (JCWI, 2000). Approximately 33 cm of precipitation falls in the watershed between April and September. Monthly maximum rainfall usually occurs in May, with secondary peaks in July and August reflecting the influence of summer convection thunderstorms. Annual snowfall averages around 180 cm in the lower reaches to over 305 cm near the headwaters. Significantly more snow accumulates along the continental divide. Snowmelt runoff from the higher elevations markedly augments the flow of James Creek through the diversion from South St. Vrain Creek.

2.6 Stream Flow

Average Lefthand Creek stream flows from 1929 to 1980, recorded at a United States Geological Survey (USGS) staff gage at 40°07'32" north latitude and 105°18'12" west longitude, range from 5.7 Ls^{-1} to 6,700 Ls^{-1} (USGS, 2004). Peak flows occur in June (Figure 4), corresponding to snowmelt in the high-elevation peaks at the watershed headwaters at the continental divide. Annual stream flows for Lefthand Creek averaged approximately 985 Ls^{-1}, varying by about 24% between the 11 years for which complete data exists (Figure 3).

Members of the James Creek Watershed Initiative installed and monitor a staff gage on James Creek at 40°07'32" north latitude and 105°18'12" west longitude, just downstream of the confluence of Little James Creek. Data from this site is available online through the Colorado River Watch program (*http://wildlife.state.co.us/riverwatch*). Data from this site show a range of stream flows in James Creek from about 170 Ls^{-1} to 5,700 Ls^{-1} from 1998 to 2003 (Figure 5). The headwaters of the James Creek watershed supply only a small fraction of the flow in the James Creek. A diversion of the South St. Vrain Creek, which drains glacial-melt lakes near the continental divide, contributes nearly all of the flow of James Creek during parts of the year (Figure 6). Snowmelt in the South St. Vrain Creek headwaters feeds high James Creek flows, which occur in May and June. Similar to Lefthand Creek, the lowest flows in James Creek occur in October through March.

No stream flow data for Little James Creek was available prior to studies conducted by the University of Colorado beginning in 2002. Observations during the years of 2003 and 2004 indicate that peak flows may occur during local snowmelt periods in early spring, and that portions of the stream flow only intermittently by late summer. The peak flow measured in Little James Creek, about 500 Ls^{-1}, occurred in late April 2003 (Wood, et al., 2004).

2.7 Historical Uses of the Watershed

Beginning in the late 1850s mineral extraction and processing occurred at hundreds of sites in the watershed (Cobb, 1988; EPA, 2003a). The USFS, which owns approximately 65% of the land area in the watershed, records 230 mining openings and 186 mine tailings piles, spoils, or dumps on USFS land alone (LWTF, 2002). A complete inventory of mining and milling sites in the entire watershed land area has not been conducted. The most recent mining activity ceased in the mid-1990s, and no mines or mills currently operate in the watershed.

Currently, the watershed supplies irrigation water to farms in Boulder County, and also serves as a source of drinking water for the towns of Jamestown and Ward, the LHWD, the City of Boulder via a feeder canal to Boulder Reservoir, and for numerous (uncounted) private well owners. The LHWD serves a population of more than 18,000 with water from Lefthand Creek. In the winter months, Lefthand Creek serves as the sole water supply for these consumers. The watershed is also a locally popular outdoor recreation destination for hikers, road cyclists, off-highway vehicle (OHV) enthusiasts, anglers, and picnickers. Furthermore, the streams and land area in the watershed provide habitat for aquatic life and wildlife.

2.8 Land Ownership

Ownership of the land in the watershed is a combination of USFS (65%), private owners (30%), unknown (4%), and the state (less than 1%). The densest concentrations of residence are in the towns of Jamestown, with a population of 300, and Ward, with a population of 170. The remainder of the watershed is sparsely populated with scattered residences.

2.9 Water Rights Ownership

The Left Hand Ditch Company (LHDC) owns the first 31 priorities for direct flow diversions from Lefthand Creek, and therefore effectively controls the entire flow of the creek in most years. The LHDC system includes most of the watershed, due to its ownership of Lake Isabelle, Left Hand Park Reservoir, significant diversion rights from the South St. Vrain River, Gold Lake, and the flows in the Little James, James Creek, and Lefthand Creeks. The LHDC is a consolidated ditch system serving agricultural and municipal shareholders, primarily in the foothills and plains east of the Lefthand Canyon. There are a total of 16,800 shares of stock in LHDC. The largest single shareholders are the LHWD, whose use is primarily for municipal water for the community of Gunbarrel and surrounding areas, Boulder County, and the City of Boulder. The County and City utilize their shares for irrigation on Open Space properties. Each share of stock in the LHDC system entitles the owner to a pro rata share of the direct flow diversions and of the storage water from LHDC reservoirs.

3 Water Quality Data Collection and Management

Various studies by the EPA, University of Colorado, CDPHE, and the USFS have been conducted to collect data regarding toxic metal inputs from mines. Table 2 briefly describes these efforts to date and provides a reference to the study reports.

3.1 Lefthand Creek

3.1.1 Metals

As described in the Lefthand Watershed Sampling and Analysis Plan developed by the EPA (EPA, 2004), URS Operating Services conducted field work at the Captain Jack Mill (CJM) site on June 25 and 26, 1997. The CJM site is located about 2.4 km south of Ward. The investigation involved the collection of 26 samples for laboratory analysis and the collection of non-site specific information. Surface water and sediment samples collected along Lefthand Creek and its tributaries indicated elevated concentrations of aluminum, calcium, copper, iron, lead, magnesium, manganese and zinc. Furthermore, calculations indicated a sizable amount of metals loading to Lefthand Creek that is attributed to the Big Five Mine adit discharge. Lefthand Creek exhibited evidence of contamination from both the CJM site and the Big Five Mine adit. Evidence of contaminant migration from the CJM site was exhibited by fine grained materials (possibly tailings) present along the stream bank immediately adjacent to the mill site. Additional evidence of contamination took the form of an orange precipitate lining the bottom of portions of Lefthand Creek and the channel of the Big Five Mine adit drainage.

The Hazardous Materials and Waste Management Division of the CDPHE, under a cooperative agreement with the EPA, conducted a Combined Assessment (CA) of the Slide Mine/Corning Tunnel area in fall 2002 and spring 2003. The CA called for the collection of 24 field samples consisting of 4 solid source, 2 aqueous source/adit, 5 surface water, 5 sediment samples and 5 aqueous QA/QC samples. The Slide Mine site covers an area of approximately 12 acres and is situated approximately 1 km west of Rowena along Lefthand Creek Road at an elevation of 2500 m. The Slide mine is located on the south side of Lefthand Creek on the hill slope overlooking the Lefthand Creek drainage. The mine is situated on the hill terrace approximately 305m above Lefthand Creek. Analysis of surface water samples collected from Lefthand Creek did not indicate a release of contaminants to the stream from the mine adit and during periods when site conditions are steady. However, sediment samples collected from Lefthand Creek downstream of the probable point of entry for site contaminants indicate that pile materials are migrating from the site to the drainage and are present at elevated concentrations in sediments 0.5 km downstream of the site. CDPHE also performed a high-flow sampling event on April 18, 2003. Field observations made on this sampling date indicated that the site was discharging to Lefthand Creek.

Surface water and sediment data was collected by the University of Colorado in 2002 and 2003; the results of these efforts are described in more detail in Section 5 of this Watershed Plan and in Wood et al, 2004 and Wood, 2004.

3.1.2 Sediment

The LHWD experiences ongoing problems with sediment deposition at its water intake on Lefthand Creek. This district has recently spent thousands of dollars on efforts to mitigate the impact of these sediments, and annually expends man and equipment hours removing sediment from intake structures. In 2004 the LHWD installed a turbidity meter at the Haldi water intake in order to monitor increases in sediment loading and prevent uptake of this sediment into the water treatment system.

3.1.3 Nutrients

There are potential nutrient (particularly total phosphorus) loading concerns from the cumulative impact of Individual Sewage Disposal Systems (ISDS). Data collected by the EPA in the summer of 2004 may provide some information on nutrient loading in the Lefthand Creek watershed; however, no comprehensive study of this issue has been conducted in the watershed to date.

3.2 James Creek

3.2.1 Metals

The Golden Age Mining district contributes runoff to James Creek. Jenks Gulch, Castle Gulch, Hill Gulch and other drainages may be contributing additional metals to James Creek. Indications are that these metals are not impacting James Creek upstream of Little James Creek. Metals concentrations at these sites were often below detection. An ecological investigation of the water quality of the upper James Creek (Duren, 2001) found that roads and off-road vehicle activity may have had a negative affect on the ecosystem health of James Creek.

Data collected by the University of Colorado in July of 2002 indicated that zinc may at times exceed acute water quality criteria in James Creek upstream of the town of Jamestown, and both copper and zinc may sometimes exceed acute water quality criteria at the point of confluence with Little James Creek. Data collected by RiverWatch, a volunteer water monitoring organization developed by the Colorado Division of Wildlife, indicate exceedance of acute criteria for copper in Upper James near Chipmunk Gulch and below Overland Mountain.

3.3 Little James Creek

3.3.1 Metals

The Little James Creek sub-watershed drains numerous adits, shafts, and tailings piles within a part of the Jamestown Mining District, including the Burlington, Emmit, and Argo Mines. The area was primarily developed for its lead-silver, fluorspar, and uranium deposits. URS Operating Services was asked by the EPA Region 8 to conduct an Expanded Site Inspection under the Superfund program at the Golden Age Mine site in Jamestown. The second field sampling event was conducted June 1 through 3, 1998. Aqueous samples collected from Little James Creek show elevated concentrations of the following total and dissolved metals: beryllium, lead, manganese, sodium, thallium, and zinc.

3.4 Data Management and Data Sharing

During the spring and summer of 2004, multiple meetings were held between agencies and organizations, including the EPA, CDPHE, USFS, University of Colorado, and LWOG, that were active in data collection in the watershed. The purpose of these meetings was to coordinate the water sampling events planned by each group, thereby fostering collaboration between groups during sampling, preventing duplications of efforts, and encouraging data-sharing. One outcome was that all of the groups involved agreed to make data available to the public through the EPA's STORET database. In the case of data collected by the University of Colorado for LWOG, all data was given to CDPHE personnel, who then made the data STORET-compatible. Available watershed data can be found online through an interactive map on the CDPHE website at http://emaps.dphe.state.co.us/HMLfHandCrk/viewer.htm. LWOG plans to continue this data-sharing and data-management system for all future data collection efforts.

4 Water Quality Concerns

Research conducted by the EPA (1995a) and the University of Colorado (Wood et al, 2004; Wood, 2004) identifies stream contamination by metals and acidity from inactive mines as a major threat to water quality. This topic is discussed in detail in Section 5 of this plan, and metal loading to streams is used as the driver for the site reclamation prioritization system presented in Sections 6, and the BMPs considered in Section 7.

At LWOG meetings and other forums, watershed stakeholders have identified other potential threats to water quality pertinent to the Lefthand Creek watershed, including sedimentation, nutrient loading, road salting, and dewatering. In general, little, if any, quantitative data is available on these topics. Therefore, this section addresses these water quality concerns, identifies data gaps, and recommends general courses of action for LWOG. Due to the lack of water quality data related to stream contamination other than metal loading, the water quality issues presented in this section will not be used in prioritization of sites for reclamation or in the discussion of BMPs. As more data becomes available to LWOG in the future, updates to the watershed plan may include management actions related to diverse water quality issues in addition to metal loading and acidity.

4.1 Sedimentation

Sediment in streams refers to rock, gravel, sand, clay, and silt particles which are large enough to settle onto the streambed during low-flow periods and in still-water areas such as pools. Sediments tend to enter the stream systems and move downstream during high flow periods, such as spring snowmelt and summer thunderstorms. When sediments settle to the streambed in large quantities the sediment clogs the spaces in between the rocks and gravel in the streambed. Excessive sediment in streams smothers aquatic habitat and may reduce the numbers and diversity of aquatic organisms that form the base of the food chain. During the summer of 2004, EPA researchers conducted a study of benthic macroinvertebrate (insect larvae) populations and habitats within the watershed. This study included evaluation of stream embeddedness from sediments and the impacts of sediments on macroinvertebrate habitats. This data will be incorporated into the Watershed Plan as it becomes available.

Sediment concentrations in streams also correspond to impacts on human health. The measure of the suspended particles content of water, measured in nephelometric turbidity units (NTUs), provides a surrogate measure of a water treatment plant's ability to remove hazardous microorganisms such as pathogens. In the Lefthand Creek watershed, a slow sand filter treatment plant treats water from James Creek for use by the town's 200 residents. The treatment plant has consistently failed to remove suspended sediments to the turbidity level of 1.0 NTU, which is required by the Safe Drinking Water Act. The CDPHE currently allows the plant to produce finished water with a turbidity of 5.0 NTU, the highest variance in effect in Colorado.

In addition to natural sources of sediment loading, observed anthropogenically-driven potential sediment loading sources in the Lefthand Creek watershed include off-highway vehicle (OHV) use, sanding roads during icy conditions, and dirt and gravel driveways located near streams, and loose mine waste piles near streams.

4.1.1 Sediment Loading from Runoff

There are many sources of sediment loading to the streams of the Lefthand Creek watershed, including naturally sediment-rich runoff from rainfall and snowmelt events. According to a study of James Creek conducted by researchers at the University of Colorado, suspended sediment concentrations in stream water increase during periods of rapid snowmelt and heavy rainfall (Ryan and Duren, 2003). Additionally, forest fires such as the Overland Fire which burned approximately 3000 acres in the watershed on October 29, 2003, damage the vegetative cover which stabilizes steep hillsides adjacent to streams. Currently, local citizens, government officials, and agencies such as the USFS are working together to study the impact of the Overland Fire and to develop management plans which will lessen the risk of future forest fires. However, current conditions in the Lefthand Creek watershed suggest a high risk for future wildfires. Considering the impacts of forest fires on general ecosystem health and water quality, LWOG should support and participate in efforts to mitigate fire hazards.

4.1.2 Sediment Loading from OHV activity

In an analysis of sediment loading from a now closed OHV area located approximately 5 km upstream of the Jamestown water treatment plant on gravel-based, unmaintained County Road (CR) 102J, researchers at the University of Colorado mimicked OHVs by driving an all-terrain vehicle over a short portion of CR 102J that is covered by James Creek, and then tracking the transport of the sediment downstream (Ryan and Duren, 2003). The experiment showed that of the 150 kg of sediment added to the stream by the researchers, 50 kg (33%) traveled downstream the entire distance to the treatment plant. Additionally, the researchers monitored James Creek and tributary suspended sediment concentrations during one heavy rainfall event, finding that tributaries with a flow path that contacted CR 102J carried higher sediment loads than those tributaries not in contact with the road. The researchers concluded that sediment generation from both OHV use and tributary flow over CR 102J places additional sediment burden on the downstream water treatment system. The report supported closure of both the road and OHV area and called for restoration of the area. In 1999, the road and the OHV area were closed and JCWI and its partners are currently working on a restoration project of that closure area.

Currently, the area with the heaviest recreational OHV use occurs in the Lefthand OHV area, located on USFS property off of Lefthand Canyon Drive approximately 9.6 km from Highway 36. Unfortunately, there is a lack of data describing the types and frequency of use of this area, as well as potential sediment loading impacts. Adam Mehlberg, president of the Trailridge Runners 4-Wheel Drive Club which sponsored a restoration effort in the Lefthand OHV area in 2004, provided some qualitative use information (personal communication, 2005). Mt. Mehlberg describes use of the Lefthand OHV area as heavy, with the primary user groups being vehicles and motorcycles, with all-terrain vehicles and mountain bikes used to a lesser degree. Recreationalists utilize the area year-round, but less often during winter months. Peak use occurs on the weekends. Mr. Mehlberg points out the need for future projects to revegetate damaged hillsides and to provide mechanisms to keep recreationalists on designated routes. The USFS is in the process of eliciting community feedback for the development of the Lefthand Canyon Travel Plan, which will include a management plan for the Lefthand OHV area.

With the exception of the University of Colorado report outlined above, no formal studies of the sources or magnitudes of sediment loading within the Lefthand Creek watershed have been conducted. This represents a significant gap in the quantitative data available to LWOG for watershed planning; LWOG should attempt to find funding to conduct sediment loading and impact studies, and will strongly encourage local, state, and federal agencies, universities, and other parties to collect such data. Similarly, statistics describing the frequency and intensity of all types of recreational uses of the watershed are sparse and need to be supplemented when possible.

4.2 Nutrient Loading

Nutrients in streams, primarily nitrogen and phosphorus, are essential for healthy aquatic life; however, an overload of nutrients in a stream often leads to excessive algal growth and productivity. This, in turn, may reduce the availability of dissolved oxygen to aquatic organisms, alter stream habitats, lead to unfavorable aesthetics and odors, and lead to the release of heavy metals from streambed sediments. Sources of increased nutrient loads to streams generally include municipal and industrial discharges, runoff of lawn and garden fertilizers, and agricultural runoff. All of these nutrient sources may be contributing factors in the agricultural and residential areas in the eastern plains portion of the Lefthand Creek watershed. In the mountainous western region of the watershed, home septic systems and septic leach fields present a potential nutrient-loading concern.

As with sediment, little nutrient data has been collected within the streams of the Lefthand Creek watershed. Nutrient data from the summer 2004 EPA-led sampling event will be available to LWOG in the future. LWOG should encourage and participate in efforts to collect such data and incorporate this information into watershed management planning.

