

SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM
WATERSHED PROJECT FINAL REPORT
Middle North Empire Creek Stream Corridor Restoration Project



by

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Clear Creek Watershed Foundation

(September 2019)

This project was conducted in cooperation with the State of Colorado and the United States Environmental Protection Agency, Region 8.

CDPHE NPS Contract # CT FAAA201700001997

1 EXECUTIVE SUMMARY

PROJECT TITLE Middle North Empire Creek Restoration Project

PROJECT START DATE 9-8-16

PROJECT COMPLETION DATE 5-31-18

FUNDING: TOTAL BUDGET \$327,006.67

TOTAL EPA §319 GRANT \$196,204

TOTAL FEDERAL (Non-Matching) EXPENDITURES OF EPA ESAT LAB FUNDS \$38,960.00

TOTAL SECTION 319 MATCH ACCRUED \$152,088.95

BUDGET REVISIONS Internal budget reallocation of \$16,044, approved on 4-23, 2018.

TOTAL EXPENDITURES \$368,154.00

SUMMARY ACCOMPLISHMENTS

Acidic and highly mineralized mine waste was removed from the middle reach of North Empire Creek, particularly from the stream bottom lands at the North and South Piles, the East and West Piles and the Equator mine waste pile. Figure 4 in the accompanying Final Project Report is an actual mine map dated 9-7-1994, which provides different names for these mine waste piles, as shown below. The mine feature names included in the PIP for this project were developed for project purposes, before the 1994 mine map was acquired. In total, 13,500 C.Y. of this mine waste was transported to an up-gradient repository, located on the west side of the creek across from the large (60,000 C.Y.) Gold Dirt mine waste pile (AKA Pioneer and Gold Fissure Mine Dumps). Following the mine waste removal activities, land reclamation activities in the project area were conducted, including: final grading; addition of 18" of topsoil to cap the repository; addition of soil amendments (lime, biosol, humate, fertilizer and compost); hand broadcast seeding immediately after soil preparation; followed by hydro seeding; and, area-wide coverage with *WoodStraw*[™] mulch. The channel of North Empire Creek was completely reconstructed through the project area using large boulders and VH angular rocks (D_{min}-18"). Armored meanders were established in the shallower gradient areas below the North and South piles (AKA Gold Fissure adit dumps) and the Mine Waste Repository. Step pools were constructed in the steeper areas where the East and West piles (AKA Gold Dirt Mine waste piles, or Pioneer and Gold Fissure Mine Dumps) and the Equator pile were located.

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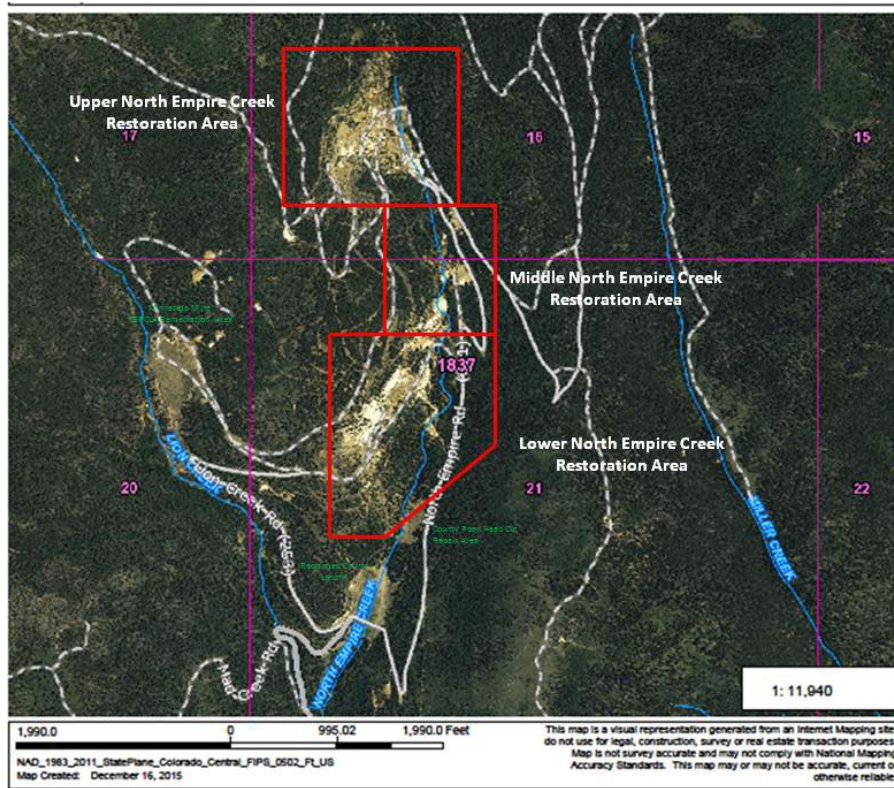
3 INTRODUCTION

The North Empire Mining District has been severely impacted by past mining activities. In general, North Empire Creek is a high-gradient drainage system with very steep side slopes, acid mine drainage and significant contamination from heavy metals. Past mining activities have included surface mining, hydraulic placer mining and lode mining. Most of the area disturbed by mining is on the slopes to the west of the Creek. Surface mined areas have also been developed along with shafts and adits mostly extending in a north-westerly direction into hardrock workings.

The placer mining removed not only the topsoil, but even much of the subsoil from many of the west side slopes of the north-to-south flowing drainage. These placer-mined hill slopes would be almost impossible to restore and revegetate using any practical and affordable approaches for reclamation. Therefore, the focus of this project is on runoff control from the denuded areas; mine waste and contaminated sediment removal from the creek bottom; and stream corridor restoration, all in order to achieve water quality improvements.

North Empire Creek is a small watershed of approximately 1 mi², ranging in elevation from 11,522 ft at the headwaters, to 9,100 ft MSL where it discharges into Lion Creek. Flows in North Empire Creek range from approximately 20 gpm to 1,148 gpm (2.5 cfs). Below the confluence with North Empire Creek, Lion Creek drains southward into the West Fork of Clear Creek within the Town limits of Empire, located approximately 40 miles west of Denver, Colorado. The West Fork of Clear Creek joins the main stem of Clear Creek about one mile east of Empire. Clear Creek is a major tributary of the South Platte River,

Figure 1 - North Empire Creek Aerial Map of Project Areas



with its confluence located just north of Denver's city limits.

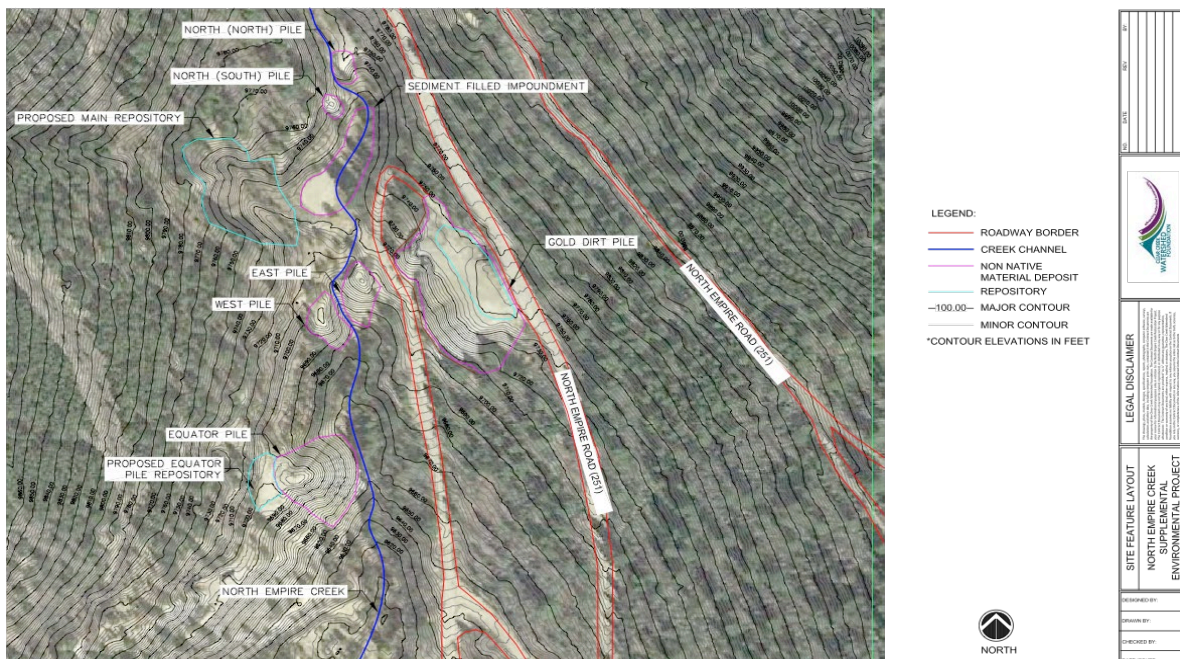
For purposes of stream restoration and mining reclamation, North Empire Creek has been divided into an upper, middle and lower reach, mainly defined by access considerations and historic mining district boundaries. This project addressed mining related impacts in the middle reach of the creek. Please see Figure 1.

CCWF restored the upper reach in the fall of 2014 through a \$400,000 Supplemental Environmental Project

fund administered by CDPHE’s Office of Sustainability, along with \$30,000 in project funding provided by the Colorado Division of Reclamation, Mining and Safety (DRMS). The upper project resulted in the complete removal of the 18,250 CY Conqueror Mine tailings pile from the stream channel and its disposal in the Upper North Empire Creek mine waste repository. This repository was sited about ¼ mile west and 300 vertical feet above North Empire Creek.

The middle reach of North Empire Creek encompasses about ¼ of the entire drainage system. This area was heavily impacted by contaminated runoff and in-stream mine waste. The focus of this project was upon removal of mine waste from the stream channel and riparian zone and disposal of this mine waste in another main approved onsite repository that was designated to receive mine waste materials from the middle reach of North Empire Creek. The large Gold Dirt waste pile and steep-lying Equator piles shown on Figure 2, were stabilized and reclaimed in place.

Figure 2 - Middle North Empire Creek Restoration Area Map



The middle reach of North Empire Creek is also known as the Gold Dirt Mining District. North Empire Creek has pristine water quality above the Conqueror Mining District (upper reach) and now has good water quality through that area, which is just upstream of the Gold Dirt Mining District (middle reach). There are several reaches of North Empire Creek that are reasonably intact with good riparian conditions. These have served as reference reaches for the restoration of impacted reaches.

The following mining features were addressed as part of this project.

1. Two mine waste piles with a total volume of 3,500 CY, were removed to the repository in their entirety. These piles were split by the active channel of North Empire Creek into four piles (N-S and E-W) as shown on Figure 2.
2. A contaminated fluvial fan was stored in the stream channel behind a remnant water impoundment. It contained an additional 4,400 CY of highly mineralized sediment deposited

from upstream areas that were impacted by historic mining activities. All of this material was hauled away and emplaced in the middle reach repository.

3. The Gold Dirt mine waste pile (~60,000 CY), which is situated adjacent to the creek, was reclaimed in place. It is no longer eroding and causing sedimentation problems in the middle reach.

4. The steep lying Equator Mine waste pile (~4,000 CY) was *mostly* removed to the repository, especially the portion that was in and alongside the actual creek channel. The remaining mine waste was reclaimed in place and now stands as one of the best examples, we have, of direct revegetation of mine waste.

5. The existing channel of North Empire Creek (approximately 750 Lineal Feet), which had been destabilized and contaminated by mining activities was re-stabilized and reconfigured with step pools and boulder-reinforced meanders to dissipate the energy of North Empire Creek, along its steep 20% gradient, through most of the middle reach.

4 PROJECT GOALS, OBJECTIVES, AND ACTIVITIES

The overall goal of watershed scale restoration activities in North Empire Creek and Lion Creek is recovery of the macro invertebrate community, which has been destroyed by past mining activities. It should be noted that without significant habitat improvements (e.g., creation of winter water holding structures) in addition to water quality improvements, this steep drainage would not support reproducing fish populations.

North Empire Creek is a tributary of Lion Creek, which is severely impaired, but not *303(d)-listed*, because of its limited use classifications and applicable standards as shown in Table 1. Lion Creek discharges into the West Fork of Clear Creek, which flows into segment 2b of Clear Creek, a §303(d) listed segment, and then into segment 2c of Clear Creek, also listed under §303(d) of the federal Clean Water Act.

From the headwaters of North Empire Creek downstream, approximately 1.2 miles, to the crossing of County Road 251 there are three distinct stream reaches (upper, middle and lower) identified primarily by access points and historic mining district boundaries, where mine waste piles directly intersect the Creek. There are literally hundreds of mining properties in this sub-watershed. The upper reach was restored through a Supplemental Environmental Project administered by CDPHE's Office of Sustainability. This project addressed the middle reach, which encompasses about ¼ of the entire drainage system. This area is heavily impacted by contaminated runoff and mine waste (Figure 3).

Figure 3 - Topsoil Salvage & Repository Enlargement



The primary goal of this Nonpoint Source Project was to remove mine waste from the natural stream channel and its flood plain in order to establish a healthy riparian buffer area and a stable drainage channel with improved water quality. The second goal was to use best management practices for removing, transporting, emplacing, hydrologically isolating, capping and revegetating the consolidated mine waste. A third goal was to divert run-on water and control runoff from the Gold Dirt waste pile through a lined, boulder rundown structure. The fourth goal was to complete revegetation of the Gold Dirt and Equator mine waste piles along with all the other disturbed areas (including the repository) after topsoil and soil amendment additions.

Table 1 - Current Stream use classifications and applicable standards for Lion Creek, West Clear Creek, Clear Creek, Mill Creek, Argo Tunnel

WBID	Segment Description	Portion	Colorado's M&E Parameter(s)	CWA 303(d) Impairment	303(d) Priority
COSPCL08	Mainstem of Lion Creek from the source to the confluence with West Clear Creek.	All	Note: This stream is classified for Aq Life Cold 2 and Recreation E. The only standards are: T=TVS(CS-I) ^a C D.O. = 6.0 mg/l D.O. (sp)=7.0mg/l pH = 3.0-9.0 E.Coli=126/100ml	No. But, TVS are exceeded for pH, Al, Cd, Cu, Fe, Mn, Ni, Pb, Zn	N/A
COSPCL05	Mainstem of West Clear Creek			Not listed	N/A
COSPCL02b	Mainstem of Clear Creek from West Fork Clear to Mill Creek.	All		Cd, Zn	H
COSPCL02c	Mainstem of Clear Creek from Mill Creek to Argo Tunnel.	All		Cd	H

Table 2 - Stream use classifications and applicable standards Lion Creek, West Clear Creek, Clear Creek, Mill Creek, Argo Tunnel applicable at the time the Project Implementation Plan was submitted for approval

WBID	Segment Description	Portion	Colorado's M&E Parameter(s)	CWA 303(d) Impairment	303(d) Priority
COSPCL06	All tributaries to West Clear Creek from the source to the confluence with Clear Creek	North Empire Creek	SO ₄ , Cd, Fe(Dis), Fe(Trec), Zn	Cu	H

4.1 PLANNED AND ACTUAL MILESTONES, PRODUCTS AND COMPLETION DATES

This project was designed to result in significant reductions in toxic metal concentrations within North Empire Creek, including aluminum, cadmium, copper and zinc as well as a reduction of acidity, with a corresponding increase in pH. The ultimate goal of this project and the others constructed in North Empire Creek was to reduce the degree of impairment in the main stem of Clear Creek, which is a significant environmental and recreational resource and a major water supply serving mountain communities and major cities along the Front Range.

Figure 4 - Equator mine waste pile removal from North Empire Creek



Figure 5 - Topsoil Stockpile left side of Gold Dirt pile



Frontier Environmental Services, Inc. (FESI) reported (Table 3) that the actual volume of mine waste removed from the four (N-S and E-W) piles was 4000 CY. This contaminated material was completely removed from the stream channel area and deposited in the repository, which is located well up gradient from the Creek. Approximately 4,450 CY of contaminated in-stream sediment trapped behind an impoundment and removed along with the impoundment and deposited in the middle reach repository. An additional 4,500 CY of mine waste was hauled to the repository from the Equator pile (Figure 4).

The footprints of the mine waste piles and the fan deposit within the flood plain of the stream channel were amended with a total of 75 tons of beet pulp lime and 240 cubic yards of compost. The repository area was capped with 12-18 inches of soil material and amended with compost. All areas were seeded with Colorado Division of Reclamation, Mining & Safety specified seed mix blanketed with WoodStraw. The stream channel was reconstructed through the reclaimed areas, using cascades and step pools in

steeper areas and a sinuous pattern in “flatter” areas. Restored stream banks were stabilized using boulders and large woody debris harvested during clear and grub operations.

The exposed surface of the Gold Dirt mine waste pile was capped with borrowed topsoil that was amended with lime and compost and then revegetated using a native seed mix broadcast at twice the specified application rate and copious amounts of WoodStraw to achieve at least a 70% coverage rate (Figure 5). This is functionally equivalent to using erosion control blankets on steep slopes, according to the USFS.

The Equator mine waste pile (Figure 4) was removed from the creek and pulled back a minimum of 10 feet from the stream bank. Approximately 4,500 CY of the Equator Pile was removed and emplaced within the Repository. A buttress was constructed along the toe of the remaining Equator Mine waste pile using rock boulders that were gathered and salvaged during other construction activities on the site. A runoff control ditch was constructed between the toe of the pile and North Empire Creek and extended another 480 LF downstream in order to control runoff from previously mined areas. The remaining portion of the pile was reclaimed in place using beet pulp, agricultural lime, compost, native seed and WoodStraw. Finally, the channel of North Empire Creek was stabilized using 2-4’ sized boulders and shaped to control velocity.