4.3 Road Salting

Along the roadways of the Lefthand Creek watershed, approximately 40 km of which lie adjacent to streams, Boulder County Road Maintenance workers apply a 5 – 15% salt mixture as a snow and ice melting agent. Additionally, the County applies magnesium chloride (MgCl) as a dust control and soil stabilizing product to gravel roads during dry summer months (Boulder County, 2005) In high concentrations for extended periods of time, chloride in streams is toxic to aquatic life. Chloride may also negatively impact vegetation near the roadside; in the Lefthand Creek watershed roadside vegetation is often also an important part of the riparian corridor. Other potential concerns related to road salting include increased availability and toxicity of heavy metals and corrosion of pavement, bridges, and culverts.

4.4 Dewatering

Dewatering of streams—the result of diverting water from a stream for agricultural, municipal, or other uses—can lead to increased stream water temperatures and algal growth, and harm to fisheries. This issue has not been studied in the Lefthand Creek watershed, and the impacts of dewatering in this watershed are unknown.

4.5 Summary of Water Quality Issues

This chapter has briefly discussed key threats to water quality that likely exist in the Lefthand Creek watershed. Toxic metals and acidity from inactive mining sites, currently the most prominent source of water quality degradation, will be discussed in detail in the following chapters. For all other potential water quality issues, including sedimentation, excessive nutrient loading, chlorination, and dewatering, the current deficit of quantitative data prohibits LWOG from determining the actual water quality impacts of these potential threats, and from identifying reclamation priorities and appropriate reclamation activities. Considering this, LWOG should encourage and participate in future data collection activities that allow for more detailed watershed characterization. In particular, LWOG should encourage and participate in further data collection by attempting to secure funding for further watershed characterization. Such data can be incorporated into future updates of the Watershed Plan. It is important to note, however, that the lack of data should not preclude LWOG from participating in efforts to manage the watershed, such as the developing a USFS travel management plan. Additionally, LWOG should consider taking pre-emptive measures, such as public outreach and education, to focus on preventing the occurrences or exacerbation of the potential water quality threats mentioned here. For instance, LWOG could promote proper driveway building practices that lessen sediment loads from gravel driveways to streams.

5 Metals and Mining

5.1 Background

Due to the strong historic presence of hardrock mining in the Lefthand Creek watershed, many problems associated with this industry remain today. One of the most significant of these problems is acid mine drainage (AMD), which occurs when sulfur-containing minerals, most commonly pyrite (FeS_2, also known as fool's gold), in mined ore bodies, waste rock, and tailings piles are exposed to oxygen and water. This results in biologically-catalyzed chemical reactions that generate sulfuric acid and iron hydroxide, and often release high concentrations of heavy metals such as copper, lead, manganese, and zinc. If streams or other water bodies are hydrologically connected to an AMD-generating site, either through direct contact, surface runoff, or groundwater transport, they often become contaminated with acidity (characterized by low pH values) and elevated concentrations of toxic metals.

Acid rock drainage (ARD) is the term applied to cases where exposure of sulfur minerals to air and water, and consequent release of acidity and metals, occurs naturally and without anthropogenic perturbation. In the case of the Lefthand Creek watershed, mining occurred in naturally mineralized areas characteristic of the Colorado Mineral Belt. Therefore, while it is possible that some cases of ARD may occur in the watershed. However, due to the prevalence of mining activities in the watershed and the quantities of exposed pyrite-containing geologic materials generated by mining, the research cited in and used for development of this Watershed Plan attributes stream contamination to anthropogenic AMD.

Acidic, metal-laden water emanating from inactive mines and waste rock piles directly impairs aquatic life in the streams of the Lefthand Creek watershed, and to a lesser degree also threatens human drinking and irrigation water supplied by Lefthand Creek. Metals and acidity pose acute and chronic risks for aquatic organisms. For example, a fish kill occurred in April 2003 in James Creek just downstream of the confluence with the Little James Creek; this kill even was likely a result of the rapid release of snowmelt water that was temporarily stored in the subsidence pits at an inactive mine. The metals in the streams, and in the stream bed sediments, also threaten human health. The potential exists for a catastrophic flood or mine collapse to mobilize toxic metals and contaminate the water supply.

5.1.1 Data Collection

Metal loadings, which are defined as the product of metal concentration and stream discharge for a given location, constitute the mass of metal entering and flowing through a stream (Kimball, 1997). Comparison of changes in instream and tributary metal loadings reveals the sources and magnitudes of metal inputs to a stream. Various efforts by the EPA, the University of Colorado, CDPHE, and the USFS have been conducted to collect data regarding toxic metal inputs from mines. Table 2 briefly describes these efforts to date and provides a reference to the study reports. In the discussions below, the authors draw on these various sources of data in an effort to (1) estimate the metal loads that each mine site contributes to streams; and (2) prioritize each site for reclamation based on metal load contributions.

5.1.2 Baseline Data

The metal concentration and load estimates presented in this Watershed Plan come from studies conducted by University of Colorado researchers from 2002 to 2004 (Wood et al., 2004; Wood, 2004). This dataset provides the most complete, pre-reclamation information available; therefore, LWOG will utilize this information as baseline watershed data. As it becomes available, the results of data collection efforts conducted by the University of Colorado, EPA, USFS, JCWI, and others will be compared to this baseline dataset.

5.1.2.1 Metal Loading Data Collection Techniques

5.1.2.1.1 University of Colorado Tracer Tests

University of Colorado researchers performed metal loading tracer dilution tests and synoptic sampling along Lefthand, James, and Little James creeks to quantify stream flows and metal concentrations at a high spatial resolution. Tracer tests involve injection of a non-reactive salt tracer into the stream followed by sampling to measure the dilution of the tracer due to inflows of surface and groundwater. Low concentrations of lithium chloride (LiCl) or sodium chloride (NaCl) were employed as tracers for the Lefthand Creek watershed studies. Collection of water samples to measure the tracer dilution provides information necessary to calculate stream flows at each sampling location. These water samples were also analyzed for metals commonly associated with mine drainage, including aluminum, copper, iron, lead, manganese, uranium, and zinc. Metal loads at over 300 sampling stations on the three creeks and their tributaries were determined from the stream flow and metal concentration data.

The James Creek water samples were collected during low flow in the summer of 2002. Lefthand Creek and Little James Creek samples were collected during high flows in the spring of 2003. Low flow experiments were conducted along the Little James Creek and the California Gulch segment of Lefthand Creek during the fall of 2003. Each test was conducted over a period of 3 to 7 hours, and over a stream reach of 2 to 7 km. The James Creek experiments were conducted using a NaCl tracer. For all other tests, lithium LiCl was used. Water metal concentrations were determined by inductively coupled plasma-mass spectroscopy (ICP-MS) and inductively coupled plasma-atomic emissions spectroscopy (ICP-AES) analyses of the water samples. A detailed description of data collection methods used by the University of Colorado researchers can be found in Wood et al., 2004 and Wood, 2004.

5.1.2.1.2 Comparison to Water Quality Standards

In order to take into account variations in metal toxicity due to differences in the complexation capacity of natural waters, CDPHE calculates water quality standards according to stream water hardness (CDPHE, 2001). Stream water hardness, reported in mg L^{-1} $CaCO_3$, was determined by summing total calcium and magnesium concentrations (CDPHE, 2001):

$$Hardness = 50.05([Ca]+[Mg])$$

where [Ca] and [Mg] are the total concentrations of calcium and magnesium ions in units of meq L^{-1}. Hardness was calculated for approximately five sites along each sample reach of Lefthand and Little James creeks. Hardness was not measured in James Creek. According to calculated hardness values, appropriate CDPHE chronic (thirty day exposure) and acute (one day exposure) aquatic life Table Value Standards (TVS) for manganese, zinc, copper, lead, and uranium were selected for comparison to synoptic sample metal concentrations. CDPHE aquatic life parameters for iron, aluminum, and pH, which are not hardness-based, were also compared to water quality results (CDPHE, 2001).

5.2 Metal Loading Contributions

Using the methods described above, University of Colorado researchers quantified metal loading sources to James Creek in 2002, and Lefthand and Little James creeks in 2003 at over 300 sample sites along approximately 30 km of stream. Water samples at each of these sample sites, collected during the tracer tests, were analyzed for total and dissolved (> 0.45 µm) metal concentrations. For each sample site, total and dissolved metal loads were calculated as the product of the stream flow rate and metal concentration. Comparison of changes in instream and tributary metal loads reveals the sources and magnitudes of metal inputs to a stream.

The product of metal concentration and discharge gives a metal loading rate in kg day^{-1} for each synoptic sample location. Total and dissolved metal loading rates were calculated for each synoptic sampling location. For each metal and each synoptic sampling location, the net load change is calculated as the difference between metal loads in two successive synoptic sample sites. Cumulative loads are the sum of all net load increases along a stream reach. The fraction of total metal loads contributed by each source was determined by the sum of cumulative total loads in the synoptic sample sites adjacent to the source divided by the sum of all cumulative total loads for the stream reach. This provides a minimum estimate of the total metal load added to the stream along the length of the stream reach (Kimball et al., 2001).

The results of the University of Colorado study are presented in detail in Wood et al., 2004 and Wood, 2004. Total metal load contributions are summarized in this Watershed Plan in Tables 3, 4, and 5. These tables show stream flow contributions and metal loading concentrations for tributaries and known mining-related sites. Additionally, areas which contributed greater than 5% of metal loads for at least one metal were included, even when the identity of the loading source was unknown. Loading contributions which are not accounted for in these tables are attributed to dispersed sources that contribute less than 5% of the total load to the stream for all of the metals analyzed at the time of the study.

5.2.1 Summary of Lefthand Creek Metal and Acidity Sources

Table 3 lists the relative stream flow and cumulative total metal loading contributions of sites identified as potential contaminant sources to Lefthand Creek. Sites located along the California Gulch segment of Lefthand Creek were the initial sources of metal loading increases and exceedances of CDPHE water quality table value standards along the 31.27 km Lefthand Creek study reach. In particular, the Big Five Mine Tunnel mine drainage contributed the largest concentrations of dissolved aluminum, manganese, zinc, copper, and lead. An increase colloidal manganese, zinc, and copper, as well as colloidal aluminum and lead, was observed in Lefthand Creek near the confluence of both a hillside seep and the unnamed tributary that flows past the Dew Drop mine site. Without further data collection, it is impossible to determine which of these sources contributed to the increase in metals. Colloidal increases of all metals analyzed, and particularly lead and zinc, were measured at 1.99 km from the reference site at the Peak-to-Peak Highway, near an unnamed mine opening. Inflows from Puzzler and Indiana Gulch diluted metal concentrations in Lefthand Creek for all metals except iron. Various unnamed and unidentified metal loading sources exist upstream of the village of Rowena. James Creek added somewhat to the iron and aluminum loading of Lefthand Creek, but diluted concentrations of all other metals. Finally, "Lee Hill" gulch added a high percentage of the aluminum, manganese, zinc, copper, and lead colloidal metal loads to Lefthand Creek. This was an unexpected source of metals, and no mines are known to exist in this area. It is recommended that more data be collected for this site, including a physical hike of the area to look for signs of mining activity.

5.2.2 Summary of James Creek Metal and Acidity Sources

Table 4 lists the relative stream flow and cumulative total metal loading contributions of sites identified as potential contaminant sources to James Creek. Highest total metal loading contributions for iron, aluminum, manganese, lead, and uranium were measured at 4.66 km from the reference site at the CR 102J creek crossing, near the "Bueno Mountain gully." The load increases at this site were primarily observed in the colloidal fraction. An ephemeral gully drains the Bueno Mountain area, which was dry at the time of sampling; this indicates subsurface flow and metal contributions to James Creek. Total and dissolved zinc concentrations and loads were highest at 2.80 km. It is possible that surface or groundwater interactions with the Bueno Mountain mine workings also explain this increase; however, further research is necessary to confidently identify this important zinc source. The principal input of total and dissolved copper loads was found at 1.71 km, near the Fairday Mine site. Finally, temporally varying measurements made at the 4.82 km and 4.95 km sample sites suggest that Little James Creek intermittently contributes dissolved aluminum, manganese, zinc, copper, and lead loads to James Creek.

5.2.3 *Summary of Little James Creek Metal and Acidity Sources*

Table 5 shows the cumulative total metal load contributions for sites located along the Little James Creek. The stream water and stream bed sediment data identifies Balarat Creek as a primary dissolved and colloidal metal loading source to Little James Creek during both high and low flow conditions for iron, aluminum, manganese, zinc, copper, and lead. Although the Emmett adit drainage exhibited extremely high dissolved metal concentrations, the small flow of this stream prevented high loading contributions even during high flow sampling. Increases in metal loads, particularly for zinc and copper, were observed downstream of the Evening Star mine site in April, when drainage from this adit at this site was flowing. Lead and copper loads increase downstream of the Argo mine site, and low flow data point toward a source of colloidal iron, copper, and lead at 1.10 km from the reference site 2.8 km upstream of the Little James confluence with

James Creek. Subsurface inputs of dissolved and total iron, aluminum, manganese, zinc, and copper loading were observed near the unnamed waste rock pile, referred to as the Roadside Tailings, at 1.55 km during both high and low flow sampling events. Spikes in all metals near 1.83 km suggest an unidentified metal source in this area. Finally, the unnamed gully, which flows through mine workings and joins Little James Creek near the downstream toe of the streamside tailings waste rock pile, added to total iron, aluminum, zinc, copper, and lead when flowing during the April 22 sampling. This tributary was dry on June 17, suggesting that it is an irregular contributor to the metal loading of Little James Creek.

5.3 Metal Concentrations in Sediments and Macroinvertebrates

As a follow-up to the analysis of stream water metal concentrations and loads conducted in 2002 and 2003, University of Colorado researchers examined metal concentrations in stream bed sediments in 2003 (Wood et al., 2004 and Wood, 2004) and metals in the body tissues of benthic macroinvertebrates living in the streams in 2004 (Bryenton et al., 2004). Metals are deposited on stream bed sediments gradually over time; therefore, sediment metal concentrations reflect longer term impacts to streams, including metal sources which may flow only ephemerally during periods of high surface or groundwater flow. Metal concentrations found in benthic macroinvertebrates, which live in streambed sediments, reflect metal sources to streams over the life span of the macroinvertebrate, which is generally one season.

5.3.1.1 Metal Data Collection Techniques

5.3.1.1.1 Sediment Metal Concentrations Data Collection

University of Colorado researchers collected stream bed sediments from the California Gulch segment of Lefthand Creek on June 16, 2003 and from the Little James Creek on June 2 and 3, 2003. The sample collection and partial digestion methods outlined by Church (1993) provided the model for the sediment collection and metal extraction techniques.

Approximately 1 liter of sediment was collected at each site, compositing five to ten sub-samples collected within a 10 m area. Sediment was collected only in depositional areas expected to be covered by water even at low stream flows, and only from the upper 5 cm of the stream bed. The composite sediment samples were dried and sieved to segregate the <63 μm size fraction, and a partial acid digestion of the sediment was employed to extract leachable metals associated with mineral coatings on the sediment particles (Church, 1993; Church et al., 1997). Sediment metal concentrations for iron, aluminum, manganese, zinc, copper, and lead were determined by ICP-MS and ICP-AES analyses of the digestion solutions. A detailed description of data collection methods used by the University of Colorado researchers can be found in Wood et al., 2004 and Wood, 2004.

5.3.1.1.2 Macroinvertebrate Metal Concentrations Data Collection

University of Colorado researchers collected multiple species of benthic macroinvertebrates from Lefthand, James, and Little James creeks on June 13 and 14, 2004. Collection procedures were based on methods outlined by Clements (1991). Field collection involved collecting all captured benthic macroinvertebrates, regardless of species, from stream riffle areas using a D-framed kick net. The macroinvertebrates collected belonged to the stonefly, mayfly, and caddisfly groups. The target goal for each sampling location was 10 grams of macroinvertebrate biomass.

Sample preparation and analysis involved a modified method of Clements (1994). Immediately following collection, samples were frozen. In the laboratory, samples were split to allow for two different sampling events (for quality control analysis). Samples were dried to a constant weight and transferred to cleaned centrifuge tubes. A complete acid digestion was performed on the samples, and the resulting digest solution was analyzed for aluminum, cadmium, copper, lead, silver, chromium, arsenic, zinc, and selenium concentrations with ICP-MS.

5.3.1.2 Sediment and Macroinvertebrate Metal Concentrations Results

Figure 11 shows metals found in streambed sediments and macroinvertebrate body tissues for Little James Creek. As shown in the figure, metal concentrations found in both sediments and aquatic life increase downstream of mine workings. This data reinforces the metal loading data discussed above. For instance, the sediment and macroinvertebrate data show that the Evening Star Mine site contributes high amounts of zinc and copper to the stream, but only small amounts of lead. The Argo Mine site, on the other hand, contributes lesser amounts of zinc and copper, but more lead, than does the Evening Star Mine site. These results follow the trends of loading percentages presented in Table 5. Similarly, the sediment and macroinvertebrate data show increases in all metals downstream of the Emmett Adit and Balarat Creek inflows, near the unidentified source at 1.83 km, and in the vicinity of the Streamside Tailings. Metal concentrations did not increase significantly near the Roadside Tailings, suggesting that the loading contributions of this site may be overestimated in Table 5.

Streambed sediment data is not yet available for James Creek; however, macroinvertebrate metals analysis has been conducted on twelve sites over about 10 km (Figure 12). The maximum macroinvertebrate zinc concentration in James Creek, 0.59 mg kg^{-1}, was three times higher than the maximum zinc concentration recorded in Little James Creek. Macroinvertebrate copper concentrations, on the other hand, were up to 5 times higher in Little James Creek than in James Creek, with a maximum of 0.2 mg/kg. Peak macroinvertebrate lead concentrations were approximately the same in both streams, and exhibited low concentrations and little variation. The highest copper and zinc concentrations in James Creek were found near the Castle Gulch area approximately 1.2 km upstream of the confluence with Lefthand Creek.

Zinc, copper, and lead concentrations in macroinvertebrates living in Lefthand Creek were highest in the California Gulch reach of the creek, ranging up to nearly 1.8 mg of zinc per kilogram of insect body tissues. This area flows through the Captain Jack Mine and Mill Superfund site, including mine sites such as the Big Five adit and the White Raven Mine (Figure 13a). Sediment samples were also collected in this portion of the creek, but have not been collected for the remainder of Lefthand Creek.

Macroinvertebrate metal concentrations appear to decrease downstream of California Gulch, with a slight increase directly downstream of the Slide Mine site, and a larger increase about 18 km downstream from the Peak-to-Peak Highway, near Nugget Gulch. Metal concentrations decrease downstream of the confluence with James Creek, and continue to decrease to the most downstream sample site near Highway 36.

6 Prioritization of Mine Sites for Cleanup

6.1.1 Site Ranking System

In Wood et al. (2004), University of Colorado researchers developed a technique to prioritize mine sites for remediation based on the stream water pH, metal concentration, and metal loading data collected in 2002 and 2003, as well as hardness-based chronic and acute aquatic life table value standards set by the CDPHE. This system provides a preliminary method for site comparison, and can be fine-tuned as more data becomes available. Factors such as aesthetics, degree of public interest, and habitat vulnerability, which are used in the priority ranking system under §303(d) of the Clean Water Act, could be applied by interested stakeholders to further distinguish between sites receiving similar scores using the preliminary standards- and loadings-based ranking system.

Potentially contaminating sites identified with metal loading tracer tests and synoptic sampling located along Lefthand, James, and Little James creeks were scored according to observed instream chronic and acute aquatic life criteria violations and according to relative cumulative dissolved metal loading contributions to the stream. Applying a simple binary scoring system (Table 6), sites received a single point for each violation of chronic iron, aluminum, manganese, zinc, copper, lead, or pH aquatic life chronic exposure criteria. Sites also received a single point for each violation of aluminum, manganese, zinc, copper, and lead aquatic life acute exposure criteria. To compare dissolved metal loading contributions from each site, a point was given to each site for contributions of more than 5%, 10%, 15%, and 25% of the cumulative instream dissolved loads for iron, aluminum, manganese, zinc, copper, and lead. To correct for weighting of the scoring system towards downstream sites with higher instream stream flow and thereby higher metal loads, a single point was subtracted from sites contributing more than 5% of the cumulative instream flow. The maximum possible score was 37 points. Sites were categorized into three priority categories: low priority (0 to 4 points), medium priority (5 to 9 points), and high priority (10 points and above).

Analysis of metal loading tracer dilution tests and synoptic sampling conducted along Lefthand Creek indicated sixteen sites with potential toxic metal impacts to the stream. Only the Big Five Mine Tunnel received a high priority ranking, with a score of 16 points. Nine sites received medium priority ranking, and six sites received low priority ranking (Table 7). Of the six potentially contaminating sites identified along James Creek, three sites received high priority ranking, two sites received medium priority ranking, and one site received low priority ranking (Table 8). Of the ten potentially contaminating sites identified along Little James Creek, seven sites received high priority ranking, one site received medium priority ranking, and two sites received low priority ranking (Table 9).

6.1.2 Site Ranking Scores

Based on the ranking system results presented above and the completed and upcoming remediation actions, the following actions are recommended for the mine sites identified in tables 7, 8, and 9.

6.1.2.1 High Priority Mine Sites

High priority sites which currently do not have planned or ongoing remediation activity and require immediate attention. LWOG should focus on evaluating the BMPs and potential funding opportunities available for reclamation of these sites, and should work with the various involved agencies and stakeholders to identify an entity or consortium of entities to lead the reclamation process. LWOG should then continue to directly assist in reclamation planning and activity, monitor stream water quality changes, and evaluate reclamation efficacy as the projects develop. High priority sites include:

- Bueno Mountain (James Creek and Little James Creek)
- Burlington Mine Pond (Little James Creek)
- Roadside Tailings (Little James Creek)
- Streamside Tailings (Little James Creek)

6.1.2.2 Medium Priority Mine Sites

Medium priority sites which currently do not have planned or ongoing remediation activity and require awareness, preparation, and monitoring, but not immediate attention. LWOG should focus on evaluating the BMPs and potential funding opportunities available for reclamation of these sites, and should work with the various involved agencies and stakeholders to identify an entity or consortium of entities to lead the reclamation process. LWOG should monitor stream water quality in the vicinity of these sites. Other activities by LWOG for medium priority sites will be undertaken only once time and resources which are focused on high priority sites become available. Medium priority sites include:

- Loder Smelter (Lefthand Creek)
- Slide Mine (Lefthand Creek)
- Castle Gulch (James Creek)
- Evening Star Mine (Little James Creek)
- Argo Mine (Little James Creek)

6.1.2.3 Low Priority Mine Sites

Low priority sites which currently do not have planned or ongoing remediation activity and require awareness, preparation, and monitoring. Further actions may not be necessary for these sites. LWOG should evaluate the BMPs applicable to these sites, and should focus on monitoring of stream water quality in the vicinity of these sites. Other activities by LWOG for low priority sites will be undertaken only once time and resources which are focused on high and medium priority sites become available; or if changes in water quality lead to re-prioritization of the site. Sites may be dropped from the low priority list if sufficient monitoring shows that these sites do not degrade watershed health. Low priority sites include:

- Indiana Gulch (Lefthand Creek)
- Nugget Gulch (Lefthand Creek)
- Lee Hill Gulch (Lefthand Creek)
- Carnage Canyon Gulch (Lefthand Creek)
- Sixmile Creek (Lefthand Creek)
- John Jay Mine (James Creek)

- Emmett Adit (Little James Creek)

6.1.2.4 Under-characterized Mine Sites

Under-characterized sites include areas which received high or medium priority ranking, but for which the probable source of contamination is unknown. These sites require immediate attention in order to identify the source, nature, and extent of contamination. LWOG should facilitate both qualitative and quantitative data collection for these sites through the development and employment of sampling and monitoring plans and the pursuit of funding to initiate these plans. Useful qualitative data may be obtained simply by on-the-ground reconnaissance near the sites to determine probable contamination sources. These sites should be better characterized and then re-classified according to high, medium, or low reclamation priority as soon as possible. Continued monitoring near under-characterized sites is also recommended. Under-characterized sites include:

- Unnamed tributary on Lefthand Creek approximately 7 km downstream of the Peak-to-Peak Highway.
- Unidentified source on Lefthand Creek approximately 8.5 to 9 km downstream of the Peak-to-Peak Highway.
- Unidentified source on James Creek approximately 2.6 to 2.8 km downstream of the creek crossing on County Road 102J
- Unidentified source on James Creek approximately 3.7 to 4.1 km downstream of the creek crossing on County Road 102J.
- Unidentified source on Little James Creek approximately 1.2 to 1.3 km upstream of the confluence of Little James Creek with James Creek.
- Unnamed tributary on Little James Creek approximately 1 km upstream of the confluence of Little James Creek with James Creek.
- Unidentified source on Little James Creek approximately 0.3 km upstream of the confluence of Little James Creek with James Creek.
- Unidentified source on Little James Creek located just upstream of the confluence of Little James Creek with James Creek.

6.1.2.5 Active and Post-Reclamation Mine Sites

Active and post-reclamation sites include areas for which reclamation activities have occurred, are underway, or are planned for the near future. LWOG should focus on facilitating communication and updates between the parties engaged in the remediation activities and the local community, initiate or maintain involvement in remediation planning, and monitor stream water quality in the vicinity of these sites. Reclamation prioritization ranking should be re-evaluated following completion of the reclamation activities. Active and post-reclamation sites include:

- All sites within the Captain Jack Mine and Mill Superfund site on Lefthand Creek, from the Peak-to-Peak Highway to approximately 2.5 km downstream from the site.
- The Fairday Mine site on James Creek.
- The Burlington Mine site on Little James Creek.

6.2.1.6 *Summary of Metals and Mining*

The results of tracer dilution tests and synoptic sampling for characterization of the Lefthand Creek watershed provided a spatially detailed set of water quality data for over 40 km of streams. Analysis of changes in metal loadings identified potential sources of contamination. Comparison of metal concentrations to CDPHE aquatic life water quality criteria helped to correlate the metal loading data with impacts on stream biota. Relative instream metal loadings and water quality criteria violations provided an empirical basis for comparison of the relative impacts of potential contamination sources and prioritization of these sites for future reclamation. By considering the collective impacts of all contaminating mine sites in the watershed as well as identifying the individual contaminant contribution of each site, LWOG can approach reclamation planning on a watershed level. This allows the group and involved landowners and agencies to target the sites that will provide the greatest improvement to overall water quality. Prioritization and targeting of key sites allows the stakeholders to, in turn, identify and pursue applicable legal opportunities and funding avenues for future reclamation activity. Furthermore, the empirical data collected for this study provides an important set of baseline water quality data which stakeholders can apply to evaluate the effectiveness of future reclamation strategies

7 Best Management Practices

This section describes BMPs that are applicable to the treatment of inactive or abandoned mines. The following information is based on the informational booklet *Best Practices in Abandoned Mine Land Reclamation: The Remediation of Past Mining Activities* produced by the State of Colorado Department of Natural Resources, Division of Minerals and Geology (2002). The *Best Practices in Abandoned Mine Land Reclamation* booklet provides more detailed information for each BMP, including advantages, disadvantages, initial cost estimates, and maintenance considerations.

7.1 Overview

BMPs are management strategies implemented in an effort to control, mitigate, or reclaim degraded environments. The BMPs presented here present a diversity of potential solutions to mine site reclamation in the Lefthand Creek watershed. Due to the complexity of mine reclamation, including the need to address waste rock and tailings, surface water, groundwater, sediments, and safety hazards, no silver-bullet technology currently exists to manage all mine sites. Rather, a collection BMPs are generally applied simultaneously or in series to complete remediation of a site. Table 10 assigns potential BMPs to each of the ranked mine sites discussed in Section 4.5. These BMPs should be used as general guidelines to reclamation, but it must be noted that Table 10 is neither exhaustive nor final. Thorough research into the specific hydrology, contamination type, and contaminant transport pathways of each site is necessary before embarking on a cleanup project.

Reclamation and treatment methods presented in this Watershed Plan include:

1) <u>Surface and Subsurface Hydrologic Controls.</u> These are generally preventative measures intended to inhibit the processes or acid formation or toxic metal dissolution by minimizing or eliminating the contact of water with mine wastes, particularly sulfide minerals. Surface hydrologic controls include surface and groundwater diversion features, mine waste removal, consolidation, and stabilization, capping, and revegetation.

2) <u>Passive Treatment</u>. Passive treatment techniques refer to a range of low maintenance drainage treatment strategies. Passive treatment BMPs include anoxic limestone drains, settling ponds, sulfate reducing wetlands, oxidation wetlands, aeration, and neutralization systems.

7.2 Mining BMPs

7.2.1 Surface and Subsurface Hydrologic Controls

7.2.1.1 Waste Rock/Tailings Consolidation, Removal, and Stabilization

Waste rock or tailings removal and consolidation, often aided by stabilization in the form of cribbing, cementation, or riprap cover, serves to move the reactive mine wastes away from areas of possible contact with water. This preventative measure tends to be effective in areas where there are several small waste piles near one another, or where waste piles are in direct contact with surface water.

7.2.1.2 Waste Rock/Tailings Regrading

Regrading of waste rock and tailings piles to a gentle slope (generally, a ratio of three feet horizontal to one foot vertical) reduces erosion of the piles by water, wind, frost, and animal action. Erosion reduction, in turn, promotes vegetation growth and decreases the transport and spread of waste materials.

7.2.1.3 Waste Rock/Tailings Capping

Capping of waste rock or tailings piles refers to covering the consolidated, regarded piles with a protective layer of clean, non-acid generating soil. This protective layer prevents or reduces water infiltration into the reactive mine waste materials, thereby slowing the processes of acid generation and metal leaching. In addition to clean soil, which reduces infiltration and promotes vegetation growth, caps may consist of synthetic filter fabrics, geotechnical materials such as clay liners, and acid neutralization materials such as limestone gravel.

7.2.1.4 Vegetation

Hardy vegetation growing on waste rock or tailings piles helps to protect the pile from erosion and reduces water infiltration into the pile. In addition, vegetative covers improve underlying soil by adding nutrients, providing wildlife habitat, and in some cases they may improve the aesthetics of the site.

7.2.1.5 Bulkhead Seals and Plugs

Bulkhead seals and plugs are closure structures that seal off open mine portals through which mine waters flow. Following closure, the mine workings behind the seal or plug flood with mine water. If the mine workings completely fill with water, oxygen is no longer available and chemical reactions that produce acidity and dissolved metals are stalled. Bulkhead seals generally refer to closures structures that allow managers to open or close a portion of the seal, allowing mine water to flow out of the mine in a controlled manner. Plugs, on the other hand, simply block all mine waters into the workings and do not allow for the controlled release of water.

7.2.1.6 Diversion Ditches

Diversion ditches channel clean surface water around the source of contamination, or intercept shallow groundwater that may interact with mine workings or mine wastes. These ditches are applicable in situations where rainwater, snowmelt, or other surface or subsurface flow is degraded by flowing over or through mine workings or mine wastes.

7.2.2 Passive Water Treatment Techniques

7.2.2.1 Chemical Amendment

Chemical amendments may be used, generally in conjunction with other BMPs, to control the acidity of mine drainage or clean water that infiltrates into acid-generating waste piles or mine workings. Generally, chemical amendments involved adding a basic (high pH) material such as lime to the water. Lime may be added directly to the water, or may be introduced indirectly as reactive limestone gravel.

7.2.2.2 Anoxic Limestone Drains

Acidic mine water may be routed through an anoxic limestone drain (ALD) in order to reduce acidity and remove metals from the system by precipitation. A method of chemical amendment, ALDs are ditches lined with limestone to neutralize the mine water, and buried in order to block oxygen from the atmosphere from interacting with the water.

7.2.2.3 Aeration and Settling Ponds

Water aeration and subsequent settling in a pond is a two-part system to reduce the dissolved metal content of mine water. Aeration, which is often accomplished by routing the mine water over a series of small waterfalls, increases the oxygen content of the water. When this water is then captured in a quiescent settling pond, metals can precipitate out of the water solution as solids that accumulate on the floor of the pond. This method generally requires that the mine water is low in acidity. This BMP may need to be combined with chemical amendments such as lime addition that decrease acidity.

7.2.2.4 Sulfate-Reducing Wetlands

Sulfate-reducing wetlands rely on common bacteria found in decomposing organic material to remove metals from mine water. Sulfate-reducing bacteria (SRBs) utilize oxygen in the water for metabolism, initiating chemical reactions that lead to the precipitation of toxic metals in the water as metal sulfides. Wetlands stocked with organic materials such as compost or manure promote the healthy growth of a SRB community, which aids in maintaining the function of the system.

8 Funding Alternatives

As emphasized by the LWTF in their 2004 Report to the Boulder County Health Department, LWOG should encourage remediation efforts that do not involve site inclusion on the National Priority List (NPL, or "Superfund"). The following list provides a brief overview of major funding resources available to LWOG that are alternates to NPL actions.

8.1 Overview of Applicable Funding Sources

8.1.1 Clean Water Act §319

The 1972 Federal Water Pollution Control Act (the "Clean Water Act") set the stage for state-enforced water quality remediation and protection. The 1987 Water Quality Act added §319 to the Clean Water Act, which created a national program to address nonpoint sources of water pollution such as mining and agricultural runoff (Ferrey, 2001). Section 319(h) provides for federal grants to state management programs which will "control particularly difficult or serious nonpoint source pollution problems, including, but not limited to, problems resulting from mining activities" and, "implement innovative methods or practices for controlling nonpoint sources of pollution." These grants to states consist of *incremental funds*, which are designated for development and implementation and implementation of the TMDL program, and *base funds,* which fund state management and staffing support of the Nonpoint Source Management Program. States may disperse incremental funds to state and local abandoned mine reclamation projects that are not covered under National Pollution Discharge Elimination System (NPDES) permitting, such as remediation of water pollution from abandoned mines, mapping and planning of remediation, monitoring for the design and effectiveness of implementation strategies, technical assistance, information and education programs, technology transfer and training, and development and implementation of policies addressing abandoned mine lands (EPA, 1996). Following the federal mandates, the Colorado Nonpoint Source Management Program requires that all projects must be consistent with the Colorado Water Quality Control Division's efforts to meet §303(d) TMDL program requirements (Colorado Nonpoint Source Program, 2004). The Colorado Nonpoint Source program allots grants of up to $25,000 per project to allow stakeholder groups to develop watershed plans outlining prioritized implementation of BMPs to restore and protect water quality. This is the funding which was granted to LWOG in September of 2003 to form the organization. Further funding up to $250,000 is available to stakeholder groups to implement their watershed plans for nonpoint source activities within §303(d) listed waters. The Colorado Nonpoint Source program requires a 40% non-federal funding match for §319 awards. Currently, only Little James Creek is listed under §303(d) and, therefore, this grant money would only be available to fund work in this portion of the watershed.

8.1.2 National Pollution Discharge Elimination System (NPDES)

Section 104(b)(3) of the Federal Clean Water Act authorizes the appropriation of monies for federal grants to promote innovative approaches to water pollution issues. Grants to state water pollution control agencies, interstate agencies, other public or nonprofit private agencies, institutions, organization, and individuals may apply for grants ranging from $10,000 to $500,000 for the purposes of conducting and coordinating "research, investigations, experiments, training, demonstrations, surveys, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of pollution (33 U.S.C. §104(a)(1), 1972)."