Table 3 - NPS summary of completed construction activities

	Activity	Description	Date Completed
NPS Summary of Completed Construction Activities	Rights of Access; Design and Construction Documents; Project Permitting	Negotiation with landowners, site surveying, drawings, permitting with County, State Stormwater, local BMP and Excavation permits	5-31-16
	EPA comfort letter	EPA Comfort Letter under CERCLA issued to CCWA	8-16-16
	NPS Contract Approval	CDPHE NPS Contract # CT FAAA201700001997 final state execution	9-8-16
	Project Mobilization	Project equipment, staging area and job site trailer	9-23-16
	CCC Access road improvements	Road grading and erosion control check dams	9-24-16
	Establish Stream Bypass System	Bypass the project construction area using 1000 feet of 8” d HDPE coupled agricultural drain pipe	9-27-16
	Clear and Grub	Tree and shrub removal along access roads and in mine waste repository area	9-30-16

	North and South Pile Reclamation	Removal of mine was down to undisturbed natural soil surface; placement and compaction in repository	10-5-16
	Loading and transport of topsoil, compost and lime	Trucking of materials to staging and hauling to reclamation areas	10-7-16
	Sprankle Mine Stope Closure	Backfill of 45' deep stope and regrading in front of the Sprankle adit for visual barrier	10-7-16
	East and West Pile Reclamation	Removal of mine waste from the east/west pile, disposal in repository, reconstruction of North Empire Creek	11-4-16
	Gold Dirt Pile reclamation	Regrading, top-soiling, compost addition, seeding and WoodStraw application	11-18-16
	Reclamation of Sediment-filled Impoundment area	Removal of contaminated sediment from the impoundment area and reconstruction of North empire Creek.	11-26-16
	Equator Pile reclamation	Removal of mine waste from the Equator pile, disposal in repository, reconstruction of North Empire Creek	11-28-16
	Repository area capping and soil amendments (topsoil, compost and lime	Placement of cap on repository, addition of soil amendments and WoodStraw application.	11-30-16
	Final Run-On/Run-Off Controls	Hydrological isolation of Gold Dirt pile, Repository, and Equator pile through runoff and runoff control systems	11-30-16
	Demobilization	Demobilization of construction equipment and removal of stream bypass system	12-6-16
	Mobilization of Excavation Equipment and crew	Re-stabilization of middle reach of N. E. Creek through construction of step pools, cascades and armored meanders. Broadcast seeding over disturbed areas within N.E. Creek bottomlands	1-15 18
	Mobilization of Hydro Mulch Equipment and crew	Hydro mulch all areas disturbed by construction in the project area	4-6-18

4.2 EVALUATION OF GOAL ACHIEVEMENT AND RELATIONSHIP TO THE STATE NPS MANAGEMENT PLAN

Colorado's approach to nonpoint source control for inactive mine sites is addressed in Chapter 5 of the state's Nonpoint Source Management Program. This project was fully consistent with that approach, insofar as it identified *reclamation and hydrologic controls for implementation, wherever feasible*. The fact that segments 2b and 2c of Clear Creek are listed as impaired because of past mining activities, raised the priority of this proposed project, because it directly addressed these causes of impairment. This project prevented any direct contact of North Empire Creek with highly mineralized mining waste in the middle reach of North Empire Creek. This contact between the drainage and its associated mine waste had been shown by USGS, USFS, CCWF and CSM to be a significant source of acidity, cadmium, copper and zinc. Both cadmium and Zinc are listed causes of impairment in the main stem of Clear Creek.

Post project monitoring commenced during the Summer 2016, including: multiple visual assessments; water quality sampling events for laboratory analysis; and, analysis for field parameters and dissolved metals. This monitoring was in accordance with the provisions of the approved SAPP for North Empire Creek. All sample results obtained by CCWF have been entered in the Colorado Data Sharing Network.

Post project inspection and maintenance consisted of comprehensive assessments in the field during and following the spring runoff each year from 2016-2018, to determine any required maintenance requirements. Maintenance work to restore the functionality of runoff controls, channel stability, mine waste containment, and vegetation cover was ordered and scheduled for early April of 2018, in accordance with an approved budget reallocation. Maintenance was completed in late May of 2018.

With the budget having been expended, maintenance responsibilities now have fallen back to the landowners (i.e., County, Forest Service and private parties) as discussed in the original Project Implementation Plan.

5 BEST MANAGEMENT PRACTICES DEVELOPED AND/OR REVISED

All of the BMP's proposed and implemented during the course of the Middle North Empire Creek Restoration Project, were *tried-and-true* methods, which have been employed in prior projects.

6 MONITORING RESULTS

A Sampling and Analysis Plan (SAP) already had been developed in support of the overall Quality Assurance Project Plan (QAPP) for the restoration of the Lion Creek watershed. This SAP was updated and revised for the purposes of this project and was provided as a separate deliverable. The SAP is included as Appendix A of this Final Report.

This project included mine waste and water quality sampling & laboratory analysis, toxicity investigations, macroinvertebrate field reconnaissance surveys (bioassessment) and contemporaneous flow measurements. This includes complete chemical analysis (i.e., 13

metals and hardness) for 6 sampling events at five stations (NE-1, 2, 3, 4 and 5) as represented in Figure 6. NPS Pollution Source categories addressed are habitat modification (drainage/filling wetlands, stream bank destabilization) and mining. NPS Pollutants addressed are metals and pH.

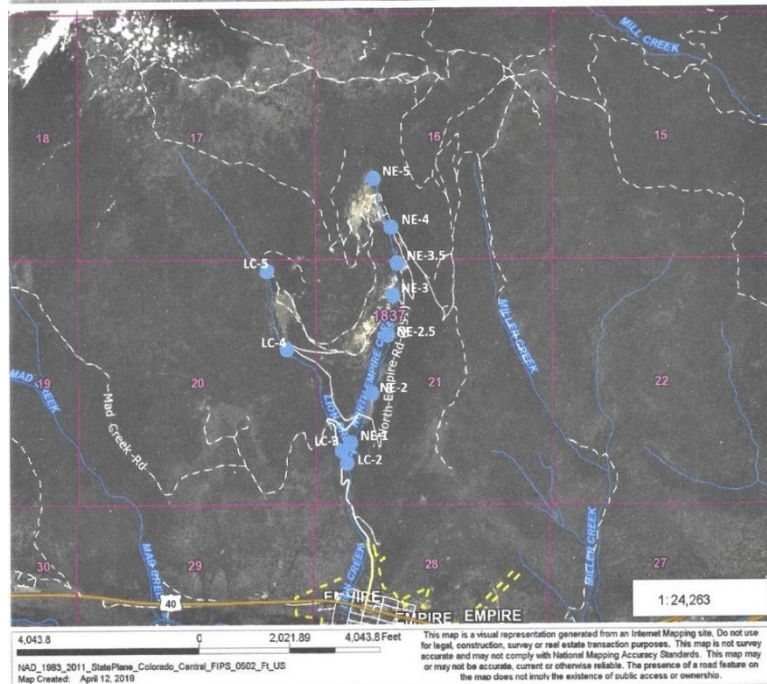
This project is expected to result in significant reductions in toxic metal concentrations, including aluminum, cadmium, copper, manganese and zinc as well as a reduction of acidity with a corresponding increase in pH. Given the importance of Clear Creek as a water supply and recreational resource, these are considered public health and source water protection benefits.

Water quality data collected as part of this project was uploaded on to the Colorado Data Sharing Network, as has been done for previous projects.

6.1 POST-PROJECT HYDROLOGY IN NORTH EMPIRE CREEK

The two water years (2018 and 2019) that followed the completion of CCWF's restoration work in the North Empire Creek watershed, were quite different from a hydrological perspective. 2018 was a below normal water year in terms of annual yield and runoff. The nearest USGS Stream gage is at CC-20, located 1 mile downstream from the Town of Empire at the Confluence of West Clear Creek with the Clear Creek Mainstem. Stream flows in the West Fork of Clear Creek range from a low of about 6 cfs to a high of about 700 cfs. This is in contrast to North Empire Creek, which has low flows of about 10-20 gpm (0.02- 0.04 cfs) and high flows on the order of 2.5 cfs. *Generally, the relative low- and high-flow conditions in one of these drainages correspond to the same flow conditions in the other.*

Figure 6 - Water Quality Monitoring Locations in Lion Creek watershed (incl. North Empire Ck.)



Our May 18, 2018 “high-flow sampling event” occurred close to the time of peak runoff (as measured at site CC-20 on West Fork Clear Creek). The streamflow measured at that time and location was 178 cfs, with the peak runoff measured 20 days later on June 8, 2018. The peak runoff flow was 229 cfs as compared to 700 cfs in a really big runoff year.

Our May 14, 2019 “high-flow sampling event” was scheduled approximately 6 weeks earlier than peak runoff for this year. The sampling date was set by CSM for academic-scheduling purposes, months before it actually occurred. The West Fork Clear Creek (CC-20) streamflow measured at the time of sampling was 40.1 cfs with the peak runoff measured on June 30, 2019. The peak runoff flow in 2019 was 425 cfs. It wasn’t a record-breaking year; however, it was almost twice the runoff of the previous year. Also, the flow measured on 5/14/2019 was less than 10 percent of the peak flow. It would be more accurate to call this an example of water-quality conditions on the rising limb of the hydrograph, rather than a high-flow sampling event. It was certainly not a low-flow sampling event.

6.2 BMP EFFECTIVENESS EVALUATIONS

As part of its senior design project for North Empire Creek, the Colorado School of Mines estimated that we could expect to remove 1655 pounds/year of total metal loading following construction of the project. CCWF included this loading reduction estimate within the Project Implementation Plan for the Middle North Empire Creek Restoration Project.

A subsequent examination of this loading reduction estimate has revealed that CSM based it upon a single sampling result during the high-flow, spring runoff period of May 2015. At that time, 24 mg/s of total metals were detected below the proposed project site (monitoring location NE-3, Figure 6) at a flow rate of 27L/s (428 gpm, or 0.96 cfs). That equates to 1665 pounds/year. However, loading is heavily dependent upon flow conditions and the average annual flow in North Empire Creek is about 100 gpm, not 428 gpm. Using the average annual flow figure to estimate annual loading results calculates a total metal load of 389 lbs./ year.

Normally, BMPs such as those that were implemented by CCWF during the upper reach project, would not be expected to result in 100% metal loading reduction, because there are other diffuse sources of loading from natural mineralization and groundwater inflow and from uncontrolled upstream sources. Also, mine waste removal efforts are *never* 100% effective in capturing any given source. Nonetheless, the water quality improvements achieved by the Upper North Empire Creek Restoration Project are very good as shown below in Table 4.

7 PRE- AND POST-PROJECT WATER QUALITY IN NORTH EMPIRE CREEK

The three nonpoint-source restoration projects conducted in the North Empire Creek sub-watershed were expected to result in “significant” reductions in toxic metal concentrations and loading, including aluminum, cadmium, copper, manganese, and zinc, as well as a reduction of acidity (e.g., with a corresponding increase in ambient stream pH). Given the importance of the upper Clear Creek watershed as a water-supply source and recreational resource, these projects are considered to be beneficial for public health and source-water protection.

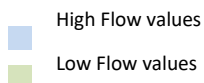
Prior to any mining-reclamation work, certain key trace metals were found to occur in this stream in relatively high concentrations; whereas, other trace metals were reported above detection levels established by the respective analytical laboratories used. For example, trace metals and metalloid species that were not generally found in North Empire Creek include: arsenic, lead, selenium, and silver. Cadmium is often detected, but in low concentrations near the detection limit. Metals generally found in elevated concentrations include aluminum, copper, iron, manganese, nickel, and zinc. Accordingly, these more concentrated *indicator* metals are the focus of this assessment.

7.1 UPPER NORTH EMPIRE CREEK

The upper reach of North Empire Creek extends about ¼ mile below its headwaters. The part of the upper reach that was affected by the Upper North Empire Creek Restoration Project is bracketed by monitoring Sites NE-5 and NE-4 and includes the Conqueror Mine seep. This seep is located in the general vicinity of the now collapsed Conqueror Mine adit. See Figure 7 below.

Figure 7, below, is a mine map of the entire North Empire Creek/Lion Creek Mining District as it existed in 1994, prior to any reclamation work in the area.¹ The top of the map shows the areas near the headwaters of both drainage systems. The bottom area of the map indicates the area about 500 lineal feet upstream of the confluence of North Empire Creek with Lion Creek, which is approximately one mile north of the Town of Empire, Colorado. This map (Figure 7) will be referred to, or relevant throughout the following discussion.²

Monitoring site NE-5 is located upstream of all *major* mining activities in the North Empire Creek drainage area. However, there is some evidence of past mining including a small mineralized seep (<1 gpm) coming from mine waste associated with an apparent mining prospect, approximately 50 yds upstream from the monitoring location. That explains the small amounts of trace metals that have been detected consistently at site NE-5.



 High Flow values

 Low Flow values

Table 4 - Headwaters WQ during low and high flow periods (above upper project area)

Site ID	Date	Flow-cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L
NE-5	Ambient Conditions (all data 2013-2019)		41	5.2	21	1.13	17
NE-5	5/12/15	0.544	11.0	2.4	12	BDL	4.3
NE-5	7/27/17		30.3	2.4	31	BDL	BDL
NE-5	9/19/17		23.5	2.4	26	BDL	BDL
NE-5	5/18/18	2.78	12.8	BDL*	2	BDL	BDL
NE-5	8/1/18		20.9	2.5	27	BDL	BDL
NE-5	10/18/18		33.4	2.8	26	BDL	BDL
NE-5	5/14/19	0.403	47.5	BDL	22.2	BDL	4.0

*BDL Below detection limit

¹ The first Reclamation Project was a Superfund effort in 1996 that was focused on the Minnesota Mine in the Lion Creek drainage, shown on the middle-left side of Figure 7.

² Please use the zoom function in your Adobe PDF or word processing software to magnify the place names and mining features on the map in Figure 7, if they are difficult to read.

The water quality measured at site NE-5 serves as the best indicator of “background”, pre-mining water quality in the sub-watershed, because it is the most accessible point where there is perennial flow in the stream channel. Generally, water quality at this location has been consistently good and not influenced by our project activities.

Between sites NE-5 and NE-4, a mineralized seep near the location of the Conqueror Mine was uncovered and became evident during the Upper North Empire Creek Restoration Project. Prior to that project, the seep location was buried under approximately 30 feet of mine waste. More than 18,000 CY of mine waste was removed from this area during the 2014 project.

The Conqueror Mine seepage is believed to be mine drainage from underground workings. The seep emerges from the west hillslope approximately 20 vertical feet above the stream. As shown in Tables 5 and 6, the seep’s water quality is quite different from that of North Empire Creek, significantly more mineralized and acidic, as reflected in comparison samples collected at site NE-5 and post-project samples at site NE-4.

Table 5 - Conqueror Mine seep water quality during 2018 Spring runoff period

Site ID	Date	Flow-cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-5	5/18/18	2.78	12.8	BDL*	2	BDL	BDL	
Conqueror Mine Seep	5/18/18	0.0051	621	101	1910	15.4	123	3.11
NE-4	5/18/18	N/A	23.6	3.8	4.6	1.2	17.0	7.4

Table 6 - Conqueror Mine seep water quality on May 14, 2019 during the rising limb of the hydrograph

Site ID	Date	Flow-cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-5	5/14/19	0.403	47.5	BDL	22.2	BDL	4.0	6.2
Conqueror Mine Seep	5/14/19	0.012	571	75.8	1710	14.7	142	5.4
NE-4	5/14/19	1.31	107	9.3	26	BDL	13.8	6.2

The Conqueror Mine seepage does have a small continuing impact on the stream, as observed at monitoring site NE-4 in May of 2018 and 2019. Note that concentrations of all trace metals are higher (yet not toxic for aquatic life) at site NE-4 for both years. But this impact from the Conqueror seep on North Empire Creek is minimal, compared to the impact that the Conqueror Mine waste piles were having prior to their removal in 2014. Note the pre-project average quality at site NE-4, compared to the post-restoration project period beginning in May 2015 and ending in 2019, as shown on Table 7, below. All post-project laboratory analyses are significantly lower in trace-metal concentrations. Removal of the Conqueror Mine waste piles resulted in a major improvement in water quality, as measured at site NE-4.

despite the unanticipated presence and impact of the mine seepage. Table 7 also presents data on North Empire Creek’s water quality, below the Upper North Empire Creek (Conqueror Mine) Restoration Project area at monitoring site NE-4. A quick scan of the data indicates a dramatic and consistent improvement in post project water quality.