8.1.3 Brownfields

Enacted on January 11, 2002, the Small Business Liability Relief and Brownfields Revitalization Act (H.R. 2869) provides grants that enable stakeholders to work together to clean up and reuse brownfields. Public Law 107-118 defines a brownfield site as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant." The law includes "mine-scarred land" as an additional area to which the term brownfield applies. This act provides up to $200 million annually, through 2006, for grants related to site assessment or direct clean up, not to exceed $200,000 per site. The Peanut Mine, near Crested Butte, provides an example of Brownfields Revitalization Act funding for mine remediation in Colorado. This mine formerly extracted and processed coal and silver, leaving a legacy of petroleum and heavy metal contamination. In 2003, Peanut Mine, Inc. received a $200,000 brownfields cleanup grant. The final goals of this remediation project include the prevention of contamination to the Slate River, as well as diversification and stimulation of the local economy (EPA, 2003c). The Boulder County Parks and Open Space department is eligible for Brownfields funding for the Argo and Evening Star mine sites on Little James Creek.

8.1.4 Targeted Watershed Grants Program

The EPA Targeted Watershed Grants Program (TWGP), formerly known as the Watershed Initiative or the President's Watershed Initiative, was funded by Congressional appropriations of $21 million in both 2003 and 2004. The TWGP encourages comprehensive, community-oriented, watershed-based approaches to the protection and restoration of water resources. In particular, grants are given to "studies of approaches that go beyond implementing separate, detached activities and will, instead, focus on the effectiveness of an integrated ecosystem-based approach to conservation and restoration throughout a watershed (Federal Register, 2003a)." The competitive granting process requires project nomination from governors or tribal leaders, who are each entitled to nominate two state or tribal watersheds. According to the 2004 Call for Nominations (Federal Register, 2003a), watershed nominations are evaluated and scored based on the criteria of innovation, measurement of environmental results, broad support, outreach, and financial integrity. Grant awards range from $300,000 to $1,300,000, depending on the size and need of projects. A 2003 TWGP grant to the Green County Watershed Alliance to restore streams impacted by abandoned coal mines in the Dunkard

Creek watershed in Pennsylvania and Virginia provides an example of TWGP funds applied to mine drainage pollution (EPA, 2003d).

8.1.5 Ecosystem Protection Regional Geographic Initiative

Established in 1994 in an effort address environmental issues not covered by existing national programs, the EPA Regional Geographic Initiative (RGI) empowers each EPA Region to address unique environmental challenges by helping to integrate local efforts in the application of modern, multi-media approaches to human health and environmental risks. RGI emphasizes a “holistic environmental approach” and grassroots, stakeholder partnerships in decision making that addresses multi-dimensional environmental problems (EPA, 2003e). As outlined in the EPA Region 8 Project Proposal Guidance (EPA, 2003e), Region 8 distributes RGI funds to a diversity of projects that:

- Address problems that are multi-media in nature;
- Fill a critical program gap in the protection of human health and the environment;
- Address places, sectors;
- Demonstrate innovation;
- Demonstrate that they are based on a regional, state, tribal or other strategic plan; and
- Demonstrate state, local and/or other stakeholder participation.

Region 8 financial assistance ranges from $1,000 - $30,000, for projects of generally one or two years in duration. Examples of RGI-funded activities in Colorado include the Virginia Canyon Project near Clear Creek, which developed BMPs for slope stabilization and the reduction of mine waste erosion, as well as disseminated information to the Clear Creek community. The JCWI received an RGI grant to fund ecological assessment, monitoring, and public outreach (JCWI, 2000). In 2004, LWOG received an RGI grant of $20,000 to quantify, over varying flow conditions, the metal contributions of potential sources of significant water quality impairment. The resulting data will provide a complete picture of stream water quality, allowing the impact of multiple sites to be compared over a range of flow conditions.

8.1.6 Colorado Watershed Protection Fund

The 2002 Colorado General Assembly established the Colorado Watershed Protection Fund (CWPF) with the adoption of Senate Bill 02-087 (C.R.S. 02-087 §1, 2002). Financed by voluntary tax refund check-offs on Colorado individual tax forms, the CWPF provides money for a competitive grant program to help grassroots watershed protection groups restore and protect watersheds. The Colorado Water Conservation Board, in cooperation with the Colorado Water Quality Commission and the Colorado Watershed Assembly, will administer CWPF resources to support the planning and implementation of watershed restoration and protection projects (C.R.S. 02-087 §1, 2002). The maximum grant award for project planning grants is $25,000, while implementation of projects may be awarded up to $50,000. The CWPF grants require a 20% in-kind or cash match (CWPF, 2004). The initial year of CWPF funding included a grant to the JCWI for implementation of their Stream Corridor Restoration Plan using BMPs to reduce sediment loading into James Creek (CWPF, 2004).

8.1.7 EPA Community Action for a Renewed Environment (CARE) Grant

An EPA initiative, Community Action for a Renewed Environment (CARE), is designed to reduce local exposure to toxic pollution by establishing community-based and community-driven projects. The EPA provides technical assistance to stakeholder groups to identify and address local sources of toxic pollution (EPA, 2005).

8.1.8 Other Funding Sources

In addition to these opportunities for the funding of mine site remediation, the LWOG may encourage further actions by the USFS and Boulder County to continue the remediation of the many abandoned mine sites on publicly-owned lands. Moreover, the State of Colorado's VCUP provides an opportunity for economically stable private land owners to remediate mine sites and avoid future CERCLA liability (EPA, 1994).

9 Information and Education

In order to build effective partnerships within the watershed community, the goals and objectives adopted by LWOG include a commitment to maintain a source for water quality and watershed-related information for the public, and to foster open communication and cooperation among stakeholders.

9.1 Goals of Information/Education Activities

The LWOG Board of Directors anticipates formation of an Outreach Committee to facilitate information and education activities. The goals of these activities are:

- To identify and facilitate the remediation of sites that have a negative impact on the water quality of Lefthand Creek or its tributaries.
- To communicate water quality and watershed –related information for the public good.
- To build strong public and financial support among stakeholders to accomplish the goals and objectives of the LWOG.

9.2 Past and Ongoing Information/Education Activities

- *Newsletter* – The LWOG newsletter, Creek Connections, is published twice a year to update recipients about the latest happenings with LWOG and the Lefthand Creek watershed.
- *Website* – The LWOG website (www.lwog.org) includes watershed information, group information, an events calendar, and a page of links to watershed-related reports and websites. As the site improves, it will be even more useful as a hub of information for the entire watershed.
- *Information booths* – LWOG members have created and staffed an information booth at the Boulder Farmer's Market in 2004 (in partnership with the Boulder Creek Watershed Initiative) and at the annual Jim Creek Fest in Jamestown in 2003 and 2004. The booth consists of a photo board showing images of the watershed and people engaged in water quality monitoring activities. Additionally, numerous handouts including LWOG newsletters, watershed informational sheets, and children's activities are freely available, and passers-by are encouraged to sign-up to be added to the LWOG mailing and emailing lists.
- *Presentations* – In 2004, LWOG members developed a twenty-minute presentation that highlights the water quality concerns in the watershed, the goals and activities of LWOG, and the resource needs of the group. To date, this presentation has been shared with the Board of the Lefthand-St. Vrain Water Conservancy District, and the Board of the Left Hand Water District.
- Community meetings – An open, community meeting was held on March 22, 2003. Presenters from the CDPHE and EPA presented watershed-related information to a small but interested crowd of approximately 25 persons at the Tahosa Boy Scout Camp near Ward. This meeting was a

collaborative effort between the EPA, CDPHE, and LWOG, and focused on public questions and feedback about watershed issues. A second community meeting took place on June 27, 2005. The purpose of the meeting was to inform interested community members about various watershed activities, especially the Captain Jack Superfund cleanup. Approximately 40 people attended this meeting. Another community watershed meeting is being planned for this fall.

9.3 Planned Information/Education Activities

Currently, no specific education and outreach activities are planned. LWOG intends to begin developing a program in the spring of 2006.

10 Watershed Management Measures

10.1 Action Items

In order to make progress towards the watershed management needs outlined in this plan, as well as towards the fulfillment of LWOG's Mission and Objectives, the following Action Items have been identified as vital projects for LWOG.

1. *Organization Strategic Plan.* Develop and implement a plan to obtain enough funding to maintain LWOG as a sustainable, functioning organization for the next 10 years. Necessary funding must cover the costs of a part-time watershed group coordinator and basic group overhead expenses. This basic organization-maintenance funding should then be leveraged to find larger grant and other monies needed to complete watershed projects.
2. *Outreach and Education.* Develop and implement a dynamic outreach and education program geared towards the Lefthand Creek watershed community.
3. *Watershed Monitoring Plan.* Develop and implement a comprehensive, volunteer-based watershed monitoring plan. This monitoring plan will involve continued cooperation with CDPHE and EPA to maintain and expand a database of all available Lefthand Creek watershed data.
4. *Continued Site Characterization.* Develop and implement a plan to continue site characterization in an effort to fill in data gaps regarding the sources, magnitude, and nature of metal loading sources within the Lefthand Creek watershed.
5. *Liability Education.* Specifically identify LWOG group members' concerns regarding potential liability risks associated with mine site reclamation, become familiar with the actual liability risks, learn how similar watershed groups have avoided these risks, and develop an agreed-upon set of criteria for reclamation projects that LWOG might seek funding to address.
6. *Restoration Plan Development.* Define opportunities for LWOG in collaboration with other concerned agencies or residents to address high-priority mining-related sites in the watershed and develop site-specific, engineered restoration plans and costs estimates. Following preparation of these plans, large funding sources should be pursued to enable LWOG or other entity to implement the planned restoration activities.
7. *Watershed Plan Updates.* Continue to refine this Watershed Management Plan with updated water quality data, watershed ecological needs, and LWOG management goals.

10.2 Milestones and Schedule

A milestone chart (Table 11) has been developed to guide the schedules and completion of the Action Items identified in Section 10.1.

11 Evaluation

Evaluation of water quality and watershed management strategies is essential to determine whether progress is being made towards attaining water quality standards and meeting the objectives of LWOG and this Watershed Plan. Management evaluation strategies, discussed in Section 11.1, provide a mechanism to examine the effectiveness of implemented management measures. Changes in water quality are the ultimate measure of management efficacy; Section 11.2 presents the fundamental elements of a water quality monitoring plan that will enable LWOG to evaluate water quality changes over time.

11.1 Watershed Management Evaluation Criteria

As described in Section 1.2.3, Watershed Plan Updates, this Watershed Plan is intended to be a working document. Qualitative information—including reports on the successes and failures of outreach, characterization, reclamation, and water quality monitoring efforts—will be added as it becomes available and will be used to evaluate the effectiveness of watershed management activities. Such general information will be used in conjunction with quantitative data, collected as described in the following section, to adjust management plans as necessary.

11.2 Water Quality Monitoring Plan

A regular, scientifically sound water quality monitoring plan is an essential component to the observation of water quality changes and, in turn, to the evaluation of the watershed management decisions and environmental alterations that cause those changes. To date, data collection efforts in the watershed have focused on compiling a thorough set of baseline water quality data, but regular water quality monitoring guidelines have not been established. As outlined in Section 10.1, Action Item 3, over the next year LWOG will work with stakeholders, partner organizations and agencies to develop and initiate a water quality monitoring plan. In their *Framework for Water Quality Monitoring* (NWQMC, 2004), the National Water Quality Monitoring Council identifies six important and interrelated features of monitoring: develop monitoring objectives; design a monitoring program; collect field and lab data; compile and manage data; assess and interpret data; and convey results and findings. An effective monitoring plan will identify specific monitoring objectives and requires the regular collection and analysis of water samples from key locations throughout the watershed. In addition, LWOG water quality monitoring should complement, rather than replicate, monitoring work which JCWI has conducted on a monthly basis for the past several years.

11.2.1 Monitoring Parameters

This Watershed Plan identifies acidity and metal loading as known water quality degradation factors. Sediment and nutrient loading, as well as road salting are identified issues which require further characterization through data collection. Therefore, monitoring parameters should provide data related to these water quality concerns. Regular water sample analysis should include the following parameters:

- *Field parameters* – temperature, stream flow, dissolved oxygen, pH, conductivity, turbidity.
- *Laboratory parameters* – total and dissolved metals, total phosphorus (TP), total suspended solids (TSS), dissolved organic carbon (DOC), hardness.

As time, funding, and volunteer support allow, additional monitoring parameters might include

- *Physical habitat parameters* – particle size analysis, habitat assessment, pebble counts.
- *Biological parameters* – benthic macroinvertebrates (species composition and tissue analysis for metals.

11.2.2 Monitoring Locations

In order to gain a spatially comprehensive understanding of water quality changes over time, monitoring locations must be located throughout the watershed and sampled frequently. However, due to limited funding and time availability of LWOG volunteers, LWOG will likely be able to maintain only a few monitoring stations at regular intervals. Important sampling locations are indicated on Figure 14 and include the following areas:

1. *Reference location* – At least one pristine reference location that is situated well upstream of any known water quality degradation. University of Colorado and EPA researchers have utilized a sampling point on Lefthand Creek just upstream of Highway 72 for this purpose. One reference location may be used for the entire watershed; however, if funding and volunteer capacity allows, reference locations specific to each Lefthand, James, and Little James creeks may be added.
2. *Lefthand Creek at Sawmill Road* – This point is located at the downstream end of the Captain Jack Mine and Mill Superfund site, and captures impacts related to contaminant sources within the Superfund site boundary.
3. *Lefthand Creek upstream of James Creek inflow* – This site encompasses all upstream impacts to water quality from the upper reach of Lefthand Creek.
4. *James Creek upstream of confluence with Lefthand Creek* – This site encompasses all upstream impacts to water quality from Little James and James creeks.
5. *Little James Creek upstream of confluence with James Creek* – This site encompasses all upstream impacts to water quality from Little James Creek.
6. *Lefthand Creek downstream of the Lefthand OHV area* – This site encompasses all upstream impacts to water quality from Little James, James, and upper Lefthand creeks.
7. *Haldi intake* – The Haldi intake diverts water from the Lefthand Creek to storage and treatment facilities operated by the LHWD. This point encompasses all upstream impacts to water quality, and represents the quality of water that goes into the treatment system for the 18,000 LHWD customers.

11.2.3 Monitoring Frequency

In addition to locating sampling stations at key locations throughout the watershed, these stations must be sampled at logical intervals. Stream flow regimes greatly influence concentrations of metals and other contaminants in streams. For example, spring snowmelt delivers large volumes of clean water to streams and may dilute contaminant concentrations. Alternatively, during base flow the lack of dilution by clean water sources may lead to very high concentrations of contaminants in the streams. Groundwater levels, mine adit flows, and thunderstorm seasons are other factors to consider when determining monitoring frequency. Sampling each monitoring locations once monthly would provide water quality data over a wide range of conditions. If once-monthly sampling is too much based on the resources available, samples should be collected at least once per season (summer, fall, winter, and spring) at each monitoring location.

12 Conclusions

Key findings and recommendations of this plan include:

1. Stakeholders, agencies, governments, and local organizations and businesses have collaborated to characterize the Lefthand Creek watershed. This atmosphere of teamwork sets the stage for future collaborative efforts for further characterization and reclamation.

2. Initial data collection efforts have allowed for the creation of a baseline metal concentration and loadings dataset. Data collection efforts conducted in 2004 will soon be available to add to this initial dataset.

3. More characterization is necessary for metals contamination and other potential watershed issues.

4. Initial data has been used to rank mine sites according to reclamation priority. Some work is already underway at some of these sites.

5. BMPS do exist that will allow for effective reclamation efforts that will lead to loading reductions.

6. Funding sources alternative to Superfund do exist; LWOG and other organizations may pursue these funding opportunities to help pay for further watershed characterization, education and outreach, and reclamation efforts.

7. LWOG has a maturing information/education program which the organization will continue to emphasize and expand.

8. LWOG has developed a list of Action Items to pursue in an effort towards reaching the objectives of the group and management of watershed activities.

9. The watershed management measures will be evaluated in order to determine their efficacy and will be adjusted in order to make the most of past experiences.

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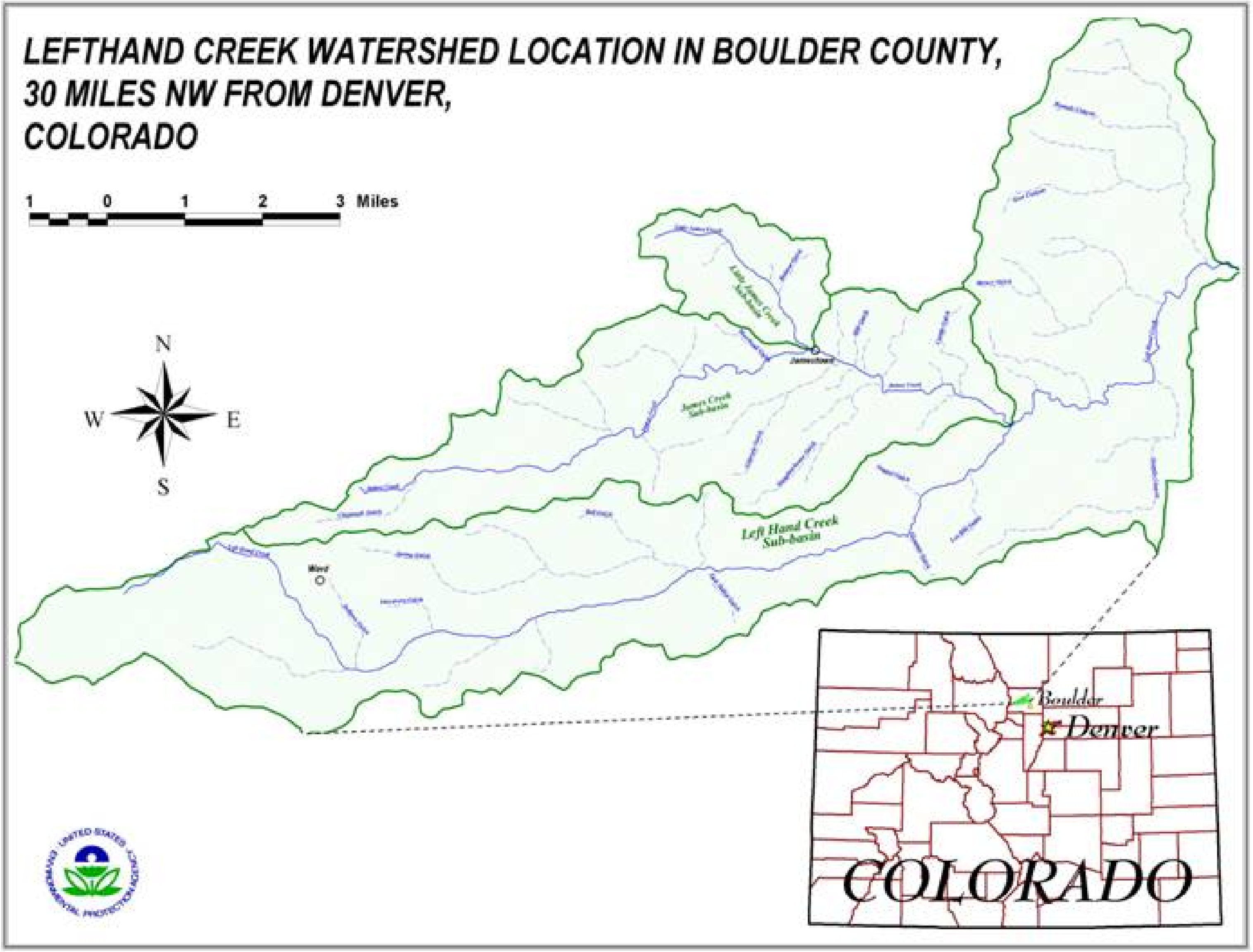


Figure 1. Location. Source: EPA Region 8 – used with permission.

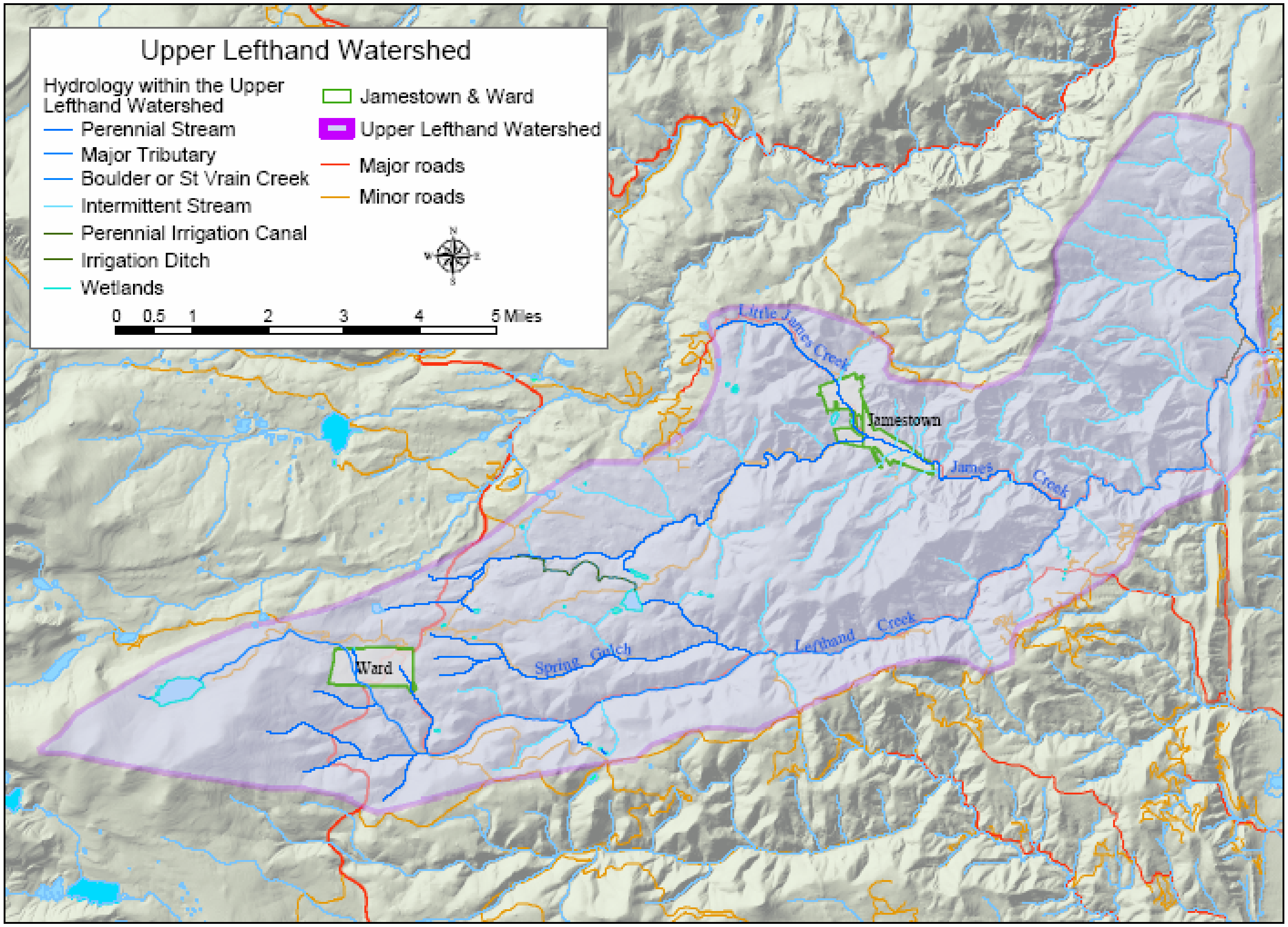


Figure 2. Upper Lefthand Creek watershed.

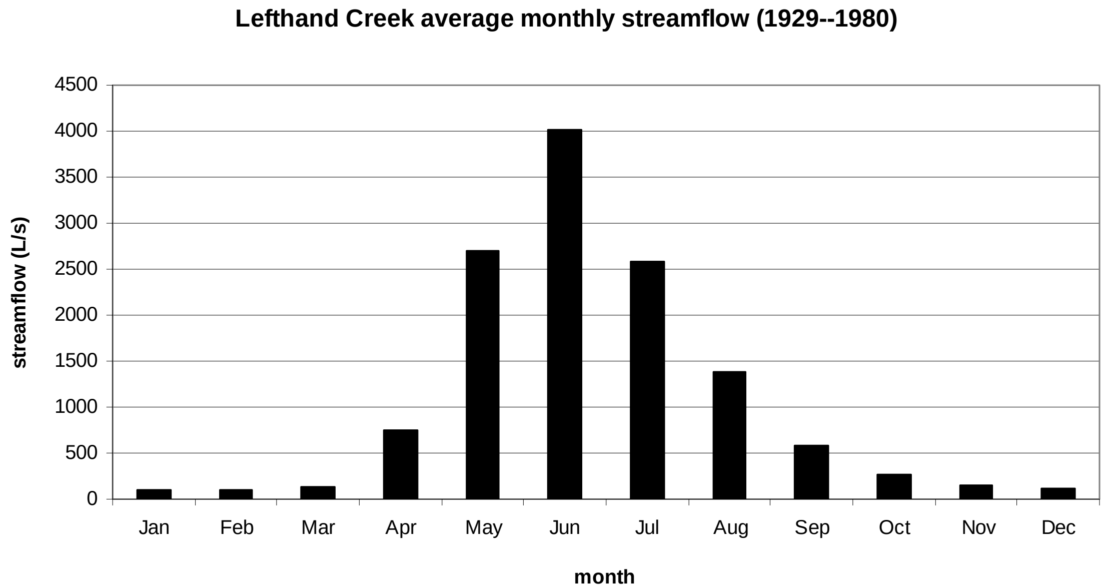


Figure 3. Lefthand Creek average monthly streamflow from 1929—1980, as recorded at a USGS staff gage west of Highway 36.

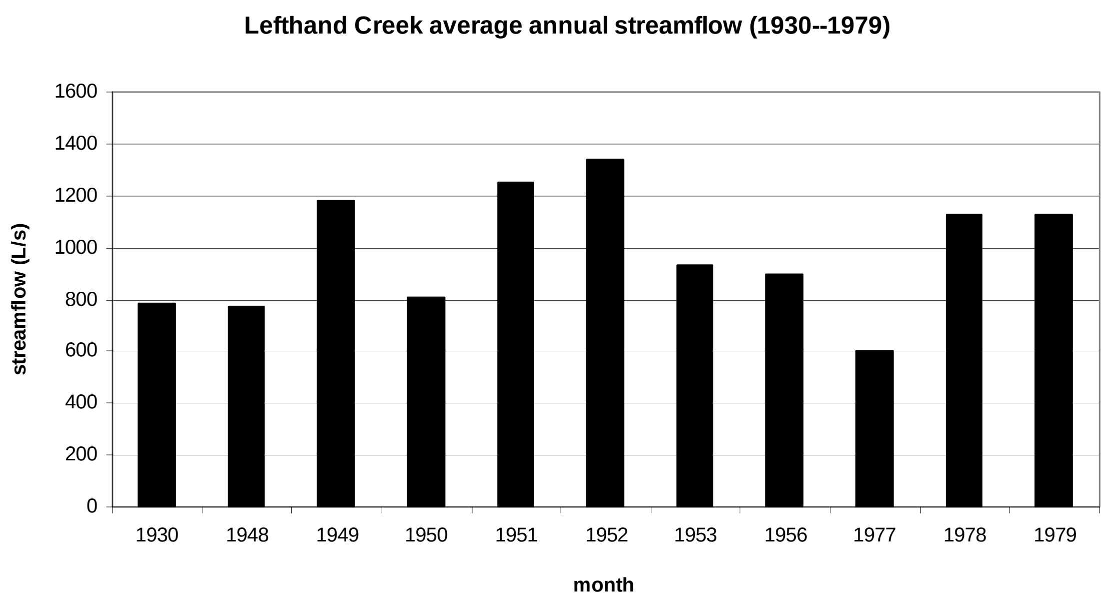


Figure 4. Lefthand Creek average annual streamflow from 1929—1980, as recorded at a USGS staff gage west of Highway 36.

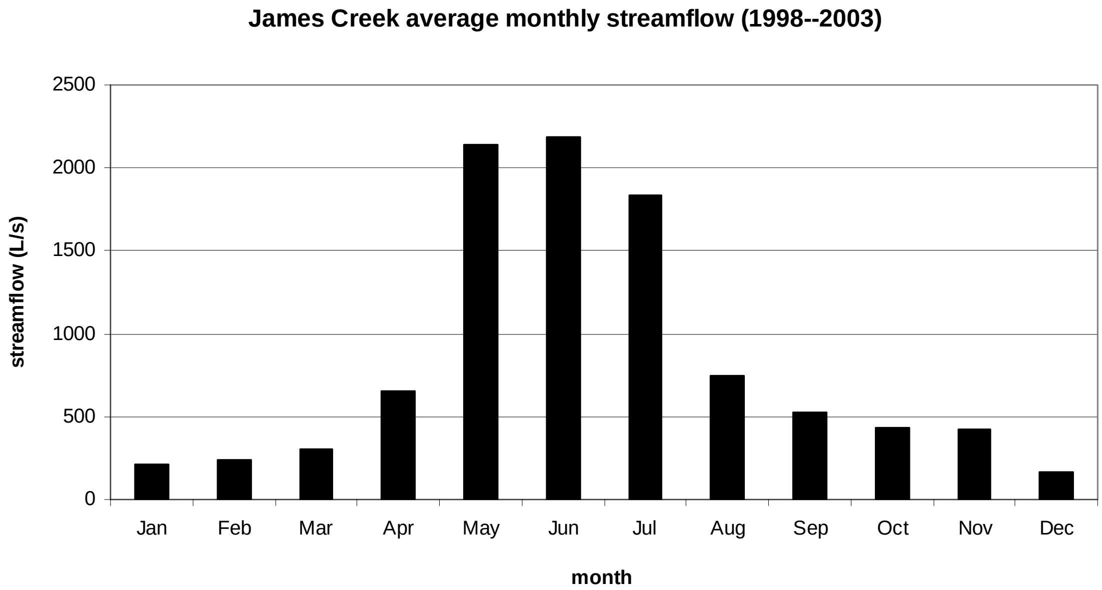


Figure 5. James Creek average monthly stream flow values as recorded by the James Creek Watershed Initiative at a staff gage in Jamestown.

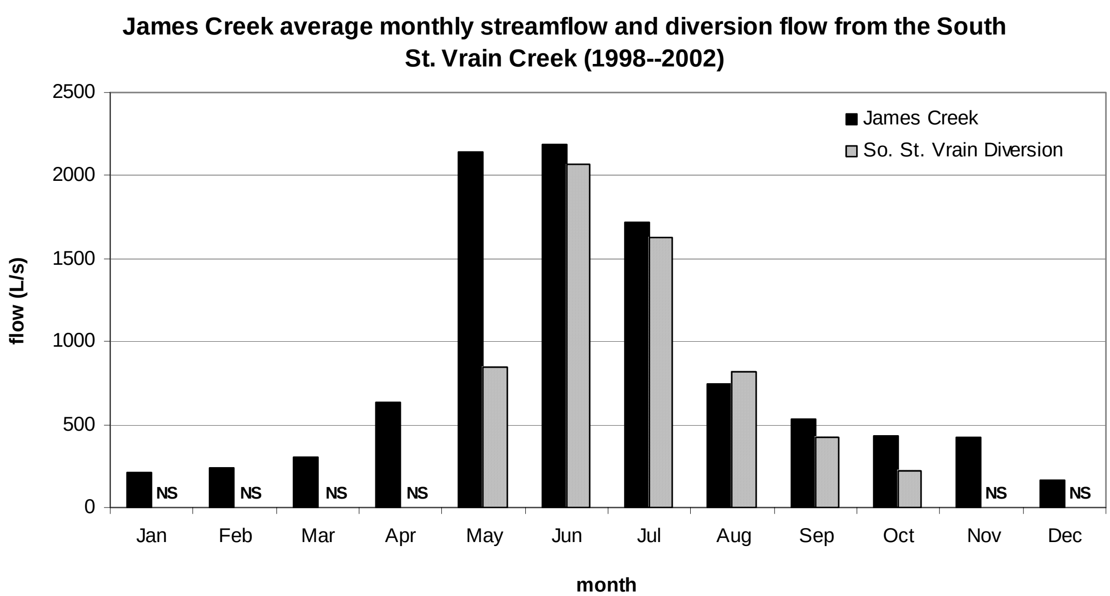


Figure 6. Vrain Creek. James Creek flow measurements were collected once each month, while South St. Vrain Creek diversion flow measurements were collected daily from late May to September 30 each year. These different data collection practices may account for circumstances where diversion flows are greater than the flow in James Creek itself. "NS" identifies months which were not sampled.

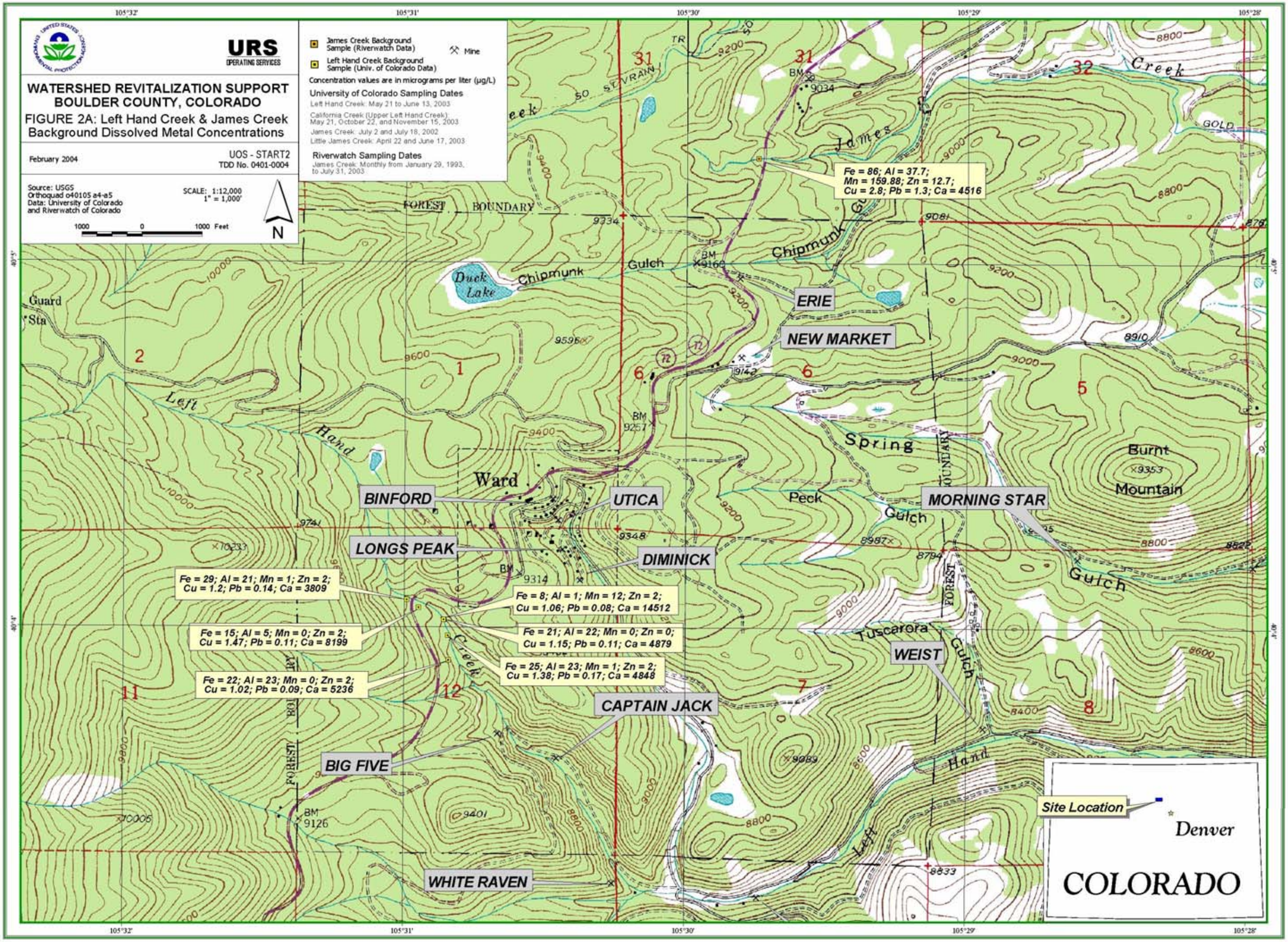


Figure 7. Lefthand and James Creek background sampling locations and average concentrations. Figure source: EPA Region 8—used with permission.