Table 7 - Water quality at NE-4, below the Conqueror Mining area

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-4	Pre-project average		117	286.1	178.5	2.85	67	3.2
NE-4	5/12/15**		5.7	4.5	115	BDL	71	7.3
NE-4	7/27/17		33.1	2.9	13.4	BDL	BDL	7.2
NE-4	9/19/17		35.5	4.9	56.1	0.63	BDL	
NE-4	5/18/18	N/A	23.6	3.8	4.6	1.2	17.0	7.4
NE-4	8/1/18		BDL	2.0	7.64	BDL	BDL	6.4
NE-4	10/18/18		BDL	1.6	7.37	BDL	BDL	5.9
NE-4	5/14/19	1.31	4.3	9.3	26	BDL	13.8	6.2

*BDL Below detection limit; **First post-project sample

- High Flow values
- Low Flow values

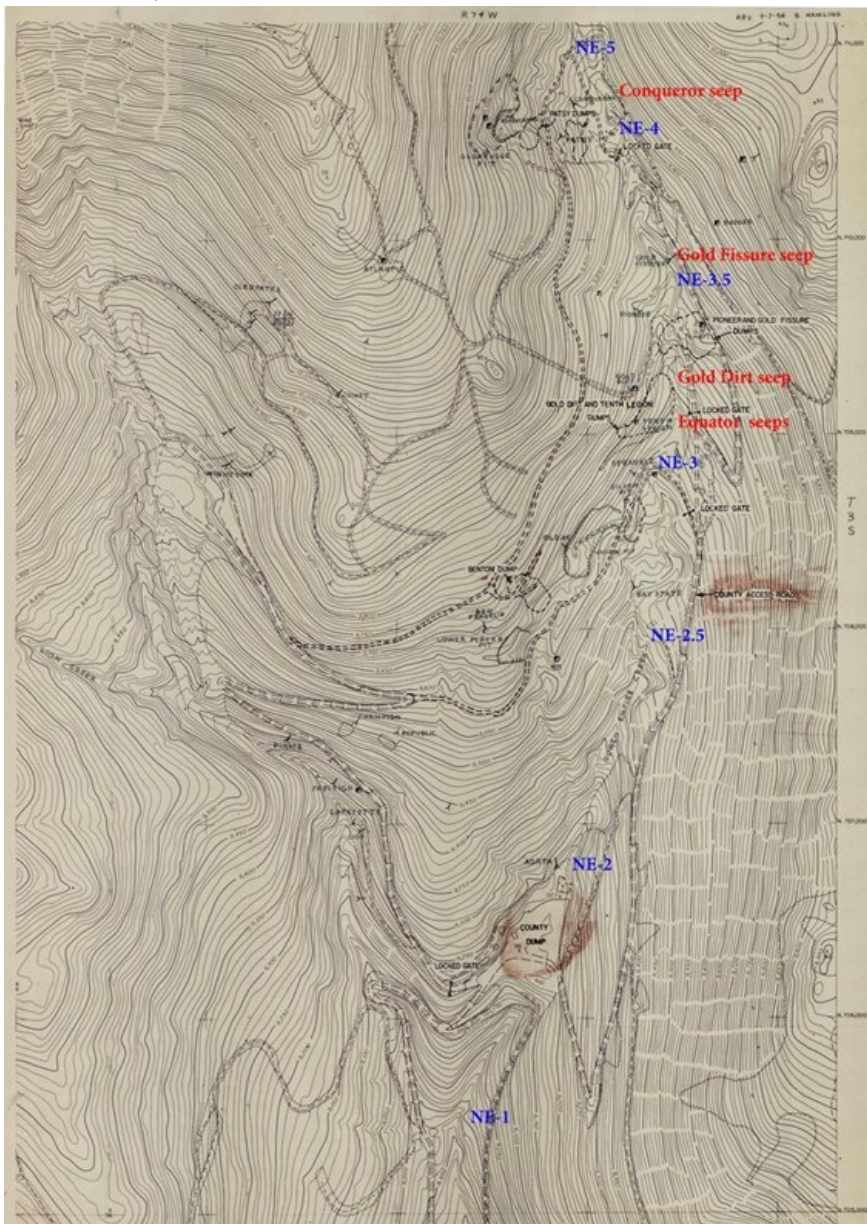
Metal *concentrations* in North Empire Creek were dramatically reduced after the Conqueror Mine waste piles and tailings were removed from the upper reach of North Empire Creek. This is evident at monitoring site NE-4, which is located immediately downstream of the upper North Empire Creek Restoration Project area, as shown in Tables 5 and 6, above. Also, average stream pH at site NE-4 increased to a post-project value of 7.4, compared with a value of 3.2 prior to the restoration project. For comparison, the stream quality at site NE-5 is characterized as having relatively pristine conditions, not influenced by the mine-remediation actions for the upper-reach restoration project.

7.2 MIDDLE NORTH EMPIRE CREEK

The middle part of North Empire Creek is known locally as the Gold Dirt mining area, because the Gold Dirt and Gold Dirt #2 mining claims were associated with the major mining activities and mine waste piles that were addressed during the Middle North Empire Creek Restoration Project. This project was constructed in late 2016 and early 2017 and, like the 2014 project, it addressed contaminated sediments in the stream channel and the removal of mine waste alongside the channel. The Pioneer and Gold Fissure Dumps located on the east side of North Empire Creek in the map on Figure 7 are also known as the Gold Dirt Mine waste piles, because the Gold Dirt Mine was the source of some of the ore and mine waste on the pile. These different place names for the same location can be confusing.

The middle reach is bracketed by monitoring sites NE-3.5 and NE-3 -- encompassing about ¼ mile of stream length. It also contains four mineralized seeps, which emerged only after the removal of about 16,000 CY of mine-waste materials in and alongside the stream-channel bottom. The Gold Dirt and Tenth Legion Mine adits and shafts are also shown on Figure 7. These are located on the west side of North Empire Creek. These shafts, adits, and subsurface mine workings are suspected sources of mine waste seepage that enters North Empire Creek at the toe of the Gold Dirt and Tenth Legion mine dumps. These are also shown on the map on Figure 7 on the west side of North Empire Creek. These mine dumps are also known as the Equator mine waste piles, because they are situated directly on the land surface of the Equator mine claim. These names are also potentially confusing, but such is the shifting nature of place names in historic mining districts throughout Colorado.

Figure 7 - North Empire Creek mining features, monitoring sites, and recently discovered mineralized seeps



Gold Fissure Mine Seep - In May 18, 2018, a mine waste seep was observed discharging to the stream, just above monitoring site NE-3.5. It was then sampled, and the lab results showed a very mineralized source of water coming into North Empire Creek. Between monitoring sites NE-4 and NE-3.5, the Gold Fissure Mine adit is shown on the map in Figure 7, just upstream of monitoring site NE-3.5 (which was established fairly recently). This mineralized seep exhibits decidedly different water quality than observed at either site NE-4 or site NE-3.5. The source of this drainage is suspected to be the (now collapsed) adit of the Gold Fissure Mine. The mine is shown on Figure 7, downgradient of County Road 251 and on the east side of North Empire Creek. This mineralized seep does have an impact, albeit slight, on the water quality of North Empire Creek, as was noted at site NE-3.5. This is shown

on Tables 8 and 9 below for the years 2018 and 2019. The majority of flow for this seep may, in fact, be subsurface in nature.

Also, a precipitous drop in streamflow occurred in May 2019, between monitoring sites NE-4 and NE-3.5. (Table 9). Both streamflow measurements were done using the salt-tracer injection method, which is generally CSM's most accurate flow-measurement technique. This steep and tight reach of North Empire Creek is inaccessible to heavy equipment. As a result, no contaminated sediment could be removed in this section, except immediately above site NE- 3.5. This raises a question about whether flow is being lost to contaminated sandy sediments in the alluvium and then being discharged downstream, where bedrock outcrops occur. If so, this could also help explain the increases in metal concentrations seen at site NE-3.5. In fact, this is an alternate explanation for all of the mineralized seeps in the middle reach of North Empire Creek.

Table 8 - Impact from the Gold Fissure mineralized seep in 2018 spring runoff

■ High Flow values

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-4	5/18/18	N/A**	23.6	3.8	4.6	1.2	17.0	7.4
Gold Fissure Seep	5/18/18	0.0038	591	234	15.2	3.3	18.8	3.3
NE-3.5	5/18/18	1.85	29.7	BDL	22.4	BDL	23.5	5.6

*BDL Below detection limit; **Flow not available, but upstream ~500 LF at NE-5 the flow was 2.78 cfs

Table 9 - Impact from the Gold Fissure mineralized seep in May 2019

■ High Flow values

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-4	5/14/19	1.31	4.3	9.3	26	BDL	13.8	6.2
Gold Fissure Seep	5/14/19	0.0053	693	189	196	3.6	38.5	3.4
NE-3.5	5/14/19	0.58	1008	195.1	202.2	4.9	37.4	6.1

*BDL Below detection limit

There is a significant degradation of water quality from the upper (NE 3.5) to the lower (NE-3) part of the middle reach of North Empire Creek, as shown in Tables 10 and 11. Three mining-related seeps have been observed and sampled in this reach, which, as in the case of the Conqueror Mine seep, were not known before the Middle North Empire Creek Restoration Project was completed in early 2017. *It is not presently known* whether these seeps are directly connected to mine workings. The Gold Dirt seep could be connected to a mine pool associated with the Gold Fissure (G.F.) shaft atop the Pioneer and Gold Fissure mine dumps (aka Gold Dirt mine waste pile). These features are shown on Figure 7.

Both the Gold Dirt shaft and adit and the Tenth Legion shaft (also shown on Figure 7) are located near the top of the now-reclaimed Equator Mine waste pile (a.k.a. Gold Dirt and Tenth Legion mine dumps). That is certainly suspicious. The Gold Dirt shaft was partially filled and closed by the State of Colorado's Division of Reclamation, Mining and Safety (DRMS) in 2014. The seeps emerge from the area alongside and just above the stream that was formerly the toe of the Equator Mine waste pile, which encroached upon North Empire Creek.

If the mineralized seeps discharging between sites NE-3.5 and NE-3 are, in fact, surface expressions of underground mine *pools*, they represent an ongoing impact on stream quality. Mine drainage treatment would likely be the only viable remedy. Alternatively, the seeps may be discharge points for alluvial groundwater that has taken a flow path through residual mine waste materials, still remaining after the extensive removal operations were conducted. This would also represent an ongoing impact upon surface-water quality, but it might be possible to attempt further remedial mine waste-removal activities in the stream channel. Finally, these seeps may represent a *temporary* condition associated with the dewatering of a groundwater table that had been established in the Equator Mine and Gold Dirt Mine waste piles. The seeps were not discharging in August or October 2018. More investigation of the likely source of these seeps and their seasonal patterns of discharge is recommended. The quality of the mine-waste seeps is shown below in Tables 10 and 11.

It's possible that a series of cleverly designed tracer-injection studies could help to resolve these questions. However, it is clear that the quality of the mineralized seeps reflects a different concentration pattern (*water-quality fingerprint, perhaps*) and is also significantly higher in trace-metals concentrations and lower in pH than the adjacent surface waters flowing in North Empire Creek.

Figure 8 below clearly shows a decrease in *loading* down to monitoring site NE-3.5, where there had been an increasing load in the downstream direction, prior to restoration efforts. All values represent conditions on May 18, 2018, after all project work was completed, except for some remedial revegetation work that occurred later only in the Lower North Empire Creek Project area.

Figure 8 - Post-project loading profile in Upper and Middle North Empire Creek

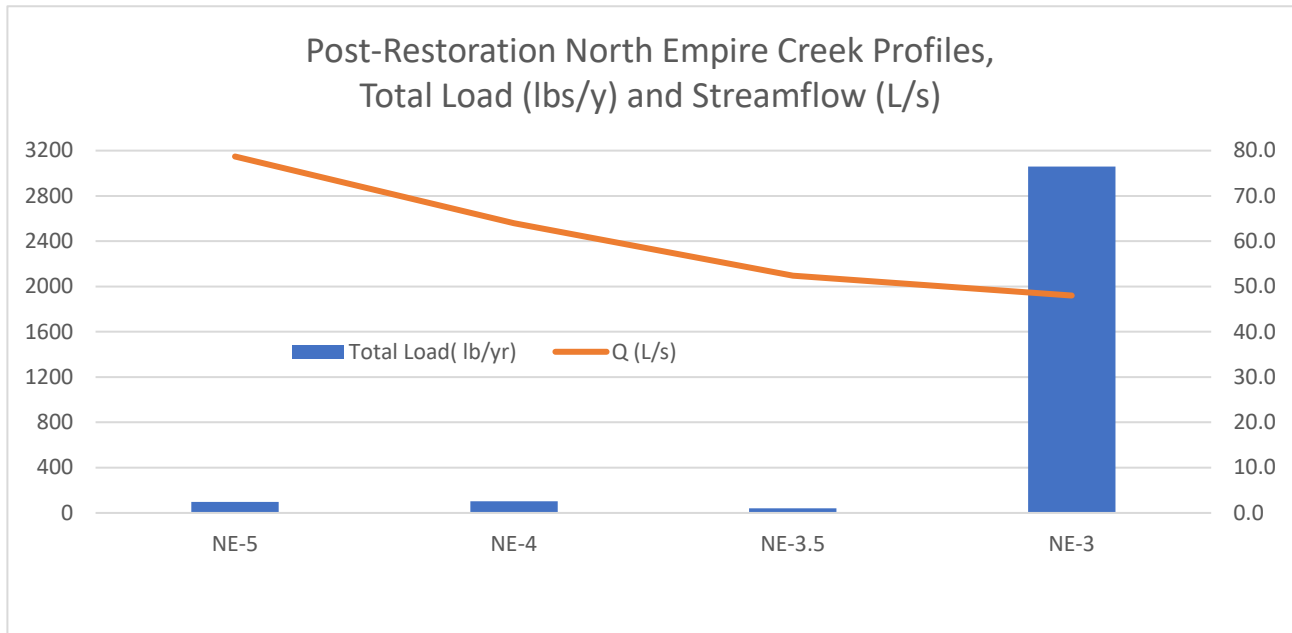


Table 10 - Middle North Empire Creek mineralized seeps impact on North Empire Creek at NE-3 (May2018)

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-3.5	5/18/18	1.85	29.7	BDL	22.4	BDL	23.5	5.6
Gold Dirt Seep	5/18/2018	0.074	1,410	573	345	7.7	56.5	3.7
Equator Combined Seeps*	5/18/2018	0.171	4,040	1,305	1,170	31.5	131	3.6
NE-3	5/18/18	1.7	608	137	148	BDL	23.5	4.7

*Upper and Lower Seep Flows were combined for flow measurement and sampling purposes

Table 11 - Contribution of known source loads in 2018, to actual measured load at NE-3

Date	5/18/18	5/18/18	5/18/18	5/18/18	5/18/18
Site ID	Measured TM load at NE-3.5 (lb/d)	Gold Dirt Seep TM load (lb/d)	Equator Seeps TM load (lb/d)	Sum of source loads	Measured load at NE-3
Al	0.30	0.56	3.72	4.58	5.56
Cu	0.06	0.23	1.20	1.49	1.25
Mn	0.22	0.14	1.08	1.44	1.35
Zn	0.23	0.02	0.12	0.38	0.22

In May 2018, there is surprisingly close level of agreement between the sum-of-sources of trace metals (TMs) loads, expressed in pounds/day (e.g., site NE-3 + Gold Dirt Seep + Equator Seeps) and the actual measured downstream trace-metals loads at NE-3. Table 12 provides the data supporting this conclusion. Figure 9 provides this same information in graphic form.

Figure 9 - Middle North Empire Creek loading sources, May 2018 sampling survey

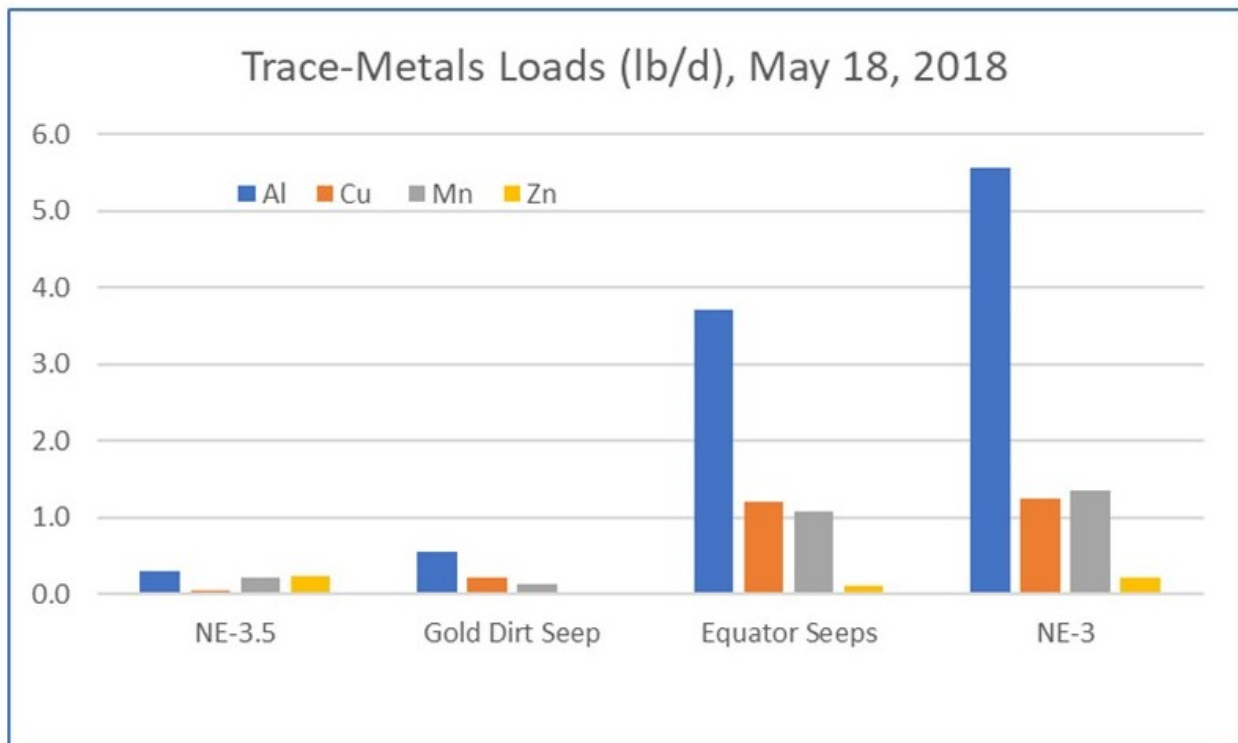


Table 12 - Middle North Empire Creek mineralized seeps impact at monitoring site NE-3, May 2019

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-3.5	5/14/19	0.58	1008	195.1	202.2	4.9	37.4	6.1
Gold Dirt Seep	5/14/19	0.051	5310	1520	1570	42.2	183	3.3
Equator Combined Seeps*	5/14/19	0.174	4530	1360	1280	34.5	163	3.3
NE-3	5/14/19	1.04	5472	1508	1538	43.8	176.4	3.2
*Upper and Lower Seep Flows were combined for flow measurement and sampling purposes								

In 2019, there was not close agreement between the sum of measured sources of trace metal (TM) loads between site NE-3.5 and the actual measured downstream trace metal loads at site NE-3. There is an apparent large gain in flow in the downstream direction in 2019. But, the increase in load cannot be explained by attributing an additional groundwater component to the measured sources. The cause of this was evaluated by accounting for the increased flow measured at site NE-3, adding a proportionate quantity of each mineralized source and using the measured quality of each source to calculate incremental groundwater-based loads. The sum of loads measured in surface water would then be added to the imputed groundwater-based loads to determine the sum of all loads. Unfortunately, the *mystery* source(s) are significantly greater than given by this explanation. Further monitoring is recommended to ascertain whether there are, indeed, additional sources of TMs loading in this reach. It would be improper to place too much confidence in this one set of monitoring data.