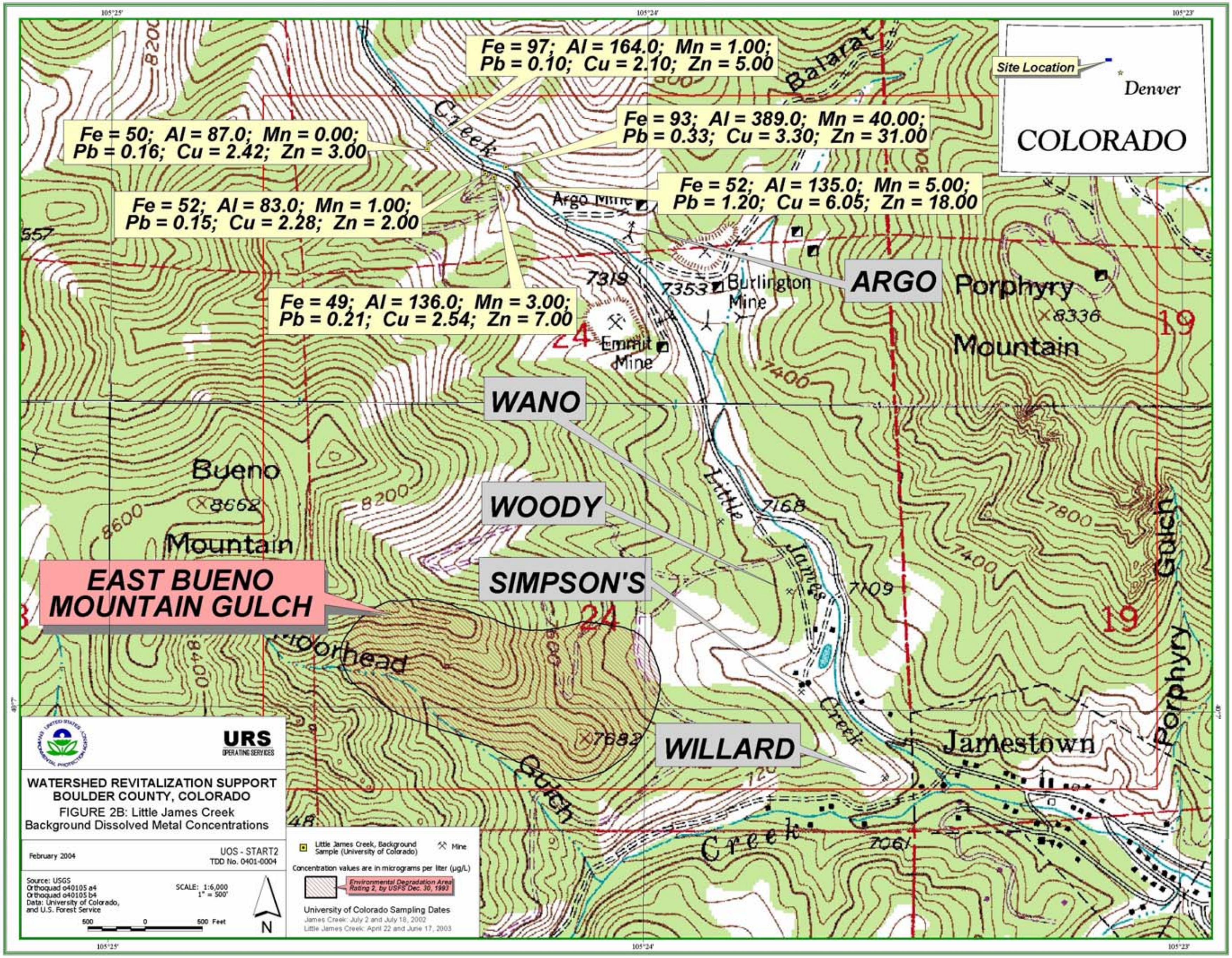


Figure 8. Little James Creek background sampling locations and average metal concentrations. Figure source: EPA Region 8—used with permission.

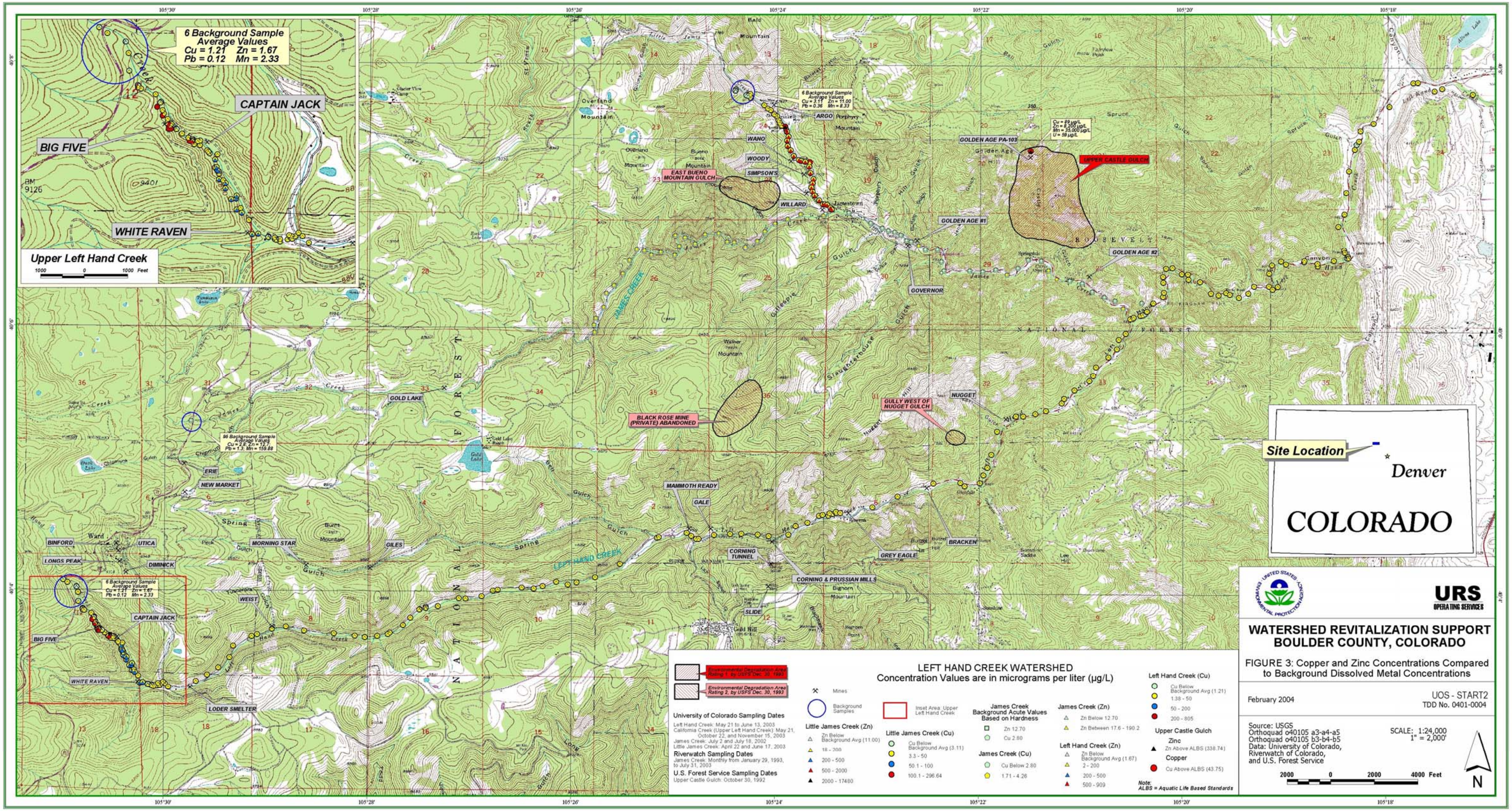


Figure 9. Lefthand Creek watershed zinc and copper concentrations as compared to background levels. Figure source: EPA Region 8—used with permission.

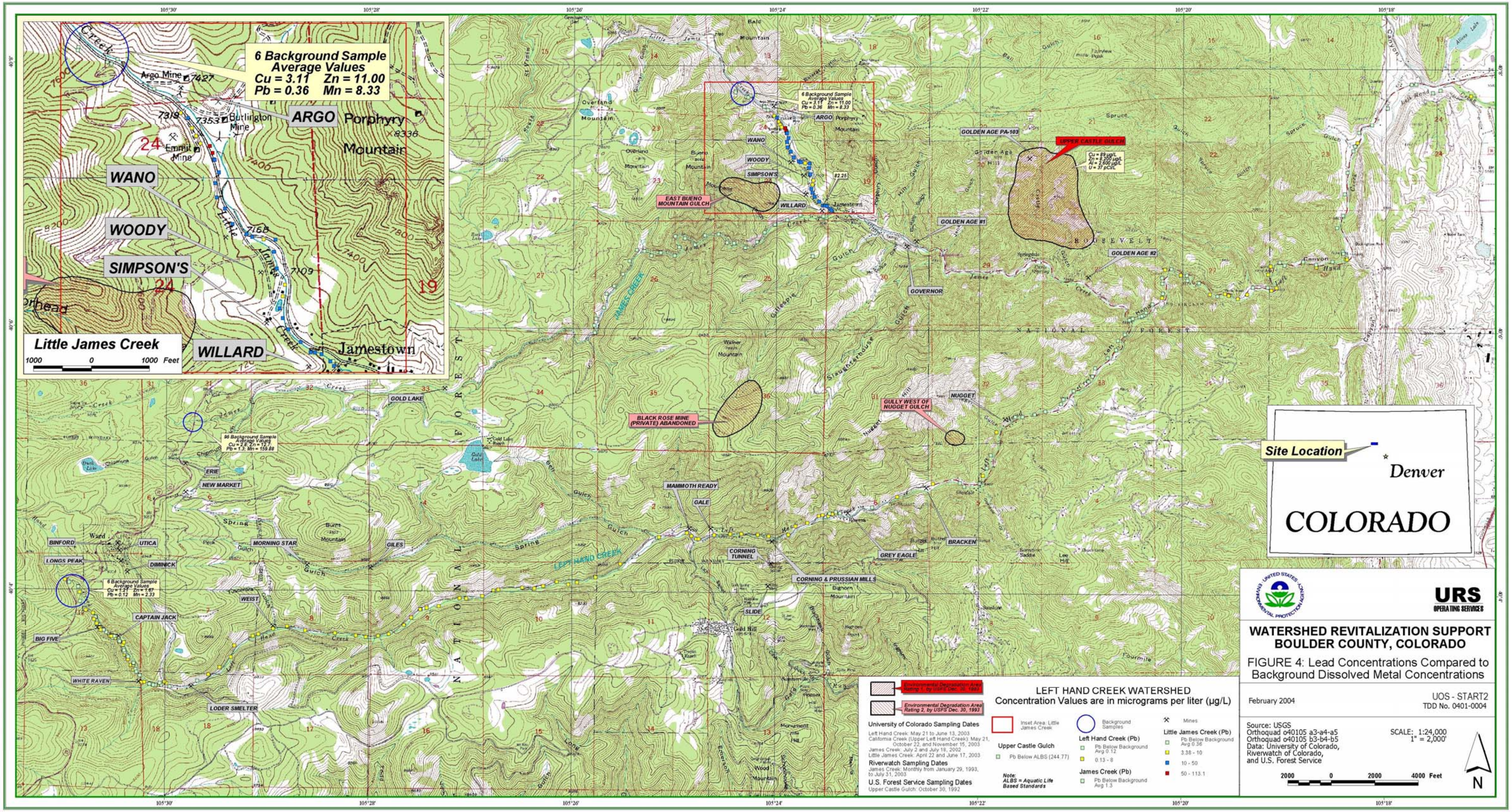


Figure 10. Lefthand Creek watershed lead concentrations as compared to background levels. Figure source: EPA Region 8—used with permission.

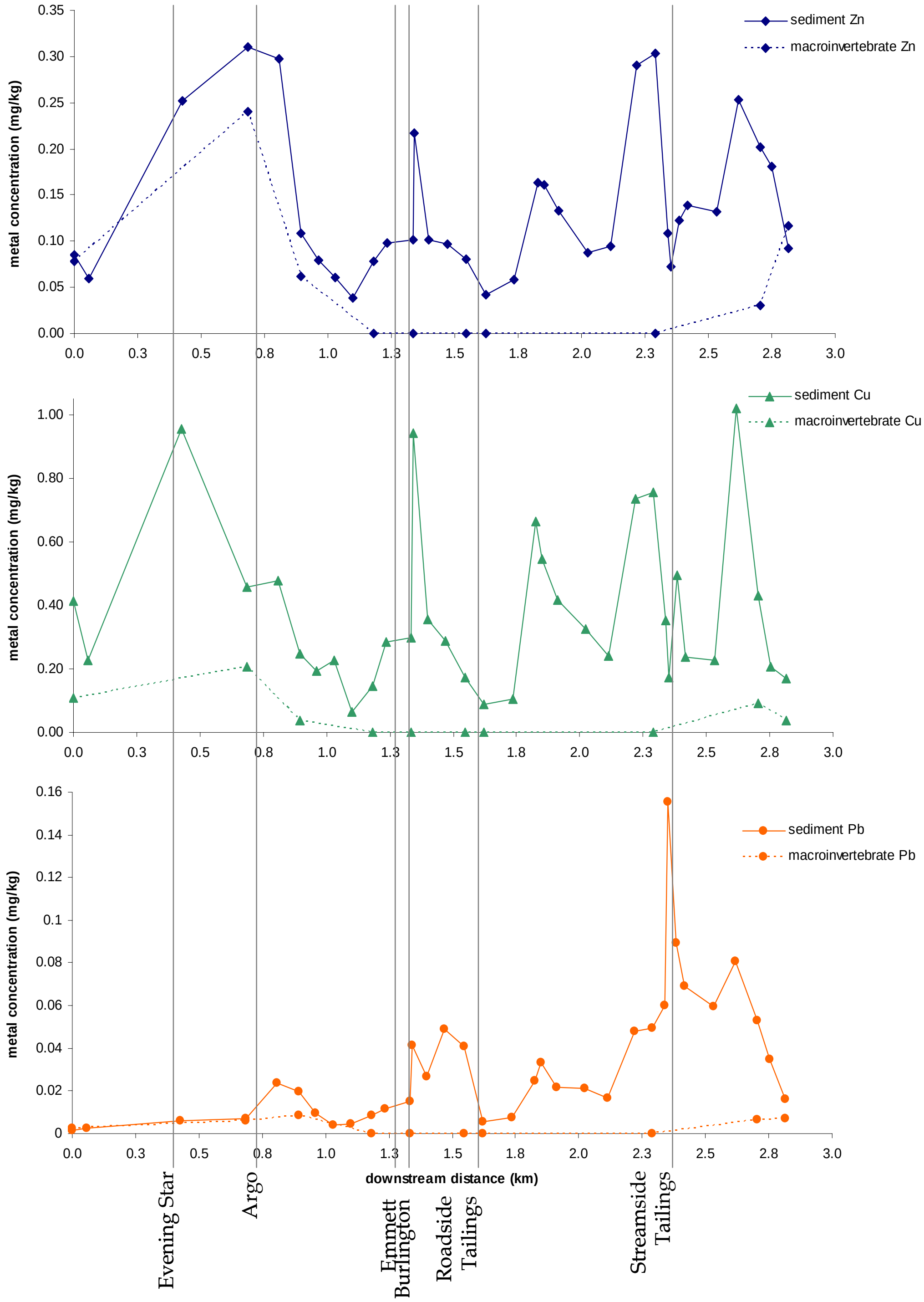


Figure 11. Little James Creek zinc, copper, and lead metal concentrations found in stream bed sediment and macroinvertebrate body tissues. Macroinvertebrate metals concentration are reported as 0 mg/kg where no macroinvertebrates were found in the stream. These sites indicate locations where habitat is unfavorable, perhaps due to high metal concentrations, for survival of aquatic life. Studies were conducted by the University of Colorado in 2003 and 2004.