Very different water-quality results were observed at site NE-3 during spring runoff in 2018 versus 2019, as shown when comparing Tables 11 and 12. Although copper concentrations in 2018 were much better (e.g., lower) than in 2014, they were still elevated above levels of concern. The other metals, though, had concentrations during high flow in 2018 that would be quite acceptable (i.e. nontoxic) over the long term. Unfortunately, this was not the pattern observed in the 2019 lab analyses, when the concentrations of all TMs except zinc were worse (higher), even than in 2013, before any project-remediation work had been undertaken. Adding to this puzzle is the fact that the seep flows were nearly the same for both years. Tables 11 and 12 indicate that the Gold Dirt Seep did have higher trace metal concentrations in 2019 than in 2018, but not enough to explain the rather alarming (high-concentration) results at site NE-3 in 2019.

Table 13 - Contribution of known source loads in May 2019 compared to actual measured load at site NE-3

Date	5/14/19	5/14/19	5/14/19	5/14/19	5/14/19
Site ID	Measured TM loads at NE-3.5 (lb/d)	Gold Dirt Seep TM load (lb/d)	Equator Seeps TM load (lb/d)	Mystery source loads (lb/d)	Measured load at NE-3 (lb/d)
Al	3.15	1.46	4.24	21.79	30.63
Cu	0.61	0.42	1.27	6.14	8.44
Mn	0.63	0.43	1.20	6.35	8.61
Zn	0.12	0.05	0.15	0.67	0.99

Figure 10 - Middle North Empire Creek loading sources, May 2019 sampling survey

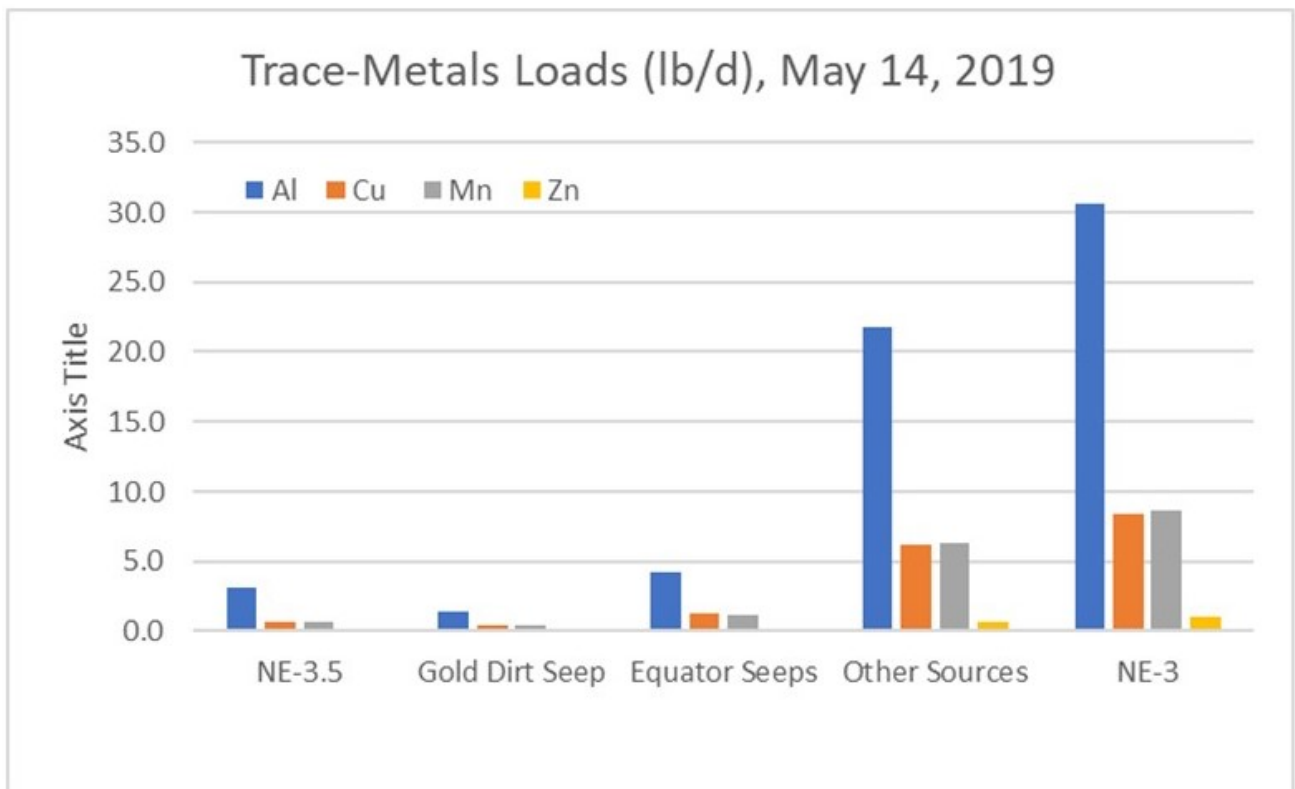


Figure 9 and 10 and Tables 10 through 13 indicate the change in water quality from monitoring site NE-3.5, which is upstream from the recently discovered mine-waste seeps, to below those seeps at monitoring site NE-3.



In 2018, the upper and lower Equator seeps have nearly identical water quality; whereas, the Gold Dirt seep has significantly lower TMs concentrations. In 2019, the upper and lower Equator seeps appear to have different water quality, the lower seep exhibiting significantly higher TMs concentrations. Still, the Gold Dirt seep exhibits much higher concentration of trace metals than does North Empire Creek at site NE-3.5. The concentrations of trace metals above and below the mine-waste seeps are given in Table 12.

The flow at site NE-3 was even lower in 2019 than in 2018. Please see the discussion on post-project hydrology (see above). This would seem to rule out the possibility that higher groundwater levels in 2019 would have caused the further degradation in water quality. Continuing monitoring of flow and water quality, especially during spring runoff conditions, is recommended to rule out potential sampling, laboratory analyses, and transcription errors reported by students.

Samples collected at site NE-3 for lower flow periods did not commence until 2017, after restoration work was completed. The USEPA’s ESAT Laboratory analyzed these recent samples. These lower flow samples, shown in the green-filled parts of Table 14, show striking similarities in the reported concentrations. These low-flow samples collected in 2017 and 2018 better represent the “new” average quality of North Empire Creek at site NE-3, better (lower) for copper, manganese, and zinc and worse for aluminum and nickel versus the pre-project conditions represented by the sample from 2013.

Table 14 - Water quality below the middle reach of North Empire Creek (site NE-3)

Site ID	Date	Flow cfs	Al ug/L	Cu ug/L	Mn ug/L	Ni ug/L	Zn ug/L	pH
NE-3	5/11/13*	1.29	770	756	560	BDL	229	3.5
NE-3	5/15/15	1.024	150	100	200	BDL	150	
NE-3	9/19/17		1610	507	393	8.12	47.4	
NE-3	5/18/18	1.7	608	137	148	BDL	23.5	3.6
NE-3	8/1/18		1850	581	363	8.1	229	3.6
NE-3	5/14/19	1.05	5472	1508	1538	43.8	176.4	3.2
*This is a pre-project comparison sample, collected and analyzed before any restoration work was done.								

 Low flow values
 High flow values

7.3 BIOLOGICAL QUALITY OF NORTH EMPIRE CREEK

West Denver Chapter of Trout Unlimited and Colorado School of Mines conducted bioassessment reconnaissance surveys in 2014 and 2015. Sampling and identification of macroinvertebrate populations was not possible because they were simply not present within North Empire Creek at that time. But, recently, a single stonefly nymph was observed at sampling station NE-4 during CCWF's October 18, 2018 water quality sampling event. This was a positive indication of the success of the reclamation work done as part of the Upper North Empire Creek Restoration project. That project addressed mining-related water quality impacts around the Conqueror Mine, near the headwaters of the creek.

The Middle North Empire Creek Restoration Project has successfully addressed impacts associated with mining features and the mine waste repository in the middle reach downstream to the point where newly discovered mine drainage is impacting water quality. Biological monitoring should be done for this drainage going forward. It is likely that macroinvertebrates will repopulate the Creek now that so much work has been done upstream of the NE-2 sampling station (including the work already done under the Lower North Empire Creek Restoration Project).

Figure 11 - Rundown Structure for Gold Dirt Run-on control



7.4 PHYSICAL/HABITAT

Physical habitat assessment protocols were not performed in the North Empire Creek watershed. This stream is not a likely candidate for reintroduction of fish or other organisms of a higher order than macroinvertebrates. There are obvious physical habitat problems that limit the aquatic life use of the stream. During hot summer periods and wintertime, flow in the creek is discontinuous, disappearing into the bottom substrate and reappearing well downstream at points where bedrock outcrops in the channel. The overall gradient of North Empire averages about 20% (Figure 7) and there are many sections with falls and cascades, which would also be barriers to normal fish migration. Moreover, there are no pools with holding water where fish could survive, especially during the winter months. Construction of such pools is not feasible given the continuously steep gradient.

North Empire Creek has been impacted by extreme sedimentation associated with past hydraulic mining activities. From the headwaters to water quality monitoring station NE-2, near the Aorta Mine, Sediment deposits 20-35 feet deep have been discovered during CCWF's reclamation activities. This sediment is highly porous and very mineralized in certain locations. Much of this contaminated sediment, but not all, has been removed during our project work. As noted above, surface water drains into this artificially created alluvial formation and disappears, leaving interspersed sections of dry stream channel.

7.5 GROUND WATER IMPROVEMENTS

Groundwater is associated with the sandy alluvial sediment deposits, which largely resulted from hydraulic placer mining in the late 1880s. This groundwater is under bedrock control, which results in significant mixing of surface and groundwater, everywhere bedrock-outcrops occur in the channel. Therefore, all improvements in surface water quality will accrue to groundwater quality, as well.

7.5.1 NUTRIENTS

The North Empire Creek Watershed has no significant non-mining related impacts. There is only one home in the entire watershed, and it is well removed from the stream channel. Nitrogen and phosphorous levels are quite low and representative of other pristine mountain water bodies, or at least, the reference conditions that have been established for such water bodies. None of the BMPs that were implemented in this watershed were aimed at nutrient reduction.

7.6 QUALITY ASSURANCE REPORTING

Detailed weekly field reports were compiled and submitted to CDPHE, DRMS and EPA during and immediately following construction. The contractor provided invoices from vendors, trip reports, mine waste haulage records, back-up information for labor, equipment and mobilization/demobilization costs. CCWF maintained a strong presence at the site during construction and kept close tabs on day-to-day activities.

7.7 RESULTS OF BMP OPERATION AND MAINTENANCE REVIEWS

CCWF conducted a field site review of BMP Operation and Maintenance needs with the project contractor in early April of 2018. A budget reallocation was submitted by CCWF and approved by CDPHE on April 23, 2018 to cover the cost of the remedial site activities. The following remedial tasks and activities were identified for the contractor on May 18, 2018.

Remedial Site Activities Required for Middle North Empire Creek Remediation Project

1. Reconstructed step pools, cascades and armored meander bends in the stream channel between the North/South Piles and the Equator Pile. Restored approximately 750 linear feet of the natural bedrock channel. Assured these features will be stable during much greater flows than experienced in 2016. The reconstructed channel should have the capacity to handle a runoff event with a 25-year recurrence interval. [Many of these features that were constructed during the initial project (2015-2016), were blown out during the very high (but not extreme) runoff that occurred in Spring 2016.]
2. Address poor revegetation results on Gold Dirt Pile, contaminated alluvial fan-removal area, east and west piles and the repository.
 - a. Engaged a soil scientist to collect and analyze representative soil samples from poorly revegetated areas to develop a more robust protocol for a remedial revegetation effort. Provided professional recommendations for soil amendments (Figure 12) and a more appropriate seed mix, including additional seed for mountain flowers in reclaimed meadow areas.

Figure 12 - Professional recommendations for soil amendments Letter of Certification

Letter of Certification

This memo is written to certify that this seed mix is true to label and has been duly tested by a fully accredited seed testing laboratory using rules sanctioned by the Association of Official Seed Analysts. The specifications of the seed used in the mix are as follows:

Common Name	Variety	Origin	Lot #	Purity	G+D+H	%PLS
Bromegrass, Mountain	Bromar	WA	1436-0	99.35	35 + 63 = 98	97.36
Western wheatgrass	Amiba	WA	1530-1	94.32	95 + 0 = 95	89.60
Indian ricegrass	Nezpar	WA	1634-1	99.72	97	96.73
Green needlegrass	Lodorm	MT	17-1-2	99.90	2 + 96 = 98	97.90
Slender wheatgrass	San Luis	WY	BG3391-16	99.09	98 + 0 = 98	97.11
Fescue, Hard	Durar	WA	L-A24M1N	98.60	80 + 0 = 80	78.88
Bluegrass, Big	Sherman	WA	1612-1	96.48	83 + 9 = 92	88.76
Fescue, Arizona	Redondo	MT	BG3388-15	95.51	94 + 0 = 94	89.78
Penslemom, Rocky Mountain	Bandera	WA	1630-0	97.08	93	90.28
Bluegrass, Canby	Canbar	ID	7DH131-26	98.97	24 + 67 = 91	90.06

Lot #	Number of Bags	Bulk Lbs. Per Bag
1	50 full	
1	5.41 partial	

Common Name	Lot #	Total Bulk Lbs.	Total PLS Lbs.	% Total Bulk Lbs.
Bluegrass, Big	1612-1	3.38	3.00	6.10
Bluegrass, Canby	7DH131-26	1.67	1.50	3.01
Bromegrass, Mountain	1436-0	12.33	12.00	22.24
Fescue, Arizona	BG3388-15	3.38	3.00	6.10
Fescue, Hard	L-A24M1N	3.80	3.00	6.86
Green needlegrass	17-1-2	6.13	6.00	11.06
Indian ricegrass	1634-1	6.21	6.00	11.20

- b. Mobilization on Tuesday May 8, 2018 included the following soil amendments:

- i. Gypsum pellets,
- ii. Lot 125 Eco-Flex Gypsum,
- iii. Biotic Earth Green,
- iv. Pelletized high calcium limestone,
- v. Tacking Agent 3,
- vi. Buffalo grass seed,
- vii. 4-6-2 rich lawn custom fertilizer blend with mycorrhizae-biochar and humate

Figure 13 - Watering Gold Dirt Waste Pile



- c. Hand broadcast pelleted lime, fertilizer and powdered lime.
- d. Applied Liquid fertilizer and Hydromulch to the parts of the site within reach of the Hydro seeder pump hose. [There were issues with the hydro seeder which delayed progress.] Four additional staffers were sent to the site to support hand application (Figure 13).

3. Demobilized after completing remedial tasks and activities.

8 COORDINATION EFFORTS

CCWF coordinated closely with the USFS Arapaho-Roosevelt National Forest and the USFS Abandoned Mine Program in Boulder, CO. CCWF obtained most current surveying information from USFS, which provided precise boundaries of mining claims and Forestlands in the project area. No USFS lands were affected by this project.

8.1 COORDINATION FROM OTHER STATE AGENCIES

DRMS was a major donor to the *upper*-reach project providing \$30,000 in support of that effort. DRMS also provided helpful technical guidance for revegetation efforts and runoff control. DRMS generously provided \$39,000.00, as Cash Match funding for the *middle*-reach project. DRMS was treated as a project sponsor (as was CDPHE and EPA) throughout the period of performance for our state contract.

8.2 OTHER STATE ENVIRONMENTAL PROGRAM COORDINATION

A Grading and Excavation permit and a BMP permit were issued by Clear Creek County for the middle-reach project. A new state stormwater permit was required for new areas of proposed disturbance.

8.3 FEDERAL COORDINATION

Since this project is located within EPA's Clear Creek/Central City Superfund Study Area, it was closely coordinated with EPA's Superfund program, as well as the Region VIII Nonpoint Source Program. Our project was approved for utilization of EPA's ESAT Laboratory as part of the agency's basin-wide metals characterization effort. The Federal Cooperator Contribution Laboratory Analysis by EPA's ESAT Lab was valued at \$38,960.00. In addition, a site-specific comfort letter was obtained from EPA regarding liability protection for CCWF under CERCLA.

8.4 OTHER SOURCES OF FUNDS

Cash Match from CDRMS	\$39,000.00
Compost from Clear Creek County valued	\$13,750.00
Special Road Maintenance by Clear Creek County	9,800.00
Rock Products Donation Clear Creek 32	\$27,140.00
Colorado School of Mines (CSM) Environmental	
Intensive Synoptic Sampling & Laboratory Analysis	\$25,300.00
TU and Mountain Pine Manufacturing WoodStraw	\$2,980.00
<u>CSM Senior Design Team Plans & Specifications</u>	<u>\$18,000.00</u>
<u>TOTAL</u>	<u>\$135,970.00</u>

9 SUMMARY OF PUBLIC PARTICIPATION

Public involvement in the project was garnered through continuing media coverage, project signage, outreach meetings with UCCWA, Clear Creek County, the Town of Empire and an educational booth display during the annual Sustaining Colorado Watersheds Conference. We also made presentations to the Upper Clear Creek Watershed Association, Clear Creek County Commissioners, Empire SWAP Planning Group and the 2017 Colorado School of Mines Mining Summit. In cooperation with Clear Creek County, we also have placed a large full color, fact-filled informational project sign at a highly visible location on County land, where all the project work for North Empire Creek has taken place (Figure 14).

Reclamation of the overall Lion Creek Watershed (including North Empire Creek) was heartily supported by the upper clear creek watershed community. The Town of Empire and the Clear Creek County Commissioners have expressed their support through official votes. The Upper Clear Creek Watershed Association has been very supportive of this effort. This project was incorporated into the adopted Upper Clear Creek Watershed Management Plan. The Freeport MacMoRan (FMI) Henderson Mine has been a technical partner providing reclamation consultation and funding for CSM 's involvement in senior design projects and the environmental field sessions. MillerCoors provided the major source of financial resources for the SEP compliance project in the upper reach of North Empire Creek. MolsonCoors also has provided major financial support (i.e., non-federal cash match) to CCWF for project management and program administration. The Frei Walstrum quarry donated rock materials for this project, also in the form of Non-federal In-Kind Match. Clear Creek County agreed to perform much-

Figure 14 - North Empire Creek informational project sign on County land



needed road maintenance on County Road 251, in order to facilitate the project which was another source of In-Kind Match for this project. This project received positive news media coverage in the Clear Creek Courant, the Firestarter and through an extended on-air interview with CCWF on KGYT radio in Idaho Springs.

Over the past 12 years, CCWF has enjoyed a longstanding partnership with the Colorado School of Mines. We have worked together on nearly a dozen projects of mutual interest through EPICs courses, Senior Design Projects and Summer Environmental Field Sessions. CSM

has helped enormously in the characterization of the environmental issues in the overall Lion Creek Watershed and in the development of site-specific reclamation plans. We had two senior design projects related to the middle-reach project and environmental field sessions from 2013-2016 and 2018 devoted to the North Empire Creek and Lion Creek problem areas. FMI agreed to support these efforts, financially in the amount of 25,000.00 per year. This was indirectly a source of match for this project.

Like the upper-reach, the middle-reach area contains significant USFS lands. We have coordinated and cooperated with USFS during joint surveying efforts and in the reclamation planning work in the Lion Creek Watershed. In 2012, we performed a reclamation project on behalf of USFS and Trout Unlimited valued at approximately \$80,000 in the Lion Creek drainage (Minnesota Mine Superfund Reclamation Site). We cooperated with USFS and Trout Unlimited's Abandoned Mine Program on a mine waste removal project in Lion Creek in 2016, as well. Trout Unlimited's West Denver Chapter has also been a technical partner on bioassessment work in upper and middle North Empire Creek. This was a source of match for this project.

Figure 15 - Staging Area follow-up revegetation effort



10 ASPECTS OF THE PROJECT THAT DID NOT WORK WELL

10.1 MAJOR SPRING RUNOFF EVENT

Stream stabilization in the vicinity of the Gold Dirt Pile was undone by a major spring runoff event in 2017. The channel was repaired during the winter of 2018, while crews were mobilized for the Lower North Empire Creek Project.

10.2 MINE WASTE REPOSITORY AND GOLD DIRT PILE REVEGETATION EFFORTS

Actual revegetation of the Mine Waste Repository and the Gold Dirt Pile was not deemed successful in 2017. There was a dramatic contrast in revegetation success at these locations in comparison to the North and South Pile and the Equator Pile sites. Hand broadcast seeding and hydro-seeding were again conducted in January and April of 2018, while crews were mobilized for the Lower North Empire Creek Project (Figure 14). Improvements in establishment of perennial grasses and forbs were observed in fall of 2018, despite a very hot and dry growing season that year.

11 FUTURE ACTIVITY RECOMMENDATIONS

Some real improvements have been observed in the quality of North Empire Creek since restoration work began in 2014. This is especially true for the upper and middle reaches of the stream, where there have been dramatic reductions in acidity, metal concentrations and mass loading of trace metals. Early signs of stream biota improvements are also occurring. The intermittent discharges from the mineralized seeps, which were first observed in May of 2017, do warrant ongoing monitoring, because they certainly are having an adverse impact on water quality that is observed at monitoring site NE-3 in 2018 and 2019. The seeps were not discharging during subsequent monitoring events in August and

October of 2018. Unfortunately, there was no stream flow at NE-3 (below the seep area) either, so it was not possible to measure any improvement in stream quality when the seeps were not discharging.

The water quality results have been less than we'd hoped for, despite truly diligent efforts by highly competent professional contractors, consultants and student engineers-in-training. Uncontrolled sources of contamination still exist. These sources were not evident before our project work was undertaken, because they were buried deeply under mine waste piles. We have indicated a number of potential avenues for further investigation and remediation in this final project report.

Removal of mine waste from the Gold Fissure mine waste pile has revealed a mineralized seep suspiciously close to the now-collapsed old fissure Mine adit. Removal of mine waste in the stream channel from the Gold Dirt mine waste piles (AKA Pioneer and Gold Fissure Dumps) revealed another mineralized seep which could be related to a mine pool associated with the now-collapsed (or previously backfilled) Gold Fissure mine shaft on top of the Gold Dirt Mine waste pile. It might also be an alternate groundwater flow path of North Empire Creek. Finally, two intermittently flowing seeps or springs were revealed near the toe of the former Equator pile before it was substantially removed to the repository in the middle project area. The water emanating from these seeps was sampled and analyzed for its quality. In each case it was significantly contaminated and different in quality from that in North Empire Creek. Follow-up investigations are needed to determine the sources of these seeps.

12 LIST OF APPENDICES

12.1 APPENDIX A – WQ NPS SAMPLING AND ANALYSIS PLAN NORTH EMPIRE CREEK AND LION CREEK

12.2 Appendix B - SEDIMENT LOADING ASSESSMENT FOR HOOSAC AND DUMONT BASINS SUBMITTED UNDER SEPARATE COVER

12.3 Appendix C – WQ NPS SAMPLING AND ANALYSIS PROJECT PLAN HOOSAC AND DUMONT GULCHES

Sampling and Analysis Plan

North Empire Creek and Lion Creek Restoration Projects

Submitted by:

Clear Creek Watershed Foundation



September 2017

Nonpoint Source Project Manager

Date

Nonpoint Source Project Quality Assurance Officer

Date

CDPHE NPS Program Coordinator

Date

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A - Sampling Project Management

A-1 -- Distribution List

Bonie Pate, Nonpoint Source Project Manager, Phone 303-692-3557

Tamara Allen, WQCD Restoration and Protection Unit Manager, Phone: 303-692-3554

Chris Theel, WQCD QA Officer, Environmental Data Unit, 303-692-3558

Dave Holm, CCWF Project Director, 303-567-2699

Diane Kielty, CCWF Project Manager, 303-916-4645

Peter Ismert, EPA Region VIII, 303-312-6753

Les Simms, EPA Region VIII, 303-312-6607

Timothy D. Steele, TDS Consulting Inc., 303-674-0266

Dr. Don Goodrich, US EPA Region 8, 303-312-6687

Scott Walker, TechLaw, Inc., EPA Region 8 Laboratory (303) 312-7726 - office

A-2 -- Sampling Project or Task Organization

Name	Project Title / Responsibility
Bonie Pate, CDPHE	Nonpoint Source Project Manager
Dave Holm, CCWF	CCWF Project Director
Diane Kielty, CCWF	CCWF Project Manager
Timothy D. Steele, TDS Consultants Inc.	CCWF, Water Quality Officer
Peter Ismert, EPA Region VIII	USEPA Project Officer (PO)
Les Simms, EPA Region VIII	USEPA Remedial Project Manager (RPM)
Peter Stevenson, USEPA	On Scene Coordinator, EPA Region VIII
Don Goodrich, US EPA Region 8; Scott Walker, Senior Chemist, TechLaw; Tom Wildman, PhD, CO School of Mines Civil Engineering Laboratory;	Laboratory Managers / Analysts

Table 1 - Sampling Project or Task Organization

A-3 -- Problem Definition / Background – Sampling Needs

1. Problem Statement:

Response activities have been conducted at the Clear Creek Site to control and/or remediate various inorganic constituent sources. These activities may or may not be completely effective and other response activities may need to be implemented. Therefore, the purpose of this investigation is to

determine if quality of surface water is sufficient to protect human health and the environment, and to determine whether or not remedial actions by this project improve water quality.

Multiple segments in the upper Clear Creek Watershed are on the WQCC 303(d) List of impaired waters for trace metals. This project proposes to remediate several of the high priority nonpoint sources, mostly comprised of mill tailings and waste rock piles that are the primary cause for the listings. The metals concentrations and acidity within the overall Lion Creek Watershed preclude the presence of aquatic life and contribute to impairments of fisheries and downstream drinking water supplies.

The purpose of the sampling and analysis plan for the Lion Creek Watershed is to evaluate the effectiveness of source removals undertaken at abandoned mine remediation projects within the North Empire Creek and Lion Creek sub-watersheds. It is intended to reveal improvement water quality in these waters, which are presently impaired or impacted by dissolved cadmium, copper, lead, zinc, and/or total iron.

The purpose of this SAPP is to provide guidance to ensure that all environmental data collection procedures and measurements are scientifically sound and of known, acceptable and documented quality and the sampling activities are conducted in accordance with the requirements of this project.

2. Intended Use of Data:

The results of this monitoring effort will help determine the following:

- Do concentrations of metals of concern (copper, zinc, lead, manganese, cadmium, iron) at 8 locations within the greater Lion Creek Watershed achieve established water quality standards?
- What are the likely sources of contamination that are still needing to be controlled so that stream reaches impacted from elevated metals can be removed from the 303(d) List?

A-4 -- Sampling Project or Task Description

1. General Overview of Project:

The overall purpose of this SAPP is to evaluate water quality in selected reaches of sub-drainages of the Lion Creek Watershed to meet the following goals:

- **Short-term:** to conduct site-specific characterizations that will assist in optimizing on-site remedial actions;
- **Intermediate:** to determine if and to what degree these projects are benefiting the reduction of water contaminants;
- **Long-term:** to document water quality improvements through measurable results with the ultimate outcome to meet standards leading to the de-listing of targeted remediation areas from the 303(d) List.

The data collected under this monitoring project will allow analysts and decision-makers to decide the effectiveness of source removal control actions and to determine if further action is warranted to adequately protect human health and the environment.

2. Sampling Project Locations and Protocol

Eight (8) locations (LC-3, LC-4, LC-5, NE-1, NE-2, NE-3, NE-4 and NE-5) will be monitored for this study encompassing both Lion and North Empire Creeks (Figure 1). Grab water quality samples and field measurement of specific conductivity and pH will be collected at each site. Discharge flow measurements will also be collected at each site where practical. Flow estimates will be correlated with collected flow data to facilitate loading calculations.

Sample locations are as follows:

LC-3: Lion Creek immediately above confluence with North Empire Creek.

LC-4: Lion Creek subjacent to uppermost mine site.

LC-5: Lion Creek Control site above uppermost mine site.

NE-1: North Empire Creek immediately above confluence with Lion Creek.

NE-2: North Empire Creek above county landfill. Site of Aorta tunnel.

NE-3: North Empire Creek culvert on Road 253.

NE-4: North Empire Creek subjacent to Conqueror mine complex.

NE-5: North Empire Creek above Conqueror mine complex. Control site.



Figure 1 - Lion Creek/North Empire Sampling Location

Coordinates of Sampling Locations			
Site #	Description	Latitude (decimal degrees xx.xxxx)	Longitude (decimal degrees -xx.xxxx)
LC-3	Lion Creek above N Empire Creek	39.77025° N	105.68497° W
LC-4	Lion Creek below Minnesota Mine site	39.77624° N	105.68944° W
LC-5	Lion Creek above Minnesota Mine site	39.77980° N	105.69036° W
NE-1	N Empire Creek above Lion Creek	39.77050° N	105.68422° W
NE-2	N Empire Creek above County landfill	39.77384° N	105.68244° W
NE-3	N Empire Creek above Rd 253 Culvert	39.77950° N	105.68064° W
NE-4	N Empire Creek below Conqueror Mine site	39.78362° N	105.68118° W
NE-5	N Empire Creek above Conqueror Mine site	39.78553° N	105.68206° W

Table 2 - Coordinates of Sampling Locations

3. – Sampling Project Timetable

	Station ID	Frequency
1	LC-3	Hi/Low – Monthly: June - October
2	LC-4	Hi/Low – Monthly: June - October
3	LC-5	Hi/Low – Monthly: June - October
4	NE-1	Hi/Low – Monthly: June - October
5	NE-2	Hi/Low – Monthly: June - October
6	NE-3	Hi/Low – Monthly: June - October
7	NE-4	Hi/Low – Monthly: June - October
8	NE-5	Hi/Low – Monthly: June - October

Table 3 - Sampling Project Timetable

A-5 -- Data Quality Objectives for Measurement Data

Response activities have been conducted at the Lion/North Empire Creek Site to control and/or remediate various inorganic constituent sources. These activities may or may not be completely effective and other response activities may need to be implemented. Therefore, the purpose of this

investigation is to determine if quality of surface water is sufficient to protect human health and the environment, and to determine whether or not remedial actions by this project improve water quality.

1. Data Precision, Accuracy and Measurement Range

Given the detailed synoptic monitoring that has already taken place in the Lion Creek Watershed, establishing the up and downstream limits of source loading areas is relatively straightforward. PARCCS are indicators of data quality; PARCCS goals are established to aid in assessing data quality. The following paragraphs define PARCCS parameters associated with this project.

a. Data Precision:

The precision of a measurement is an expression of mutual agreement among individual measurements of the same property taken under prescribed similar conditions. Precision is quantitative and most often expressed in terms of relative percent difference (RPD).

Comparing original and duplicate results will assess the precision of laboratory analysis. The RPD will be calculated for each pair of duplicate analyses using the following equation:

$$RPD = |S - D| / (S + D) / 2 \times 100$$

Where:

S = First sample value (original Value)

D = Second sample value (duplicate value)

Precision of reported results is a function of inherent field- related variability plus laboratory analytical variability, depending on the type of QC sample. Various measures of precision exist depending upon "prescribed similar condition." Field duplicate samples will be collected to provide a measure of the contribution to overall variability of field-related sources. Acceptable RPD limits for field duplicate measurements will be less than or equal to < 20% for aqueous matrices. Contribution of laboratory-related sources to overall variability is measured through Laboratory QC samples.

Since the objective of this investigation is to determine a change in water quality since the time of response action implementation, the following data are needed:

- Historical inorganic constituent concentrations of copper, zinc, lead, manganese, cadmium, iron in surface water in and leaving the targeted remedial areas. (*We do have 11 years' worth of historical data for the Lion Creek Watershed going back to 2006.*)
- Current and future inorganic constituent concentrations of copper, zinc, lead, manganese, cadmium in surface water in and leaving the targeted remedial areas. (*We are monitoring currently and this project will carry that effort into the future.*)

b. Data Representativeness:

Representativeness is a qualitative and quantitative parameter that is most concerned with the proper design of the sample plan and the absence of cross-contamination of samples. Acceptable

representativeness will be achieved through (1) careful, informed selection of sampling locations, (2) selection of testing parameters and methods that adequately define and characterize the extent of possible contamination and meeting the required parameter reporting limits, (3) proper gathering and handling of samples to avoid interferences and prevent contamination and loss, and (4) use of uncontaminated sample containers as the sample collection tool, eliminating the need for decontamination of sampling equipment and possible cross contamination of samples.

Representativeness is a consideration that will be employed during all sample location and collection efforts. The representativeness will be assessed qualitatively by reviewing the procedures and design of the sampling event and quantitatively by reviewing the laboratory blank samples. If an analyte is detected in a laboratory blank, any associated positive result less than five times the detected concentration of the blank may be considered undetected.

c. Data Comparability:

Comparability is a qualitative parameter. Consistency in the acquisition, handling, and analysis of samples is necessary for comparison of results. Data developed under this investigation will be collected and analyzed using standard EPA analytical methods and QC procedures to ensure comparability of results with other analyses performed in a similar manner. Data resulting from this field investigation may subsequently be compared to other data sets.

d. Data Completeness:

Completeness is a measure of the amount of usable data obtained from a measurement system compared to the amount that was expected to be obtained under correct normal conditions. Usability will be determined by evaluation of the PARCCs parameters excluding completeness. Those data that are reviewed and need no qualification or are qualified as estimated or undetected are considered usable. Rejected data are not considered usable. A completeness goal of 90% is projected for the data set collected for this investigation. Completeness is calculated using the following equation:

$$\% \text{ Completeness} = (DO/DP) \times 100$$

Where:

DO = Data obtained and usable

DP = Data planned to be obtained

e. Data Sensitivity:

Sensitivity is the achievement of method detection limits and depends on instrument sensitivity and sample matrix effects. Therefore, it is important to monitor the sensitivity of data-gathering instruments to ensure that data quality is met through constant instrument performance. Instrument sensitivity will be monitored through the analysis of blanks.

A-6 -- Training Requirements and Certification

CCWF along with its contractor Water Quality Specialists will ensure that qualified, experienced, and trained staff perform or oversee all data collection and sampling tasks. Each entity involved in this project is responsible for the safety of its employees.

A-7 -- Documentation and Records

The USEPA Region VIII laboratory will submit their standard analytical data reports to the USEPA RPM. Each data report will contain a case narrative that briefly describes the number of samples, the analyses, and any noteworthy analytical difficulties or QA/QC issues associated with the submitted samples. The data report will also include signed chain-of-custody forms, analytical data, and a QC package. The laboratory will keep the original data, however the USEPA PO can request a copy of the raw data (if needed). An electronic copy of the data will also be supplied to the RPM. The analytical data will be formatted to be compatible with USEPA's STORET database.

B - Measurement / Data Generation and Acquisition

B-1 -- Sampling Process Design

1. Rationale for Selection of Sampling Sites:

The field procedures are designed so that the following occurs:

- Sample collection is consistent with project objectives. Samples are collected in a manner so that data represent actual Site conditions.

The general goal of the field investigation is to obtain surface water quality data before and after remedial actions have been implemented.