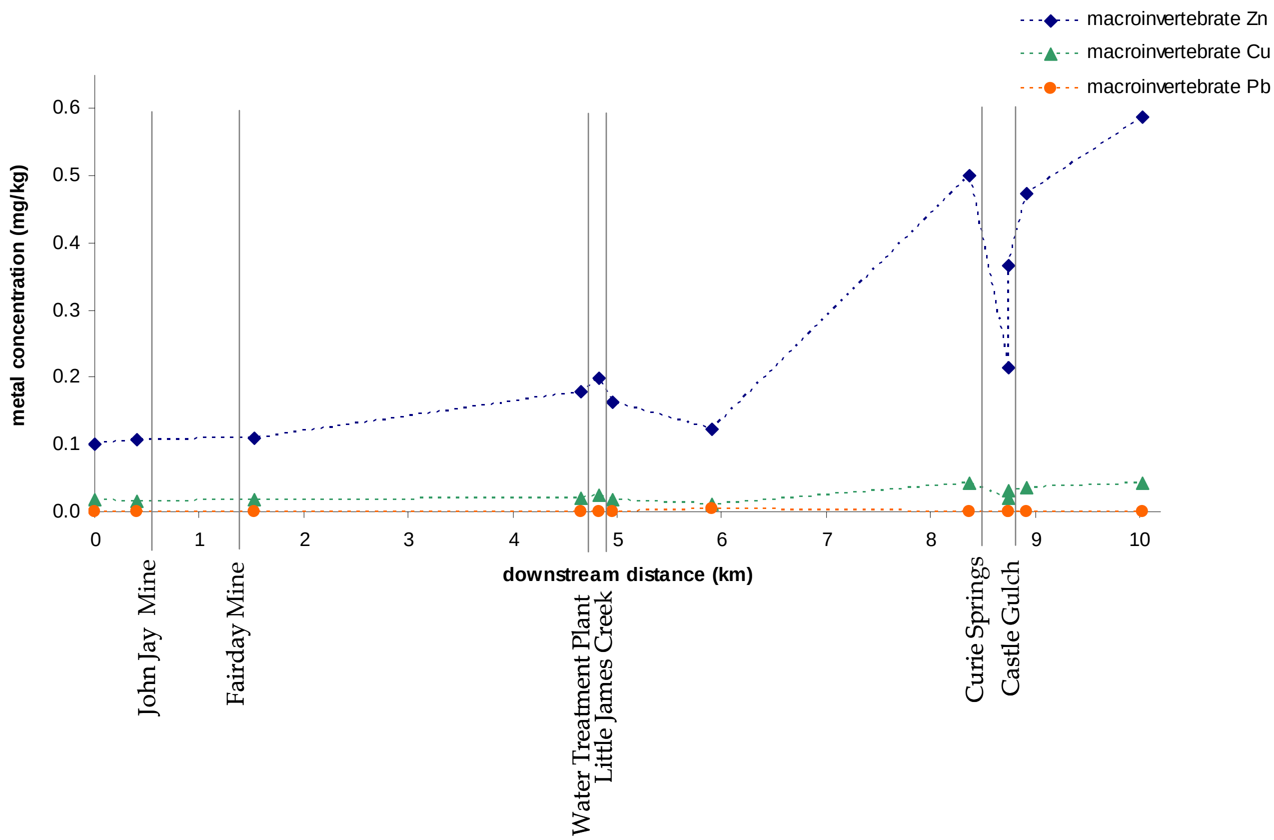
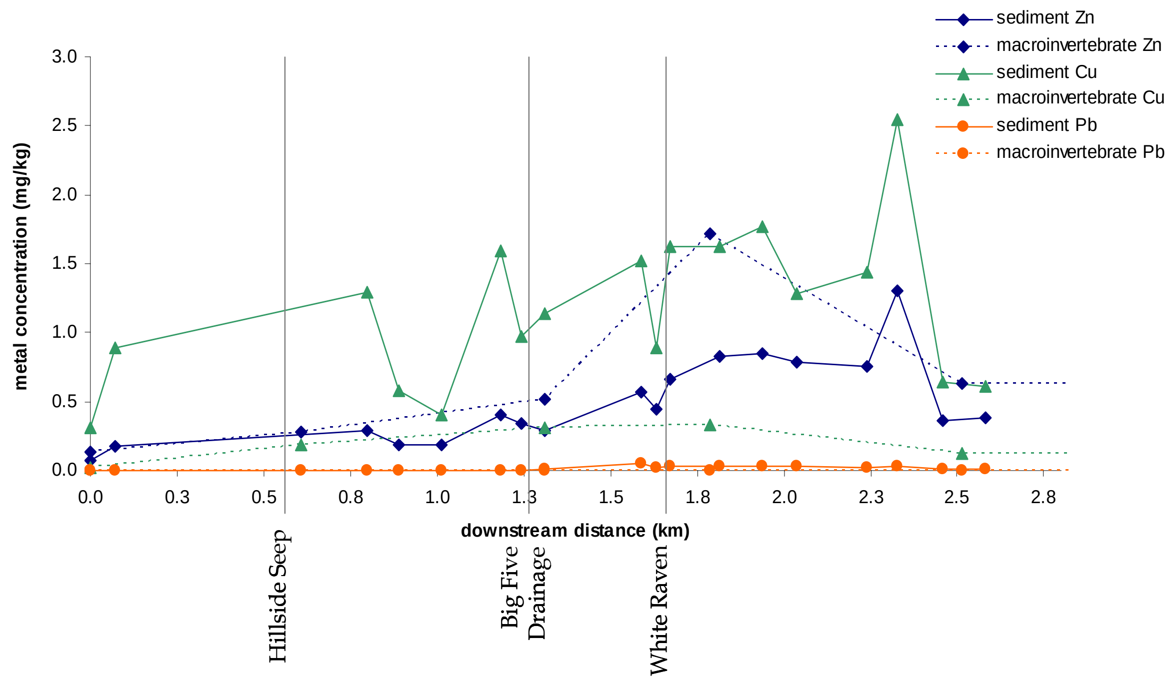


Figure 12. Macroinvertebrate body tissue metal concentrations for James Creek from the reference site at the creek crossing of County Road 102J to the confluence with Lefthand Creek. Macroinvertebrate analysis was conducted by the University of Colorado in 2004. Sediment data is not available for James Creek.



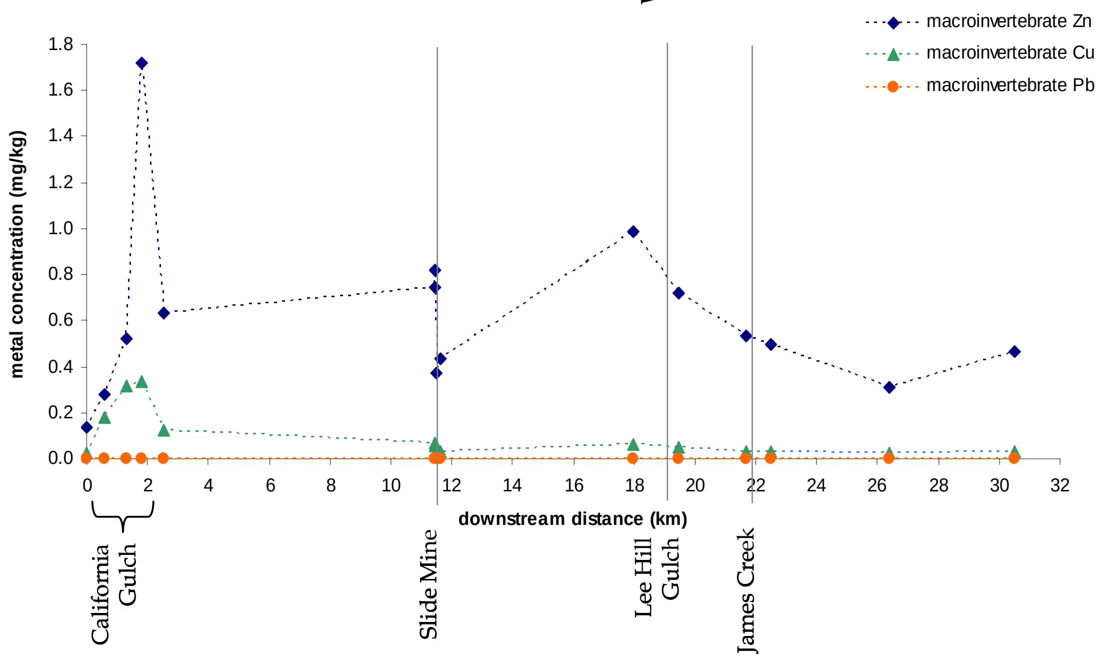


Figure 13. (a) Sediment and macroinvertebrate body tissue metal concentrations for the California Gulch reach of Lefthand Creek, which includes the Captain Jack Mine and Mill Superfund Site. (b) Macroinvertebrate body tissue metal concentrations for Lefthand Creek from the Peak-to-Peak Hwy to Hwy 36. Studies were conducted by the University of Colorado in 2003 and 2004.

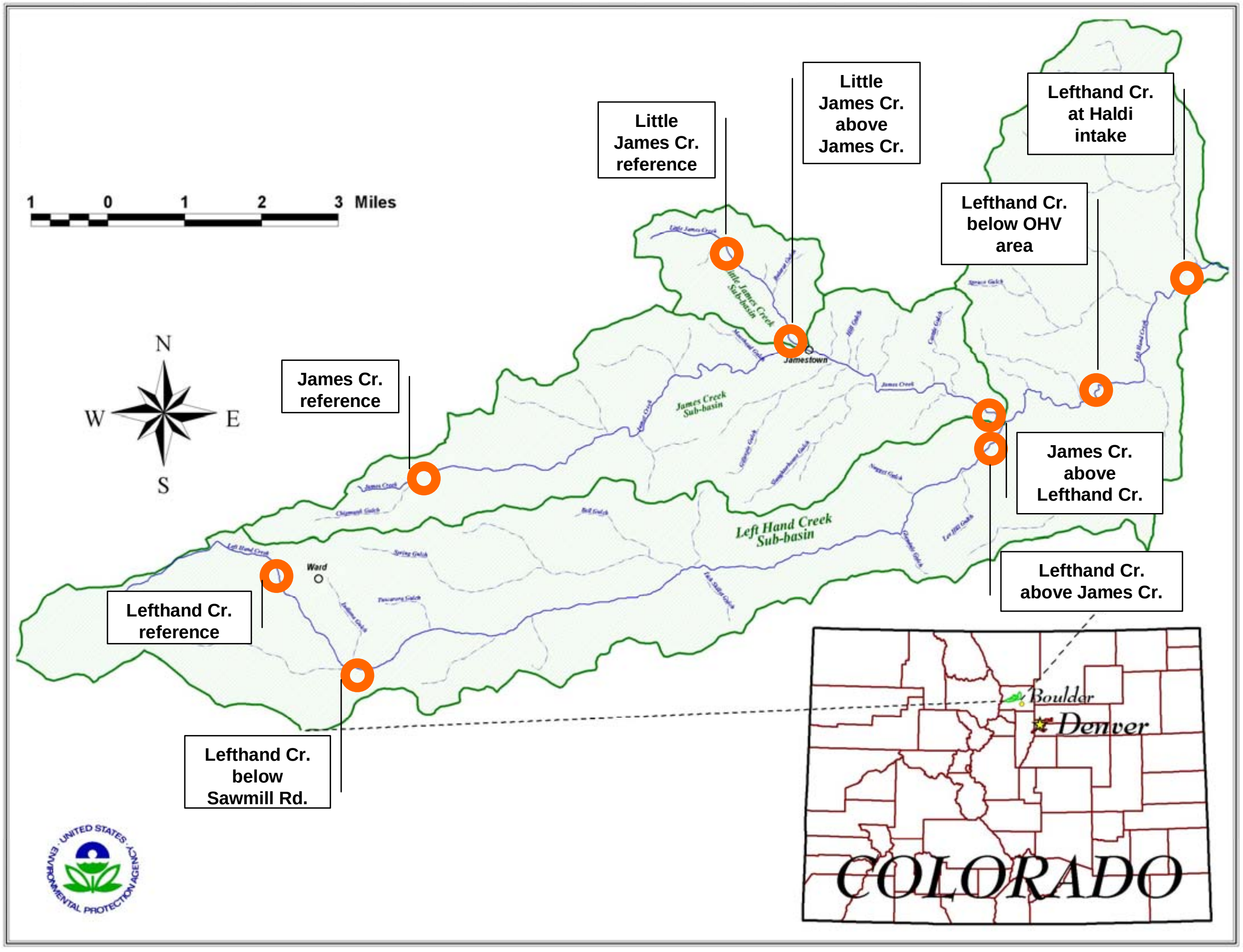


Figure 14. Proposed monitoring locations (overlaid onto map created by the EPA – used with permission).

Table 1. Current and prospective LWOG partner organizations and resources.

Organization Name	Key Areas that this Organization May Assist LWOG	Currently an LWOG Partner?	Contact Information
Federal Agencies			
US EPA Region VIII	Funding for specific projects, TAG grants, community outreach, restoration, education	Yes	(303) 312-6312
US Forest Service	Board member, data, technical advise	Yes	(303) 541-2500
Army Corps of Engineers	Will need to review any "waters of the US restoration projects"	No	http://www.usace.army.mil/
State Agencies			
CDPHE	Regulate water quality, technical assistance, grants, assistance in review, organization, work with domestic water providers	Yes	Bill McKee (303) 692-3583
CO Division of Minerals and Geology	Technical assistance, grant assistance, education	Yes	Julie Annear (303) 866-3687
Local Government			
Boulder Co. Parks and Open Space	Board member, legal assistance, public relations	Yes	(303) 441-3950
Boulder County Health Department	Technical assistance, local water quality regulation and enforcement	Yes	Mark Williams (303) 441-1100
BASIN	Outreach, information, events	No	http://bcn.boulder.co.us/basin/
Local Organizations			
James Creek Watershed Initiative	Cooperative opportunities, board member, experience and expertise	Yes	Colleen Williams (303) 449-2126
Boulder Creek Watershed Initiative	Events, volunteers, outreach	No	P.O. Box 18, Boulder CO, 80306
Trout Unlimited (local branch)	Volunteers, on-the-ground reports	No	Dave Nickum (303) 440-2937

Left Hand Water District	Corporate headquarters for organization, funding for operations, board member	Yes	Kathy Peterson (303) 530-4200
Left Hand Ditch Company	Water rights ownership within the watershed, operational assistance in controlling flows, accessing sites for testing	No	PO Box 582, Berthound, CO, 80513
Other Organizations			
University of Colorado	Technical assistance, labor, data collection and analysis, cooperative ventures, expertise, grant funding	Yes	Joe Ryan (303) 492-0772
Colorado Watershed Assembly	Networking, outreach	Yes	(970) 484-3678
National Water Quality Monitoring Council	Partnership, national coordination	No	http://water.usgs.gov/wicp/acwi/monitoring/

Table 2. Overview of mining-related water quality data, sources, and availability of data for the Lefthand Creek watershed.

Lead Research Entity	Study Area	Dates of Study	Approximate Number of Samples Collected	Availability of Data	Brief Description of Study
URS/EPA	Upper Lefthand Creek, mid-Lefhand Creek, Little James Creek	2005	Unknown	EPA Start Reports	Site assessments of the Captain Jack, Burlington, and Slide Mine areas
University of Colorado	James Creek	2002	63	Wood et al., 2004; Wood, 2004	Tracer tests and synoptic sampling of surface water (low flow)
University of Colorado	Lefthand Creek, James Creek, Little James Creek	March—November, 2003	300	Wood et al., 2004; Wood, 2004	Tracer tests and synoptic sampling of surface water (both high and low streamflow conditions for some stream reaches)
University of Colorado	Upper Lefthand Creek, Little James Creek	March—November, 2003	43	Wood et al., 2004; Wood, 2004	One-time analysis of metals in streambed sediments
University of Colorado	Lefthand Creek, James Creek, Little James Creek	March, April, and September, 2004	146	Unpublished (expected summer 2005)	Tracer tests and synoptic sampling of surface water during high spring flow conditions
EPA	Lefthand Creek, James Creek, Little James Creek	May and November, 2004	105	Unpublished (expected summer 2005)	Analysis of surface water metals during high and low streamflow conditions.
SeaCrest	Lefthand Creek, James Creek, Little James Creek	May—November, 2004	20 sites/7 sampling periods	Unpublished (expected summer 2005)	Monthly analysis of surface water toxicity to aquatic organisms.
EPA	Lefthand Creek, James Creek, Little James Creek	June, 2004	70	Unpublished (expected summer 2005)	One-time community analysis of benthic macroinvertebrates; rapid bioassessment protocol survey of riparian habitat
University of Colorado	Lefthand Creek, James Creek, Little James Creek	June, 2004	50	Bryenton, D., Wood, A.R., and Ryan, J.N., 2004. Unpublished data.	One-time analysis of metals in body tissues of benthic macroinvertebrates
EPA	Lefthand Creek, James Creek, Little James Creek	June and July, 2004	19	Unpublished (expected summer 2005)	One-time analysis of mine waste rock pile metal and acidity
University of Colorado	Lefthand Creek, James Creek, Little James Creek	Februrary and March, 2005	18	Unpublished (expected summer 2005)	One-time analysis of mine waste rock pile metal and acidity

Table 3. Cumulative total metal loading contributions to Lefthand Creek.