2. Sample Design Logistics:

	Type of Sample / Parameter / Matrix	Number of Samples	Sample Frequency	Sampling Period
Biological	Macro grab sample	1	Annual	August
	Flow	2	Bi-annual	June/October
Physical	Temperature	8	Bi-annual	June/October
	pH	8	Bi-annual	June/October
	Conductivity	8	Bi-annual	June/October
Chemical	Selected metals	8	Bi-annual	June/October
	Hardness	8	Bi-annual	June/October

Table 4 - Sample Design Logistics

B-2 -- Sampling Methods

Samples collected during this investigation will consist of surface water, field blanks, and duplicate samples. All sample collection procedures are outlined in the following SOPs, which have been derived from WQCD protocols:

- SOP 1, Surface Water Sampling
- SOP 2, Storm Event/Snowmelt Surface Water Data Collection
- SOP 3, Sample Custody
- SOP 4, Packaging and Shipping of Environmental Samples
- SOP 5, Field Logbook Content and Control
- SOP 6, Control of Measurement and Test Equipment

QC samples will be collected, handled, and shipped in accordance with these procedures.

1. Sampling Needs:

Parameter / Matrix	Sampling Method	Sampling Procedures	Sample Container	Sample Preservation
Metals	Total	grab	Nalgene	none
Metals	Dissolved	grab	Nalgene	Nitric acid
Hardness	Total	grab	Nalgene	none
Temperature	meter	composite	none	none
pH	probe	composite	none	none
Conductivity	meter	composite	none	none

Table 5 - Sampling Needs

2. Equipment Needs:

Parameter / Matrix	Sampling Equipment	Equipment Decontamination /Cleaning Method	Equipment Inspection / Maintenance (include methods and dates)	Spare Parts / Back-up Equipment Needed
Metals/ stream	Nalgene	Bottles clean and sealed by lab	When picked up from lab	Filter pump
Hardness/ stream	Nalgene	Bottles clean and sealed by lab	When picked up from lab	None
pH/stream	Meter/Probe	DI water rinse	Before and during use	Battery, cleaning brushes
Conductivity/ Temperature	Meter Probe	DI water Rinse	Before and during use	Battery, cleaning brushes

Table 6 - Equipment Needs

B-3 -- Sample Handling and Custody

Custody and documentation for field and laboratory work are described below, followed by a discussion of corrections to documentation.

1. Field Sample Custody and Documentation:

The information contained on the sample label and the chain-of-custody record will match. The purpose and description of the sample label and the chain-of-custody record is discussed in the following sections.

2. Sample Labeling and Identification:

An alphanumeric coding system will identify each sample collected during sampling events. The coding system will provide a tracking record to allow retrieval of information about a particular sample and to ensure that each sample is uniquely identified. Sample numbers will correlate with locations to be sampled.

Sample identification numbers will begin with the letters abbreviating the stream (e.g. LC-1 for Lion Creek) to identify the surface water sampling location. The third character represents the station number. These are identified on the site map. The date and time will identify the time of day that a sample was collected. The following is an example of a sample number shown as LC-1:

LC = Lion Creek (stream)
1 = station number (location from upstream to downstream)
Dec-04 15:30 (date and time)

Sample labels or tags will be completed and taped to the appropriate sample containers. Preprinted labels may be used. These labels will be written with indelible ink and secured with waterproof tape and will include the sample identification number, the parameter(s) to be analyzed, the sampler's initials, and the preservative used. At the time of sample collection, a member of the field team will add the date and time of sample collection.

3. Chain-of-Custody Requirements:

Chain-of-custody procedures and sample shipment will follow the requirements of EPA's ESAT Laboratory. The chain-of-custody record is employed as physical evidence of sample custody and control. This record system provides the means to identify, track, and monitor each individual sample from the point of collection through final data reporting. A complete chain-of-custody record will be provided as required to accompany each shipment of samples.

4. Sample Packaging and Shipping:

Samples will be packaged and shipped in accordance with SOP 4. Samples will be placed in a cooler with ice. Custody seals will be placed over at least two sides of the cooler, and then secured by tape. All samples will be shipped to:

USEPA Region VIII laboratory
 16194 W. 45th Drive
 Golden, CO 80403
 (303) 312-7700 (main lab)
 (303) 312-7708 Lab Office

5. Field Logbooks and Records:

Each field team in accordance with SOP 5 will maintain Field logbooks. The log is an accounting of the accomplishment of scheduled activities, and will duly note problems or deviations from the governing plan and observations relating to the field program.

B-4 -- Analytical Methods Requirements

Analytical methods, reporting limits, holding times, and QC analyses are discussed below (Table 7). Laboratory analysis will be conducted at the EPA Region VIII Laboratory by the ESAT contract. Surface water samples collected under this QAPP will be analyzed for the following parameters using analytical methods and detection limits identified below:

Parameter	EPA Method	MDL	Units	Holding Time
Calcium (dissolved)	200.7	0.2	Mg/L	6 months
Magnesium (dissolved)	200.7	0.2	Mg/L	6 months
Metals (dissolved and total recoverable)				
Aluminum	200.7	0.03	Mg/L	6 months
Arsenic	200.8 or 200.9	0.001	Mg/L	6 months
Cadmium	200.8 or 200.9	0.0002	Mg/L	6 months
Copper	200.8 or 200.9	0.001	Mg/L	6 months
Iron	200.7	0.02	Mg/L	6 months
Lead	200.8 or 200.9	0.0001	Mg/L	6 months
Manganese	200.7	0.005	Mg/L	6 months
Zinc	200.7	0.002	Mg/L	6 months

Table 7 - Surface Water Laboratory Analyte List

MDL - Method Detection Limit; NA - Not Applicable

The reporting limits are presented in the above table. If the result is between the instrument detection limit (MDL) and the reporting limit, the value will be reported as an estimated concentration and qualified by the laboratory. The achievement of the IDL depends on instrument sensitivity. It is therefore important for the laboratory to monitor the sensitivity of data-gathering instruments to

ensure data quality through constant instrument performance checks.

Holding times are storage times allowed between sample collection and sample analysis when the designated preservation and storage techniques are employed. Required holding times must be considered when determining the method of shipment. Holding times and preservation for each analytical method used in this investigation are provided in the work plans.

To provide an external check of the quality of the field procedures and laboratory analytical data, field duplicate samples will be collected at a rate of 5% per media/event and submitted to the EPA Region VIII laboratory, in accordance with standard QA protocol. Duplicate samples provide a check for sampling and analytical error. Duplicate samples that will be analyzed for this investigation are discussed in the Work Plan. Equipment rinsate blanks will also be collected for this investigation.

In addition to the external QA/QC controls, the laboratory maintains internal QA procedures. Internal QC samples may include laboratory blanks (i.e., method blanks, preparation blanks), laboratory duplications, matrix spikes, and laboratory control samples (known standards).

B-5 -- Quality Control Requirements

Documentation modification requirements are described in SOP 5. For the logbooks, a single strikeout initialed and dated is required for documentation charges. The correct information will be entered in close proximity to the erroneous entry. All deviations from the guiding documents will be recorded in the field logbook (s). Any modifications to chain-of-custody forms will be made on all copies.

1. Field QC Checks:

Duplicates and equipment or bottle blanks are the types of QC samples that will be collected in the field. Each field duplicate will be collected at a single sampling location and collected identically and consecutively over a minimum period of time. This type of field duplicate measures the total system variability (field and laboratory variance), including the variability component resulting from the inherent heterogeneity of the medium. Blank samples will be collected to ascertain contaminants in the laboratory-supplied bottles or preservatives. Field duplicate and blank samples will be collected at a minimum frequency of one per 20 samples per media/event (5%).

2. Laboratory QC Checks:

USEPA Region VIII laboratory will follow all laboratory QC checks, which may include matrix spikes, laboratory control samples, laboratory duplicates and laboratory blanks (i.e., method blanks, preparation blanks).

Laboratory custody procedures are provided in the laboratory's QA management plan, upon receipt at the laboratory, each sample shipment will be inspected to assess the condition of the shipping cooler and the individual samples. This inspection will include measuring the temperature of the temperature

blank within the cooler to document that the temperature of the samples is within the acceptable criteria (4+/-2 degrees Celsius), if samples are cooled, and verifying sample integrity. The pH of the samples will also be measured, if preserved with an acid or base. The enclosed chain-of-custody records will be cross-referenced with all of the samples in the shipment. These records will then be signed by the laboratory sample custodian and copies provided to the EPA. The sample custodian will continue the chain-of-custody record process by assigning a unique laboratory number to each sample on receipt. This number will identify the sample through all further handling. It is the laboratory's responsibility to maintain internal logbooks and records throughout sample preparation, analysis, data reporting, and disposal.

EPA Region VIII laboratory will be used as the laboratory for this investigation. Samples collected during this project will be analyzed in accordance with methods determined by the EPA (see laboratory Quality Management Plan).

The methods to be used for chemical analysis will be determined by the EPA. The holding time requirements for each analytical method are determined by the analytical methods.

3. Data Analysis QC Checks:

QC data are necessary to determine precision and accuracy and to demonstrate the absence of interferences and/or contamination of glassware and reagents. Each type of laboratory-based QC sample will be analyzed at a rate of 5% or one per batch (batch is a group of up to 20 samples analyzed together), whichever is more frequent. Results of the QC will be included in the data package and QC samples will consist of laboratory duplicates, laboratory blanks, MSs and LCS/LCSDs, whichever is applicable, and any other method-required QC samples.

Laboratory blank samples will be analyzed to assess possible contamination so that corrective measures may be taken, if necessary. Laboratory duplicate samples are aliquots of a single sample that are split on arrival at the laboratory or upon analysis. Results obtained for two replicates that are split in a controlled laboratory environment will be used to assess laboratory precision of the analysis. MS and LCS analyses may be used to determine both precision and accuracy.

B-6 -- Instrument/Equipment Testing, Inspection and Maintenance

Equipment required for sampling, health and safety, documentation, and field parameter monitoring is presented in this SAPP. Field preparatory activities include review of SOPs, procurement of field equipment, laboratory coordination, confirmation of Site access (if necessary), as well as a field-planning meeting that includes field personnel and QA staff.

Clean polyethylene sample containers (or cubitainers) will be pre-rinsed with an aliquot of the water to be sampled, and then emptied before collection and preserving (as required) samples in the field. If sample containers are pre-preserved, sample water will be filled directly into the container without rinsing.

B-7 -- Instrument / Equipment Calibration and Frequency

Calibration is prepared in the laboratory by dissolving a known amount of a standardized compound in an appropriate matrix or dilution. The final concentration calculated from the known quantities is the true value of the standard. Where applicable, reference standard solutions will be traceable to the National Institute of Standards and Technology or other nationally recognized source. The analysis results obtained from these standards are used to prepare a standard curve and, thereby, quantify the compounds found in the environment samples. The number of calibration standards is prescribed by each individual analytical method procedure.

A description of the field instruments used to gather, generate, or measure data is provided below. Measurements will include flow measurements and surface water pH, temperature, and specific conductance. Portable meters will be used to obtain field measurements. Commercial available calibration standard solutions are used for the pH meter. Tap water is used to calibrate the conductivity / pH meter. The instrument will be calibrated prior to use each day and as often as needed to maintain calibration in accordance with the manufacturer's instruction.

Calibration of laboratory equipment will be based on written procedures approved by ESAT laboratory management. Instruments and equipment will be initially calibrated and continuously calibrated at required intervals as specified by either the manufacturer or more updated requirements (e.g., methodology requirements).

Records of initial calibration, continuing calibration and verification, repair and replacement will be filed and maintained by the laboratory. Calibration records will be filed and maintained at the laboratory location where the work is performed and may be required to be included in evaluation data reporting packages.

Equipment / Instrument Type	Calibration Frequency	Standard or Calibration Instrument Used
pH meter / YSI	Prior to each use	Standard Solutions
Conductivity-Temp/ YSI	Prior to each use	Tap water

Table 8 – Equipment / Instrument Calibration Chart

B-8 -- Inspection / Acceptance Requirements for Supplies

Internal QC checks will be conducted throughout the project to evaluate the performance of the project team during data generation. All internal QC will be conducted in accordance with the applicable procedures listed below:

- All project deliverables will receive technical and QA reviews prior to being issued. Completed review forms will be maintained to the project files.
- Corrective action of any deficiencies is the responsibility of the ESAT manager.

All supplies and consumables will be inspected by the field sampling team or other contractors prior to acceptance, to ensure that they are in satisfactory condition and free of defects.

B-9 -- Data Acquisition Requirements

Certain sampling sites have been established during previous investigations. Any non-direct measurement data acquisition will conform to SOPs and/or manufacturers guidelines.

B-10 -- Data Management

The resultant sample data will be delivered by ESAT to the USEPA RPM as hard copy and as an electronic data deliverable to CCWF. Field data will be collected by field personnel and submitted to CCWF. CCWF will develop and maintain a database of field analysis data. This database will be used to generate annual data reports. Electronic copies of all project deliverables, including graphics, will be maintained by project number. Electronic files will be routinely backed up and archived by CCWF, who will prepare and submit annual data reports to CCWF. Ultimately, all data generated pursuant to this QAPP/SAPP will be entered into the Water Quality Sharing Network or other state-approved data repository.

C - Assessment and Oversight

C-1 -- Assessment and Response Actions

Performance assessments are quantitative checks on the quality of measurement systems. Performance assessments for the laboratory can include “blind” reference samples, samples of known concentration. The samples may be included in the sampling stream to evaluation laboratory performance.

System assessments are qualitative reviews of different aspects of project work to check on the use of appropriate QC measures and the functioning of the QA system. System assessments include field and office audits. USEPA and CCWF will each be responsible for overseeing the quality control aspects of each of their contractors. USEPA is responsible for the overall Quality Control assessment of the project and may perform system audits at any time.

Response Actions will be implemented on a case-by-case basis to correct quality problems. Minor response actions taken in the field to immediately correct a quality problem will be documented in the applicable field logbook and verbally reported to the CDPHE project officer and USEPA RPM. Major response actions taken in the field will be approved by the USEPA RPM prior to implementation of the change. Such actions may include revising field procedures, resampling and/or retesting, changing sampling frequency, etc. Quality control problems that cannot be corrected quickly through routine procedures require implementation of a corrective action request. This action can be initiated by the RPM or field personnel, if the need arises.

C-2 -- Reports

QA reports to the RPM will be provided whenever quality problems are encountered. Field teams will note any quality problems in the applicable logbook or other form of documentation.

D - Data Validation and Usability

D-1 -- Data Review, Validation and Verification

CCWF will rely upon its water Quality Officer Dr. Timothy D. Steele to review data and make decisions regarding accepting, rejecting, or qualifying the data. Such decisions will be based upon an examination reported results in the context of results for other proximate sites and based upon the QA data provided by the lab.

D-2 -- Validation and Verification Methods

Data validation consists of examining the data packages against pre-determined standardized requirements set forth in this QAPP and referenced methods. The validator examines the reported results, QC summaries, case narrative, instrument calibration runs, chain-of-custody information, raw data, QC samples, calibration, blank results, and other information as appropriate to the data package. The validator checks to determine if project quality objectives were met in the analysis of the data and qualify data according the National Functional Guidelines for data review.

CCWF will employ the validation and verification methods that the WQCD Environmental Data Unit uses to verify data precision and accuracy as presented in the Division's online SAPP Template.

D-3 -- Reconciliation with Data Quality Objectives

The analytical data will be provided to all interested parties and decision makers. The data will be examined to determine overall water quality trends and if stream standards are likely to be achieved and how far from meeting those standards impaired stream segments in the upper Clear Creek Watershed might be. In addition, the data collected for this project will be used to determine if additional source removal will be necessary at the Site.

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Sediment Sampling and Analysis Project For Hoosac Gulch and Dumont Basins

Final Report

Clear Creek Watershed Foundation
3-15-2019

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Project Description and Purpose

The Clear Creek Tributaries Sediment Control and Metal Removal Project was a partnership effort between Colorado Department of Transportation (CDOT), Colorado Department of Public Health and Environment (CDPHE) and the Clear Creek Watershed Foundation (Foundation). The project was undertaken to prevent contaminated runoff and sediment from discharging into Clear Creek. Project construction was completed on March 18, 2015.

The Clear Creek Tributaries Project is located at two different sites along Clear Creek in segment COSPCLO(2c) in Clear Creek County. One site is very near the mouth of Fall River, at the outlet of Hoosac Gulch. The other is at the outlet of an unnamed tributary located just downstream of the mouth of Mill Creek at milepost 235.5 on I-70, near Dumont. Both sites are a short distance upstream of Idaho Springs.

Clear Creek crosses the Colorado Mineral Belt from Silver Plume near the headwaters, downstream through Idaho Springs. There are a number of small watersheds (ranging in size from ~ 1/8 sq. mi. to >2 sq. mi.) draining from the north side of I-70 into Clear Creek that have experienced significant mining in the past. These are steep side-tributaries with a southern aspect that typically have intermittent flows. Frontal weather systems and intense, short duration thunderstorms can mobilize substantial loads of contaminated sediments from mine waste and mill tailings in the drainage ways. Hoosac Gulch and the Unnamed Tributary located near Dumont are good examples of such mining impacted tributaries coming into Clear Creek from the North.

Access to the previously mined areas that drain into these small runoff channels is extremely difficult. It is doubtful that these areas will ever be reclaimed. They would be ongoing sources of metals and acidity unless their runoff was captured and detained, preventing contaminated solids from entering Clear Creek. Hoosac Gulch is located 1 1/4 mile west of Idaho Springs. It is a prime example of an inaccessible drainage with an abundance of mine waste in the upper (roadless) portion of the watershed on Bellevue Mountain, and a large mill tailings pile near its mouth. The Unnamed Tributary (Dumont Gulch) located about 0.7 miles east of Dumont also has numerous inaccessible mine waste piles in its drainage way

The primary goal of this Project was to significantly reduce the load of particulate metals in drainage that reaches Clear Creek. This includes the TMDL target metals: cadmium, copper and zinc. The detention basins put in place at Hoosac Gulch and near Dumont were also designed to facilitate efficient maintenance operations to allow the captured contaminated mine waste sediment to be removed entirely from the drainage area. CDOT has accepted the responsibility to maintain the functionality of these sediment control basins and to remove sediment to an off-stream location whenever they are full. Construction of sediment control basins was a high priority, as reflected in CDOT's Sediment Control Action Plan for the I-70 corridor between the Eisenhower Tunnel and the bottom of Floyd Hill.

The overarching environmental goal of this project is to improve water quality in Clear Creek Segment 2c to become fully supporting for Aquatic Life Use. While this project will not achieve that goal on its own, it will contribute to the required loading reductions that have been established to meet that goal.

CSM Sampling Methods

One significant benefit of having tributary sediment basins in place is that the mass loading of contaminated mine waste metals being prevented from going into Clear Creek can be measured. Two

sampling events have taken place. The first, an Environmental Field Session conducted by the Colorado School of Mines (CSM), occurred in May of 2016.

The measured quantity and chemical quality of the sediment captured in basin were used to calculate the toxicity and metal load being prevented from entering Clear Creek by the two tributary sediment basins. The metals of interest for which Colorado risk-based standards have been promulgated include: aluminum, cadmium, copper, iron, lead, manganese, and zinc.

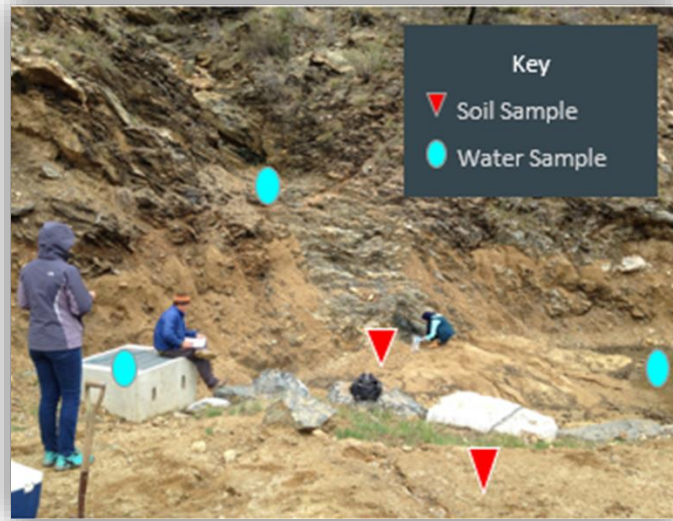


Figure 1 - CSM Water and Soil Sample Field-Testing Dumont Basin

The Colorado School of Mines chemical characterization of the contained sediment included a modified Toxicity and Metals Leaching Assessment (TCLP) with a focus on the metals for which standards exist, along with 21 additional metals and metalloid elements. Field measurements included mineral acidity, alkalinity, pH, Eh, conductivity, flow and volume determinations. Water samples related to the solid samples were collected and field-tested for pH, specific conductance, and or mineral acidity. (See Figure 1)

Simple systematic random sampling was used to evaluate the average concentrations of chemical constituents of

concern (COC) in the surficial soils. To implement the sampling, a geo-referenced systematic grid was established over the entire surface area of each sediment basin dividing each site into 30 cells of equal area. (Please see Appendix A - CSM Sampling and Analysis Procedures Hoosac & Dumont Gulches). Each grid was scaled to the size of the basin. There were 30 sub-samples per basin where surface samples (15

Dumont and Hoosac Gulch Data Summary				Metals							
				Al	Cd	Cu	Fe	Mn	Pb	Zn	
EPA MCLs (mg/L)				N/A	1	N/A	N/A	N/A	5	N/A	
RCRA (mg/L)				0.05	0.0	1.3	0.3	0.05	0.0	5	
CDPHE Acute (mg/L)				3.421	0.0027	0.13	1	2.99	0.0646	0.143	
CDPHE Chronic (mg/L)				0.488	0.0004	0.009	N/A	1.65	0.00465	0.124	
Hardness (mg/L CaCO ₃)				25	25	25	25	25	25	25	
Detection Limit (mg/L)				0.0045	0.00031	0.0004	0.00025245	0.0003169	0.0018325	0.0004048	
Sample Name	Test Type	Latitude	Longitude	Al	Cd	Cu	Fe	Mn	Pb	Zn	
Dumont Lower	CDMG	39.764494° N	105.588960° W	2.372	0.040	3.114	0.301	5.2786	0.006	5.247	
Dumont Lower	TCLP	39.764494° N	105.588960° W	0.384	0.011	0.720	0.007	1.350	0.007	1.290	
Dumont Upper	CDMG	39.764418° N	105.588930° W	0.109	0.003	0.143	0.012	1.845	BDL	0.613	
Dumont Upper	TCLP	39.764418° N	105.588930° W	0.274	0.005	0.425	0.006	2.528	0.010	0.753	
Dumont Rock Wall	CDMG	39.764523° N	105.590744° W	205.56	0.095	0.528	475.83	19.484	0.377	2.749	
Dumont Rock Wall	TCLP	39.764523° N	105.590744° W	1.643	0.003	0.069	11.562	1.608	0.017	0.386	
Hoosac Sediment	CDMG	39.753559° N	105.554086° W	0.141	0.002	0.073	0.101	1.358	0.002	0.719	
Hoosac Sediment	TCLP	39.753559° N	105.554086° W	0.446	0.007	0.219	0.163	1.882	0.068	0.766	
Hoosac Moss Soil	CDMG	39.753462° N	105.554098° W	1.360	0.017	0.556	16.236	1.060	0.004	3.181	
Hoosac Moss	CDMG	39.753462° N	105.554098° W	1.711	0.009	0.728	8.026	0.808	0.002	1.661	

Table 1 - CSM Data Summary of Dumont & Hoosac Gulches - 2016

cm depth) were collected of at least 100 g from each cell. There was one composited sample by combining the sub-samples, which were duplicated for analysis. At Dumont, water was present outside of the basin and next to the road. Water samples were obtained from inside the outlet structure casing and outside the casing. Soil samples were collected from the retained sediment.

CSM sampling methods consisted of a distometer and tape measure to approximate sediment volume, a Multimeter to capture pH and Conductivity. Using ArcGIS, CSM identified mine waste piles up the gulch and collected both water and moss samples. Two leaching tests were performed on the combined, sieved sample: the CDMG field leach test (CDMG) (Herron et al., 2001), and a modified toxicity characteristic leaching procedure (TCLP) test (U.S. EPA, 2002). In addition to the volumetric measurement of the sediment in each gulch basin, to the extent possible, pH and conductivity measurements were made in the laboratory (See Appendix B-CSM Laboratory Analysis Data).

CSM Volume Characterization Results

CSM conducted a volume assessment for the Hoosac and Dumont Gulches and provided characterizations. Their assessment of Hoosac Gulch showed a sediment basin capture volume of 2,275 ft³. The observed sediment volume was 65 ft³. The Hoosac Gulch basin is located at Lat: 39° 45' 11.43028" N / Long: 105° 33' 14.47675 W

	Hoosac	Dumont
Length (ft)	5577	3182
Area (acres)	167	82.6
Average Slope	0.32	0.30
Curve Number (CN)	79.5	81.4
Sedimentation Basin Storage Volume (ft³)	2275	9521
Precipitation to Fill Basin (in)	0.62	0.74

Table 2 - CSM Hoosac & Dumont Gulches Sediment Capture Volume Results

CSM’s assessment of the Dumont basin showed a basin volume of 9,520 ft³ and a sediment volume of 226 ft³. GPS readings showed that the Dumont basin is located at Lat: 39° 45' 52.26428" N / Long: 105° 35' 20.29804" W. (See Table 2)

During CSM’s sampling event, water was present in the outlet structure casing and in the basin. The water samples were taken from 3 locations:

- Water dripping into the basin from the mine-impacted area upstream;
- Water retained in the basin and water standing inside the Outlet structure (casing 1);
- Soil Samples taken from the retained sediment and just above the cross-drain structure (casing 2) adjacent to I-70.



Figure 2 - Water Samples Collected Inside and Outside the Cross-Drain Structure Hoosac Gulch

The water samples collected inside and outside the cross-drain structure below the sediment basin, near the highway frontage road, yielded nearly identical analytical (ICP) results.

Therefore, the source of the water in the cross-drain may have water from the road, and not from the basin. Algae found along the gulch was tested for to see whether or not it was taking in and treating some of the metals found in the water. The algae had low concentrations of metals in comparison to the water found. Therefore, the algae was not providing significant metal uptake.

Hoosac Gulch water samples shows certain metals that exceed the CDPHE acute toxicity standards for aquatic life by significant margins. Cadmium, copper and zinc are of highest concern, especially zinc,

CSM Basin Analytics

The Hoosac basin pH and Conductivity results are shown in Table 3. Metal levels were quite elevated in the basin and in the mine drainage flowing into the basin. A comparison of the upstream and downstream pH values with the casing values show that the values are very similar.

Sample Type	Sample Location	pH	Conductivity (µS/cm)
Water	Hoosac Outside Casing	3.91	848
Water	Hoosac Casing	4.00	808
Water	Hoosac Downstream	3.75	931
Water	Hoosac Upstream	3.59	865
Soil	Sediment in Basin	3.72	146
Moss	Upstream	NA	NA

Table 3 - Hoosac Gulch pH and Conductivity Results

which is around 60x higher than the applicable stream standard. The graph (Figure 3) also shows that the upstream flow closer to the source of the mine drainage has higher concentrations of metals.

Comparison of Hoosac Water Samples

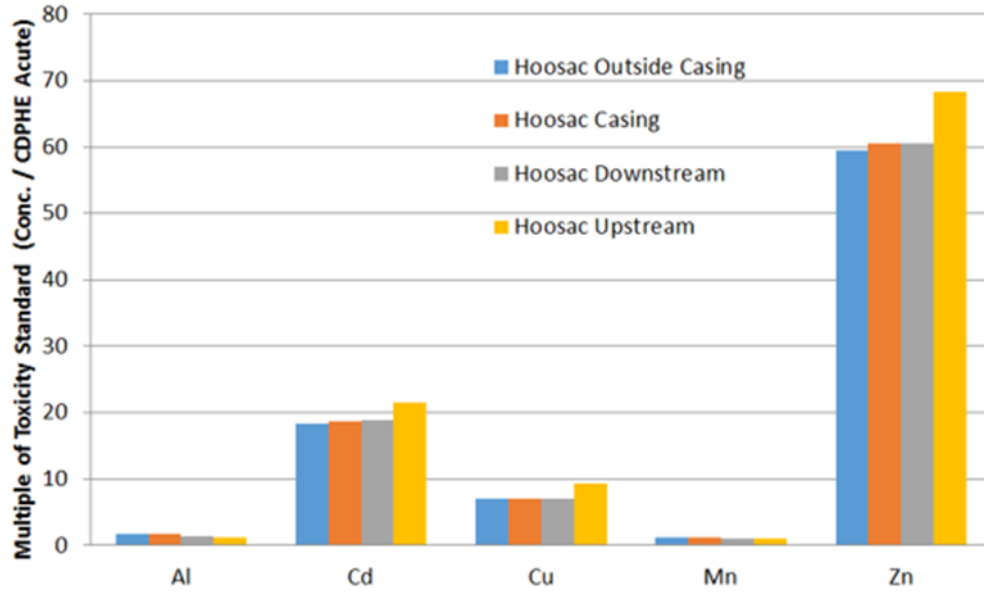


Figure 2 - Hoosac Water Samples Metals Concentration Graph

In the comparison of Dumont water samples that were extracted as leachates from the sediment samples collected, the metals levels are presented as ratios of the observed concentrations to the applicable CDPHE water quality standard. For example, as shown below in Figure 4, the observed copper concentration in the Dumont sediment leachate is approximately 150 times the value of the chronic stream standard copper.

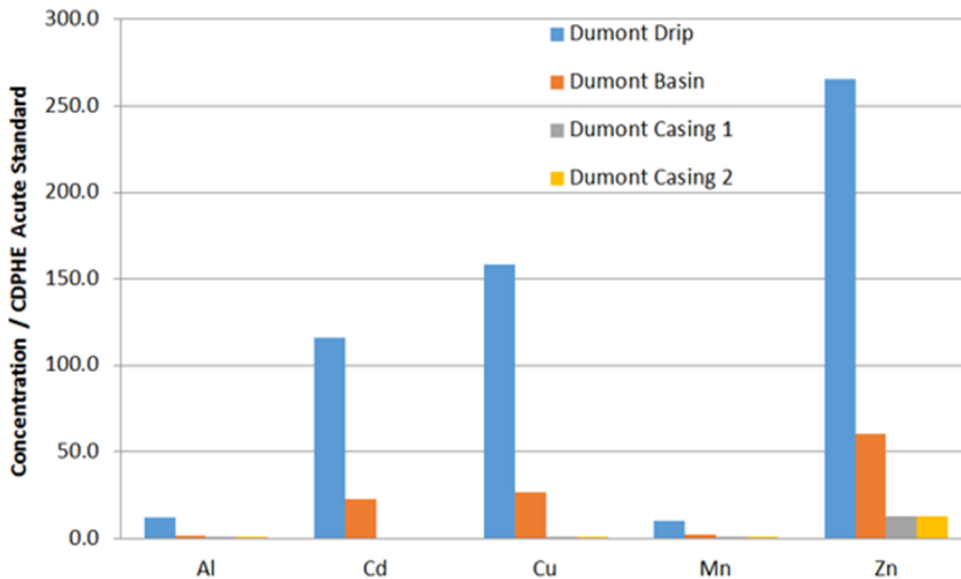


Figure 3 - Dumont Water from Sediment Samples Metals Concentration Graph

CCWF Sampling Methods

The Clear Creek Watershed Foundation sampled the basins on July 24, 2017. Samples were delivered to Colorado Analytical Lab for total metals analysis that same day. The Dumont Basin sub-sample location flags are shown in Figure 5. The samples were collected as grab samples. CCWF prepared a primary sample and a duplicate sample from the 20 sub-samples collected from each Basin. The samples were dried in the lab, prepped for analysis and analyzed for their total metals content. Sampling methods, measurement techniques, analytical procedures and data generation are discussed in detail in Appendix A.



Figure 5 - Dumont Basin Sub-Sample Location Flags

CCWF Basin Analytics

The results of the laboratory analysis of the sediment samples collected from Dumont and Hoosac Gulch tributary basins were delivered by Colorado Analytical Laboratories on August 4, 2017. The chemical results are shown below.

Sample Type*	Sample Name	Al	Cd	Cu	Fe	Mn	Pb	Zn	
Basin Soil Composit 2017 (mg/kg)	Dumont Basin D-1	8298.8	1.2	487.6	29788.6	284.3	1118.3	285.31	
	Dumont Basin D-Dup	9737.5	1.6	544.5	34246.5	314.6	985.9	339.37	
	Hoosac Basin H-1	5487.2	0.7	99.6	8448.8	298.3	97.8	121.75	
	Hoosac Basin H-Dup	5736.2	0.7	120	8950.7	294.2	150.3	134.76	
Test Method	EPA SW-846-6020	Please see method description in Appendix A							
EPA Risk-based screening levels contaminated sediment to GW		3000	0.3	28	350.0	28	0.002	370	

Table 4 - Dumont & Hoosac Basins Sediment Geochemistry - CCWF Sampling Results 2017

All levels exceed Colorado Department of Public Health & Environment (CDPHE), Hazardous Materials & Waste Management Division Groundwater Protection Values for soil cleanup actions. Therefore, the maintenance plan calling for off-site removal of accumulated sediment was warranted.

The picture below is of the Hoosac basin, shortly after it was constructed. Since then only 6.4 m³ of sediment has accumulated in the basin. One storm parked and pouring over the headwaters of Hoosac



gulch and Bellevue Mountain could take the remaining volume capacity in a matter of hours.

The full storage capacity of the Hoosac Basin is 64.5 m³. An example **Aluminum load** calculation for Hoosac Basin is shown below. Please note the Hoosac Sediment Basin Metal loading table, as well just below the example calculation.

Figure 6 - Hoosac Basin Post-Construction Photo

[Al Concentration (5487 mg/kg)] X [Bulk Sediment Density (1.3 kg/m³)] X [Basin Volume (1.84 m³)] ÷ [1000(unit conversion)] = 13 kg. This is the Aluminum load (kg) *presently* stored in the Hoosac Basin. When full of sediment, the basin will contain 459 kg of Aluminum, or 0.46 metric tons. This will be removed to a repository and prevented from entering Clear Creek. The metal loads in the existing captured sediment as well as the expected load at the Hoosac Basin’s full capacity are presented below. The bulk of the metal load would consist of Aluminum and Iron- well over a metric ton. Meanwhile, the TMDL target metals Cd, Cu, Pb and Zn would only account for about 27 kg at full capacity.

Hoosac Gulch Basin Sediment Sample H-1 July 2017							
Metal Parameter	Al	Cd	Cu	Fe	Mn	Pb	Zn
Concentration (mg/kg)	5487.2	0.7	99.6	8448.8	298.3	97.8	121.75
Existing Volume (m ³)	1.84	1.84	1.84	1.84	1.84	1.84	1.84
Existing Load (kg)	13.1	0.002	0.24	20.2	0.71	0.23	0.29
Full Basin Volume (m ³)	64.3	64.3	64.3	64.3	64.3	64.3	64.3
Full Basin Load (kg)	459	0.06	8.3	706	25	8.2	10
Hoosac Gulch Basin Sample H-D July 2017							
Metal Parameter	Al	Cd	Cu	Fe	Mn	Pb	Zn
Concentration (mg/kg)	5736.2	0.7	120	8950.7	294.2	150.3	134.76
Existing Volume (m ³)	1.84	1.84	1.84	1.84	1.84	1.84	1.84
Existing Load (kg)	13.7	0.002	0.29	21.4	0.70	0.36	0.32
Full Basin Volume (m ³)	64.3	64.3	64.3	64.3	64.3	64.3	64.3
Full Basin Load (kg)	479	0.06	10.0	748	24.6	12.6	11.3
Average Basin Metal Load at Hoosac Gulch							
Average existing load (kg)	13	0.002	0.26	20.81	0.71	0.30	0.31
Average full basin load (kg)	469	0.1	9.2	727.2	24.8	10.4	10.7

Table 5 - Hoosac Sediment Basin Metal Loading

Dumont Basin Sample D-1							
Metal Parameter	Al	Cd	Cu	Fe	Mn	Pb	Zn
Concentration (mg/kg)	8299	1.2	487.6	29788.6	284.3	1118.3	285.31
Existing Volume (m ³)	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Existing metal Load (kg)	69	0.01	4.06	247.84	2.37	9.30	2.37
Full Basin Volume (m ³)	270	270	270	270	270	270	270
Full Basin Load (kg)	2913	0.42	171.15	10455.80	99.79	392.52	100.14
Dumont Basin Sample D-D							
Metal Parameter	Al	Cd	Cu	Fe	Mn	Pb	Zn
Concentration mg/kg	9737.5	1.6	544.5	34246.5	314.6	985.9	339.37
Existing Volume (m ³)	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Existing Load (kg)	81	0.01	4.5	285	2.6	8.2	2.8
Full Basin Volume (m ³)	270	270	270	270	270	270	270
Full Basin Load (kg)	3418	0.56	191	12021	110	346	119
Average Basin Metal Load at Dumont							
Average existing load (kg)	75	0.01	4.3	266	2.5	8.8	2.6
Average full basin load (kg)	3165	0.49	181	11238	105	369	110

Table 6 - Dumont Sediment Basin Metal Loading

These tables show the volume of the current accumulations of sediment and the full basin volume capacities in conjunction with the total metals analyses of the sediment. Clearly, the Dumont basin yields greater metal removal than the Hoosac basin.