Source	Distance (km)	Stream flow (%)	Fe (%)	Al (%)	Mn (%)	Zn (%)	Cu (%)	Pb (%)
"Dew Drop mine" tributary and seep	0.61—0.68	1.1	< 1	< 1	< 1	1.2	< 1	< 1
Big Five Mine Tunnel	1.18—1.29	< 1	< 1	1.6	5.5	4.7	7.7	< 1
White Raven mine	1.55—1.71	< 1	< 1	< 1	< 1	6.7	< 1	< 1
Unnamed mine opening	1.99—2.19	< 1	< 1	< 1	< 1	< 1	2.22	1
Puzzler Gulch	2.24—2.38	1.3	< 1	< 1	< 1	< 1	< 1	< 1
Indiana Gulch	2.38—2.42	2	< 1	< 1	< 1	< 1	< 1	< 1
Loder smelter	2.66—3.21	< 1	< 1	< 1	1	1.3	1.3	1.6
Tuscarora Gulch	4.35—4.84	2.1	3.2	3.3	6.9	3.2	7.4	11.8
Unidentified source	4.84—5.12	1.8	< 1	1.7	2.9	3	11.5	2
Unnamed tributary	6.98—7.19	< 1	7.1	6.7	6.3	12.3	11.9	9.6
Unidentified source	8.48—8.96	5.8	5.9	5.6	6.9	7.7	9.5	8.4
Spring Gulch	10.64—11.43	6.5	1.8	2.3	1.5	1.7	2.2	2.8
Reedy mine and Lick Skillet gulch	11.90—12.07	< 1	1.6	1	3.1	< 1	1.4	1.3
Prussian mine waste pile	12.60—13.01	< 1	2.7	2.7	4.1	2	2.2	3.5
Slide mine	13.16—13.50	2.4	1.2	1.6	< 1	< 1	< 1	< 1
"Lee Hill" gulch	19.25—19.48	1.5	1.5	17.8	21.1	12.9	8.3	16.1
James Creek	21.22—21.37	20.5	7.9	3.2	< 1	< 1	< 1	< 1
Carnage Canyon gulch	24.14—24.31	1.7	4.3	2.9	< 1	1	< 1	1.4
Sixmile Creek	26.09—26.39	< 1	< 1	< 1	< 1	< 1	< 1	< 1
TOTAL	---------	46.7	37.2	50.4	59.3	57.7	65.6	59.5

Note: Metal loads based on metal loading tracer tests conducted by the University of Colorado from May 21 to June 12, 2003.

[1] Distance refers to distance downstream of reference sample site. For Lefthand Creek, the reference sample site was located at the Highway 72 near the town of Ward.

Table 4. Cumulative total metal loading contributions to James Creek.

Source	Distance (km)	Stream flow (%)	Fe (%)	Al (%)	Mn (%)	Zn (%)	Cu (%)	Pb (%)	U (%)
John Jay mine	0.40—0.73	3.7	2	1.5	1.5	6.1	1.6	< 1	< 1
Fairday mine	1.34—1.71	7.8	5.1	5.8	3.1	5.6	35.5	13.3	7.4
Unidentified source	2.62—2.80	< 1	2.8	2.1	4.1	28.8	< 1	< 1	2.5
Unidentified source	3.7—4.1	12.5	6.4	7.1	4.9	12.8	4.4	8.3	9.2
Bueno Mountain	4.27—4.82	11.6	56.1	26.6	42.9	16.6	22.5	53	45
Little James Creek	4.82—4.96	12.6	28.9	12.4	11.4	< 1	3.4	< 1	14.6
Castle Gulch	8.74—8.92	3.4	7.2	2.1	2.2	< 1	< 1	< 1	1.2
Unidentified source	9.29—9.47	< 1	9.5	4.3	5.3	< 1	1.2	2.5	5.3
TOTAL	-------	51.6	118	61.9	75.4	69.9	68.6	77.1	85.2

Note: Metal loads based on metal loading tracer tests conducted by the University of Colorado on July 2 and July 8, 2002.

[1] Distance refers to distance downstream of reference sample site. For James Creek, the reference sample site was located at the upper creek crossing on County Road 102J, approximately 10 km upstream of the confluence with Lefthand Creek.

Table 5. Cumulative total metal loading contributions to Little James Creek under high and low stream flow conditions.

Source	Distance (km)	April Fe (%)	June Fe (%)	April Al (%)	June Al (%)	April Mn (%)	June Mn (%)	April Zn (%)	June Zn (%)	April Cu (%)	June Cu (%)	April Pb (%)	June Pb (%)
Evening Star Mine	0.37—0.64	6.8	--	3.1	--	< 1	--	2.3	--	5.4	--	1	--
Argo Mine gully	0.77—0.89	4.9	2.2	3.8	1.7	< 1	< 1	1.8	8.8	3.6	12.8	5.2	13.6
Emmett adit	1.18—1.23	< 1	11.7	1.1	27.4	1	13.4	1.1	18.7	< 1	17.1	< 1	4.8
Balarat Creek (Burlington Mine)	1.23—1.34	30.4	58.3	20.1	64.1	23.9	86.3	17.6	61	16	37.2	20.5	62.7
Roadside Tailings	1.55—1.83	11.2	--	31.8	--	42.8	--	31.1	--	32.8	--	12.5	--
Unnamed tributary	1.85—1.91	< 1	--	9.3	--	2.4	--	9.4	--	3.7	--	2.2	--
Streamside tailings and unnamed drainage	2.36—2.41	6.4	--	9.4	--	6.1	--	5.5	--	6.1	--	9.8	--
Subsurface inflow	2.59—2.68	2.2	--	4.6	--	8.1	--	8.4	--	8.1	--	8.5	--
Subsurface inflow	2.76—2.87	20.7	--	9.4	--	8.7	--	10.2	--	9.8	--	34.8	--
TOTALS	--------	82.6	72.2	92.6	93.2	93	99.7	87.4	88.5	85.5	67.1	94.5	81.1

Note: Metal loads based on metal loading tracer tests conducted by the University of Colorado on April 22, 2003 (high flow) and June 17, 2003 (low flow).

[1] Distance refers to distance downstream of reference sample site. For Little James Creek, the reference sample site was located approximately 2.9 km upstream of the confluence with James Creek.

Table 6. Metal standards- and loadings-based priority ranking scoring system.

Criteria	Analyte	Score
Exceeds chronic standards	Fe	1
	Al	1
	Mn	1
	Zn	1
	Cu	1
	Pb	1
	pH	1
Exceeds acute standards	Fe	1
	Al	1
	Mn	1
	Zn	1
	Cu	1
	Pb	1
Adds over 5% of dissolved load	Fe	1
	Al	1
	Mn	1
	Zn	1
	Cu	1
	Pb	1
Adds over 10% of dissolved load	Fe	1
	Al	1
	Mn	1
	Zn	1
	Cu	1
	Pb	1
Adds over 15% of dissolved load	Fe	1
	Al	1
	Mn	1
	Zn	1
	Cu	1
	Pb	1
Adds over 25% of dissolved load	Fe	1
	Al	1
	Mn	1
	Zn	1
	Cu	1
	Pb	1
Adds over 5% of stream flow	n/a	
TOTAL POSSIBLE SCORE		37

Table 7. Lefthand Creek priority ranking system results and reclamation notes.

Source	Distance (km)[1]	Primary Contaminants of Concern	Score	Priority	Reclamation Notes
"Dew Drop mine" tributary and seep	0.61—0.68	pH, Zn, Cu	3	low	Falls within boundaries of the Captain Jack Mine and Mill Superfund Site
Big Five Mine Tunnel	1.18—1.29	pH, Zn, Cu, Pb	16	high	Falls within boundaries of the Captain Jack Mine and Mill Superfund Site
White Raven mine	1.55—1.71	pH, Zn, Cu	5	medium	Falls within boundaries of the Captain Jack Mine and Mill Superfund Site
Unnamed mine opening	1.99—2.19	pH, Zn, Cu	5	medium	Falls within boundaries of the Captain Jack Mine and Mill Superfund Site
Indiana Gulch	2.42—2.54	pH, Mn, Zn, Cu	2	low	
Loder Smelter	2.66—3.21	pH, Zn, Cu	5	medium	
Unnamed triubtary	6.98—7.19	pH, Zn, Cu, Pb	9	medium	
Unidentified source	8.48—8.96	pH, Zn, Cu, Pb	7	medium	
Spring Gulch	10.64—11.43	pH., Zn, Cu, Pb	5	medium	
Prussian mine waste pile	12.60—13.01	pH, Zn, Cu, Pb	6	medium	
Slide Mine	13.16—13.50	pH, Zn, Cu	6	medium	Under consideration for both Superfund listing and voluntary cleanup
Nugget Gulch	17.98--18.35	Cu, Pb	3	low	
"Lee Hill" gulch	19.25—19.48	Cu	2	low	
Carnage Canyon gulch	24.14—24.31	Al, Cu	3	low	Part of the US Forest Service travel management plan focus area
Sixmile Creek	26.09—26.39	Mn, Cu	3	low	

Note: Contaminants of concern and score based on metal loading tests conducted by the University of Colorado in May and June 2003.

[1] Distance refers to distance downstream of reference sample site. For Lefthand Creek, the reference sample site was located at the Highway 72 near the town of Ward.

Table 8. James Creek priority ranking system results and reclamation notes.

Source	Distance (km)[1]	Primary Contaminants of Concern	Score	Priority	Reclamation Notes
John Jay mine	0.40—0.73	Zn	2	low	
Fairday Mine	1.34—1.71	Mn, Zn, Cu, Pb	13	high	US Forest Service reclamation occurred in 2004
Unidentified source	2.62—2.80	Zn, Pb	7	medium	
Unidentified source	3.7—4.1	Al, Mn, Zn, Cu	11	high	
Bueno Mountain	4.27—4.82	Al, Mn, Zn, Cu, Pb	15	high	Under consideration for EPA Emergency Response Action
Castle Gulch	8.74—8.92	Al, Mn, Cu	7	medium	US Forest Service Remedial Investigation/Feasibility Study underway

Note: Contaminants of concern and score based on metal loading tests conducted by the University of Colorado on July 2 and July 8, 2002.

[1] Distance refers to distance downstream of reference sample site. For James Creek, the reference sample site was located at the upper creek crossing on County Road 102J, approximately 10 km upstream of the confluence with Lefthand Creek.

Table 9. Little James Creek priority ranking system results and reclamation notes.

Source	Distance (km)[1]	Primary Contaminants of Concern	Score	Priority	Reclamation Notes
Evening Star Mine	0.37—0.64	Al, Cu, Pb	4	medium	Boulder County Brownfields application has been submitted
Argo Mine	0.77—0.89	Al, Cu	5	medium	Boulder County Brownfields application has been submitted
Emmett adit	1.18—1.23	pH, Al, Zn, Cu	4	low	Under consideration for EPA Emergency Response Action
Balarat Creek (Burlington Mine)	1.23—1.34	pH, Al, Mn, Zn, Cu, Pb	20	high	Reclamation of Burlington Mine in 2003-2004; mine pond drainage still an issue
Roadside Tailings	1.55—1.62	pH, Al, Mn, Zn, Cu, Pb	16	high	
Yellow Girl	1.73—1.83	pH, Al, Mn, Zn, Cu, Pb	27	high	
Unnamed tributary	1.85—1.91	pH, Al, Mn, Zn, Cu, Pb	12	high	
Streamside tailings and unnamed drainage	2.36—2.41	pH, Al, Mn, Zn, Cu, Pb	11	high	Under consideration for EPA Emergency Response Action
Unidentified source	2.59—2.68	pH, Al, Mn, Zn, Cu, Pb	13	high	
Unidentified source	2.76—2.87	pH, Al, Mn, Zn, Cu, Pb	13	high	

Note: Contaminants of concern and score based on metal loading tests conducted by the University of Colorado on April 22, 2003.

[1] Distance refers to distance downstream of reference sample site. For Little James Creek, the reference sample site was located approximately 2.9 km upstream of the confluence with James Creek.

Table 10. Best Management Practices applicable to the reclamation of abandoned mine lands in the Lefthand Creek watershed.			
Site Name	**Impacted Stream**	**Description**	**Best Management Practices**
High Priority Mine Sites			
Bueno Mountain	James Creek and Little James Creek	Very large tailings pile	(1) Diversion Ditches
			(2) Removal, consolidation, stabilization
			(3) Regrading
			(4) Capping
			(5) Vegetation
			(6) Chemical amendment (neutralization)
Burlington Mine Pond	Little James Creek	Pond and flow of mine water (estimated flow rate: ~ 5—10 GPS)	(1) Diversion Ditches
			(2) Aeration and settling ponds
			(3) Sulfate-reducing wetlands
			(4) Anoxic limestone drain
			(5) Chemical amendment (neutralization)
Roadside Tailings	Little James Creek	Small tailings and waste rock pile	(1) Diversion Ditches
			(2) Removal, consolidation, stabilization
			(3) Regrading
			(4) Capping
			(5) Vegetation
			(6) Stream Diversion
			(7) Chemical amendment (neutralization)
Streamside Tailings	Little James Creek	Medium/large tailings pile	(1) Diversion Ditches
			(2) Removal, consolidation, stabilization
			(3) Regrading
			(4) Capping
			(5) Vegetation
			(6) Stream Diversion
			(7) Chemical amendment (neutralization)

Table 10. Best Management Practices applicable to the reclamation of abandoned mine lands in the Lefthand Creek watershed.			
Site Name	**Impacted Stream**	**Description**	**Best Management Practices**
Medium Priority Mine Sites			
Loder Smelter	Lefthand Creek	Small/medium waste rock and tailings pile	(1) Diversion Ditches
			(2) Removal, consolidation, stabilization
			(3) Regrading
			(4) Capping
			(5) Vegetation
			(6) Stream Diversion
			(7) Chemical amendment (neutralization)
Slide Mine	Lefthand Creek	Very large tailings and waste rock pile; flow of water through and over piles	*Waste Rock BMPs*
			(1) Diversion Ditches
			(2) Removal, consolidation, stabilization
			(3) Regrading
			(4) Capping
			(5) Vegetation
			Water BMPs
			(1) Diversion ditches
			(2) Aeration and settling ponds
			(3) Sulfate-reducing wetlands
			(4) Anoxic limestone drain
			(5) Chemical amendment (neutralization)
Castle Gulch	James Creek	Waste rock and tailings piles; adit flow	*Waste Rock BMPs*
			(1) Diversion Ditches
			(2) Removal, consolidation, stabilization
			(3) Regrading
			(4) Capping
			(5) Vegetation
			Water BMPs
			(1) Diversion ditches
			(2) Aeration and settling ponds
			(3) Sulfate-reducing wetlands
			(4) Anoxic limestone drain
			(5) Chemical amendment (neutralization)

Table 10. Best Management Practices applicable to the reclamation of abandoned mine lands in the Lefthand Creek watershed.

Site Name	Impacted Stream	Description	Best Management Practices
Evening Star Mine	Little James Creek	Small waste rock pile; deep open pit; occasional adit flow	*Waste Rock BMPs* (1) Diversion Ditches (2) Removal, consolidation, stabilization (3) Regrading (4) Capping (5) Vegetation *Water BMPs* (1) Diversion ditches (2) Aeration and settling ponds (3) Sulfate-reducing wetlands (4) Anoxic limestone drain (5) Chemical amendment (neutralization)
Argo Mine	Little James Creek	Small/medium waste rock piles; many subsidence pits; large open stope (may be 200' deep); upwelling of spring with high metals concentrations	*Waste Rock BMPs* (1) Diversion Ditches (2) Removal, consolidation, stabilization (3) Regrading (4) Capping (5) Vegetation (6) Stream Diversion (7) Chemical amendment (neutralization) *Water BMPs* (1) Diversion ditches (2) Aeration and settling ponds (3) Sulfate-reducing wetlands (4) Anoxic limestone drain (5) Chemical amendment (neutralization)

Table 10. Best Management Practices applicable to the reclamation of abandoned mine lands in the Lefthand Creek watershed.

Site Name	Impacted Stream	Description	Best Management Practices
Low Priority Mine Sites			
Emmett Adit and Mine	Little James Creek	Very low flow from adit opening with very high metals concentrations; medium waste rock and tailings pile; large (~300'wide x ~100' deep) glory hole	*Waste Rock BMPs* (1) Diversion Ditches (2) Removal, consolidation, stabilization (3) Regrading (4) Capping (5) Vegetation (6) Chemical amendment (neutralization) *Water BMPs* (1)Diversion ditches (2)Aeration and settling ponds (3) Sulfate-reducing wetlands (4) Anoxic limestone drain (5) Chemical amendment (neutralization)
John Jay Mine	James Creek	Waste rock and adits (needs more characterization)	Further characterization and monitoring needed prior to BMP development
Indiana Gulch	Lefthand Creek	Stream that drains mine workings in town of Ward	Further characterization and monitoring needed prior to BMP development
Nugget Gulch	Lefthand Creek	Stream that drains mine workings downstream of Rowena	Further characterization and monitoring needed prior to BMP development
"Lee Hill Gulch"	Lefthand Creek	Unknown mining activity in area. Very high hardness in this stream.	Further characterization and monitoring needed prior to BMP development
Sixmile Creek	Lefthand Creek	No known mining activity. Can probably be dropped from consideration as a contaminant source.	Further characterization and monitoring needed prior to BMP development
Non-Mining Sites			
Carnage Canyon	Lefthand Creek	Heavy OHV usage; no metals from mining	

Table 11. Milestone table.

Action Item	Products						2006											
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Organization Strategic Plan	1) Funding needs matrix 2) Funding collection plan																	
Outreach and Education	1) Develop education and outreach program																	
Watershed Monitoring Plan	1) Watershed monitoring plan 2) Monitoring database to be shared with CDPHE and EPA																	
Continued Site Characterization	1) Specific list of characterization needs 2) Site characterization plan																	
Liability Education	1) List of all LWOG members' liability concerns 2) Report summarizing legal realities and other watershed group strategies																	
Restoration Plan Development	1) Define opportunities to address high-priority mining-related sites in the watershed																	
Watershed Plan Updates	1) Annual Watershed Plan review and summary of changes																	