Conclusions

The results from CCWF's sampling effort provided the most direct answer to the Initial fundamental question: How much metal would be prevented from reaching Clear Creek after being trapped in the Hoosac and Dumont sediment basins? This Sediment Loading Assessment is based on sampling and laboratory analysis of mine waste impacted sediments contained in these two sediment basins. The answer required a computation of the volume of sediment stored in each basin, plus the analytical results for total metals in the trapped sediment.

Because of the specific geochemical constituents found in the sediment, the highest bulk metal loads are associated with aluminum and iron in both basins. For example, when the Dumont basin is full, over 11 metric tons of iron will have been stored, prior to removal during a maintenance operation. But, the Dumont basin at full capacity would also contain significant amounts of trace metals, including copper (181 kg), lead (369 kg) and zinc (110 kg). These have been the TMDL target contaminants in the various iterations of the 303(d) list of impaired water for segment 2c of Clear Creek. Since maintenance will be done, as needed and not on annual, or other regular basis, the loading removal accounting (truck load count) will be done by CDOT, accordingly. An annual load reduction, albeit misleading, can be obtained for each of the TMDL target metals and for each basin from Tables 5 and 6. The Average Annual Load Reductions shown at the bottom of page 10 portray about one year's (14 months) worth of sediment capture for each basin.

The Hoosac basin has less than 25% of the storage capacity of the Dumont basin. It also has lower capture rates of the TMDL target constituents. However, presumably, any removal of these metals from the stream system would decrease the degree of impairment in this segment of Clear Creek. Cadmium is the most persistent TMDL target constituent in Segment 2c of Clear Creek. Unfortunately, neither basin will do much to address the cadmium issue. Cadmium is present, but in low concentrations in both drainages and their associated sediments.

The CSM 2016 Field Session group drew the following conclusions from their sampling investigations. Water that comes into contact with the sediment in either or both basins will become toxic to aquatic organisms. For example, in the case of Hoosac Basin, Zinc levels were 60 times higher than the acute water quality standard for Zinc. Meanwhile, the observed copper concentration in the Dumont

sediment leachate is approximately 150 times the value of the stream standard for copper. This was demonstrated through the use of the CDMG field leach test and a modified toxicity characteristic leaching procedure (TCLP) test, as described in Appendix A.

The sediment basins were constructed 14 months prior to CSM’s sampling effort. In both the Dumont and Hoosac basins the water drip concentrations coming into the basins are higher than the water concentrations within the basins. Based on the basin volume and the *observed* accumulation rate, CSM concluded that it would take 49 years to fill with sediment. However, because of the propensity of stationary convective storms to develop over the small drainages alongside I-70 in Clear Creek County, including Dumont and Hoosac Gulches, any single storm event could fill these basins with contaminated sediment in any given year, even while that event’s contribution to the overall watershed might be minor. In fact, a single localized storm in 2014 completely filled the Dumont basin. A crude sediment basin was present at the Dumont site, before it was re-deigned and re-constructed as part of the Tributary Basins Sediment Control and Metal Removal Project.

CSM concluded that the Hoosac Gulch basin has high concentrations of metals and acid forming materials present in the accumulated sediment. Extrapolating from the current rates, this basin will take 47 years to fill with sediment. That is not a reliable estimate, however. As already noted, sediment accretion is a flashy phenomenon, not a steady incremental process. The runoff containment in the basins should withstand a 25-year design storm, a 0.616” precipitation event over a 6-hour period. The basins are subject to relatively frequent maintenance inspections by CDOT.

Finally, it is worth considering a bigger question regarding the value of constructing tributary basins akin to those at Dumont and Hoosac gulches. These basins were constructed pursuant to a Sediment Control Action Plan (SCAP) that had been developed by CDOT for the I-70 corridor in Clear Creek County. In the lexicon of CDOT’s MS4 stormwater management permit, a tributary basin is positioned near the outlet of a natural ephemeral tributary that mixes with the runoff from the Highway Right-of-Way (ROW) in the vicinity of Clear Creek. The concept of Tributary Basin was identified as a nonpoint source best management practice for runoff *not* subject to permitting requirements, but adversely impacting the receiving waters. Under its permit, CDOT is only responsible for runoff generated within its Right-of-Way. But this BMP would offer the possibility of controlling and isolating contaminated runoff flowing onto the ROW, while improving its quality. Most importantly, CDOT committed to maintaining these facilities over the long run.

It’s that last point that tips the balance in favor of these tributary basins. Structures, like these, would be ill advised if they were not subject to regular and reliable maintenance operations. They must be maintained in a condition capable of managing (routing, storing, discharging) natural seasonal variations in runoff draining from their flow capture areas, or sub-watersheds. Without such attention these systems would fail over time and could even become hazardous.

Average Annual Load Reduction

Metal Parameter	Al	Cd	Cu	Fe	Mn	Pb	Zn	Cumulative Annual metal load Captured (kg)
Hoosac Average Annual load (kg)	13.0	0.002	0.26	20.9	0.71	0.30	0.31	35.5
Dumont Average Annual load (kg)	75.0	0.01	4.3	266	2.5	8.6	2.6	359.0

Appendix A - Sediment Sampling and Analysis Project Plan

Sediment Sampling and Analysis Project Plan

Hoosac Gulch

and

Dumont Basins:

Covering field sampling and laboratory analysis of sediment conducted by the Colorado School of Mines in 2016 and the Clear Creek Watershed Foundation in 2017

Hoosac Gulch
and
Dumont Basins:
Sediment Sampling and Analysis Project Plan

Clear Creek Watershed Foundation
Contracting Entity

June 7, 2017

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A - Sampling Project Management

A-1 -- Distribution List

NAME	Project Title/Responsibility
Ben Moline (CCWF Board President)	Stakeholder Group
Dave Holm (CCWF Executive Director)	Project Manager
Diane Kielty (KDP Consultant)	Project Team
Tim Steele, PhD	Data Quality Officer
Bonie Pate	NPS Project Manager and NPS Quality Control Officer

A-2 -- Sampling Project or Task Organization

Name	Project Title / Responsibility
Bonie Pate	NPS Quality Control Officer
Dave Holm (CCWF Executive Director)	Project Manager
Jonathan O. (Josh) Sharp, PhD, Associate Professor	Colorado School of Mines Field Session Supervisor
Thomas Wildman	CSM Project QA Officer – SAPP responsibilities
Diane Kielty	Field / Sampling Leader
Colorado Analytical	Laboratory Manager / Leader

A-3 -- Problem Definition / Background – Sampling Needs

The Clear Creek Tributaries Sediment Control and Metal Removal Project is located alongside Clear Creek (segment COSPCL02c) in Clear Creek County, a short distance upstream of Idaho Springs. Clear Creek crosses the Colorado Mineral Belt from Silver Plume through Idaho Springs. There are a number of small watersheds (ranging in size from ~ 1/8 mi. to >2 mi) draining from the north side of I-70 into Clear Creek that have experienced significant mining in the past. These are steep side-tributaries with a southern aspect that typically have intermittent flows.

Frontal weather systems and intense, short duration thunderstorms can mobilize substantial loads of contaminated sediments from mine waste and mill tailings in the drainage ways. Access to many of these previously mined areas is difficult and even impossible for vehicles in some cases. Therefore, many of these areas will not be reclaimed and will be ongoing sources of metals, acidity and nutrients- that is, unless the runoff is captured and detained, so that contaminated solids can be removed and prevented from entering Clear Creek. Hoosac Gulch and the Unnamed Tributary located near Dumont at I-70 milepost 235.5. are examples of such mining impacted tributaries coming into Clear Creek from the North.

Hoosac Gulch is a direct tributary of segment COSPCL02c of Clear Creek, located 1 1/4 mile west of Idaho Springs, Lat: 39° 45' 11.43028" N / Long: 105° 33' 14.47675 W. It is a prime example of an inaccessible drainage with an abundance of mine waste in the upper (roadless) portion of the watershed and a large mill tailings pile near its mouth. The Unnamed Tributary located at milepost 235.5, about 0.7 miles east of the confluence of Mill Creek with Clear Creek at Dumont Colorado, Lat: 39° 45' 52.26428" N / Long: 105° 35' 20.29804" W, also has numerous inaccessible mine waste piles in its drainage way.

The primary goal of the Hoosac Gulch and Dumont drainage contaminated mine waste sediment control and metal removal projects is to significantly reduce the loading of particulate metals, including the TMDL target metals cadmium, copper and zinc, from reaching Clear Creek. Important secondary goals in these project areas include reduction of total phosphorus and sediment loading to Clear Creek. Construction of sediment control basins was a high priority, as reflected in CDOT's Sediment Control Action Plan for the I-70 corridor between the Eisenhower Tunnel and the bottom of Floyd Hill.

The environmental goal of this project is to improve water quality in Clear Creek Segment 2c to become fully supporting for Aquatic Life Use. While this project will not achieve that goal on its own, it will contribute to the required loading reductions that have been established to meet that goal.

I – Problem Statement

The detention basins put in place at these locations were designed to facilitate efficient maintenance operations to allow the captured contaminated mine waste sediment to be removed entirely from the drainage area.

II – Intended Use of Data

The quantity (mass loading) of contaminated mine waste metals being prevented from going into Clear Creek by the detention basins.

A-4 -- Sampling Project or Task Description

The measurable results for this SAPP will be used to determine the effectiveness of the sediment

Basins constructed as part of the Clear Creek Tributaries Sediment Control and Metal Removal Project.

I – General Overview of Project

The project will focus on a chemical characterization and loading assessment for sediment in Hoosac Gulch and Dumont sediment basins.

CCWF will collect soil samples for total metals analysis by Colorado Analytical Lab. The results from this sampling effort will provide the most direct answer to the question: How much metal is being prevented from reaching Clear Creek as a result of being trapped in the Hoosac Gulch and Dumont sediment basins? The answer will require a computation of the volume of sediment stored in the basin plus the total metals analytical results.

The Colorado School of Mines chemical characterization of the contained sediment will include a modified Toxicity and Metals Leaching Assessment (TCLP) with a focus on metals including Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg 279.553-R, Mg 285.213-R, Mn, Na, Ni, P, Pb, S, Se, Si, Sr, Tl, V, Zn, Sn, Mo, Sb, Ti plus acidity/pH, conductivity and volume determination. If possible, a water sample related to the solid samples (such as a seep, storm water runoff, or other associated water) will be collected, and field-tested for pH, Eh, specific conductance, and alkalinity or mineral acidity. It is expected that most this data can be provided by early Summer 2017.

Simple systematic random sampling will be used to evaluate the average concentrations of chemical constituents of concern (COC) in the surficial soils. To implement the sampling, a geo-referenced systematic grid will be established over the entire surface area of each sediment basin dividing each site into 30 cells of equal area. (Please see Figures 1 and 2). We will scale each grid to the size of the basin. There will be 30 sub-samples per basin where surface samples (15 cm depth) will be collected of at least 100 g from each cell. There will be one composited sample by combining the sub-samples, which will be duplicated for analysis. We will sieve the composite to <2 mm for at least 1 kg of final composite sample. Two leaching tests will be performed on the combined, sieved sample: the CDMG field-leach test (CDMG) (Herron et al., 2001), and a modified toxicity characteristic leaching procedure (TCLP) test (U.S. EPA, 2002).

A field survey and sampling trip will be made 3-weeks after the SAPP has been approved by CDPHE/NPS. In addition to the volumetric measurement of the sediment in each gulch basin, to the extent possible, pH and conductivity measurements will be made in the laboratory.

Pre-field activities involve the following:

- preparing the work plan and data quality objectives (DQOs) for field sampling, sample analyses, and data reporting
- procuring the field sampling equipment
- coordinating site access and scheduling field sampling

Information inputs include:

- Coordinate maps for the Hoosac Gulch and Dumont Basins
- List of Colorado's "risk-based" concentrations for metals of concern in Clear Creek.

Field Activities include:

- Randomized grid sampling of surficial soils for metals.
- Field sieving of samples unless samples are sand-sized or smaller particles. The lab will perform any further required sieving.
- Preparation of composite samples of surficial soils subjected to the Total Metals analysis by Colorado Analytical Lab and the Toxicity Characteristic Leaching Procedure to be performed by CSM

TCLP and subsequent analysis of the leachate for metals to evaluate the potential leachability of metals from contaminated sediment to groundwater and surface water in concentrations that exceed levels of concern.

Spatial Boundaries: Samples to be collected within the boundary of the sediment basins are designed to characterize the average concentration for each regulated metal in surface sediments within each basin.

Temporal Boundaries: The samples will be collected as grab samples at one point in time. There are no plans to conduct temporal or time-weighted sampling because the conservative nature of the analytes of concern (metals) renders them unlikely to change quickly in concentration over time.

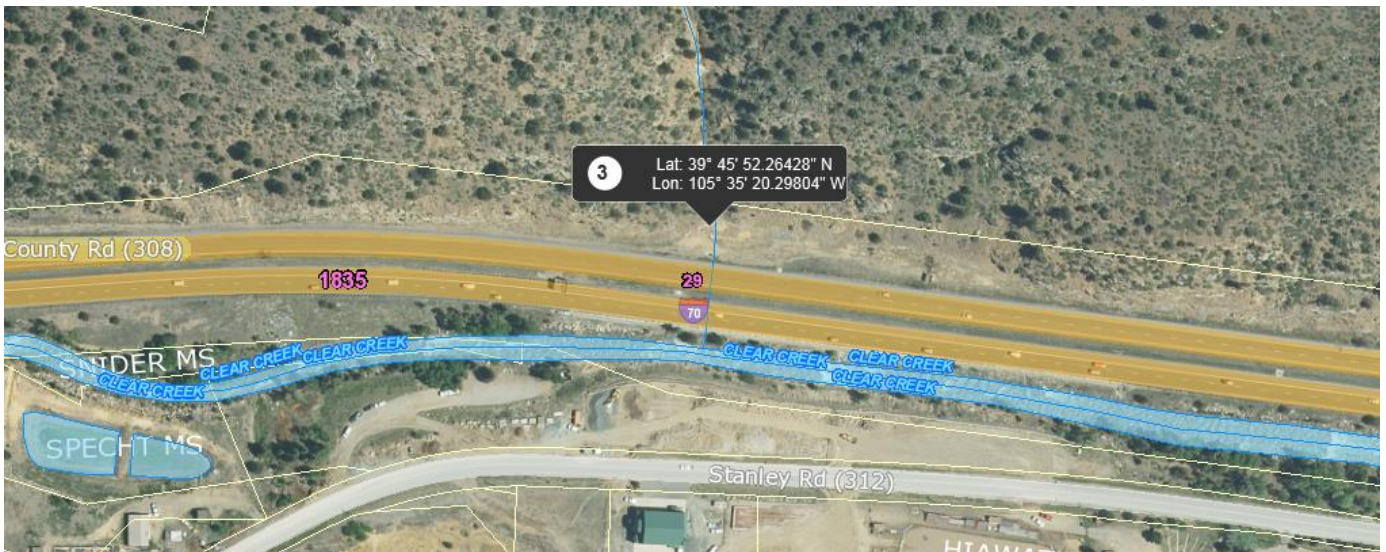
Chemical constituents: Metals for which there are corresponding Colorado risk-based standards promulgated. These metals include: aluminum, cadmium, copper, iron, lead, manganese, and zinc.

II – Sampling Project Locations

Map 1 - Hoosac Gulch Coordinates



Map 2 - Dumont Sediment Basin Coordinates



Sampling Timeline Overview & Responsibilities							
Goal	Activity	Method	Location(s)	Projected Start Date	Reoccurrence	Anticipated Date of Completion	Responsible Party
Sediment Quality	Sediment Chemistry Sampling (metals)	EPA SW-846-6020	Hoosac Gulch & Dumont Basin	July 2017	None	July 2017	CCWF

Sampling Locations			
Site #	Description	Latitude	Longitude
1	Hoosac Gulch	39° 45' 11.43028" N	105° 33' 14.47675" W
2	Dumont Basin	39° 45' 52.26428" N	105° 35' 20.29804" W

III – Sampling Project Timetable

Major Tasks	J	F	M	A	M	J	J	A	S	O	N	D
Field Sampling Event							x					
Sample Preparation (Compositing, etc...)							x					
Lab analysis (CSM & Colorado Analytical)							x					
Data processing, analysis & reporting								x				

A-5 -- Data Quality Objectives for Measurement Data

a. Data Precision, Accuracy and Measurement Range:

Precision will be determined by comparison of the analytical results for duplicate samples. There will be 2 composite samples from each basin for a total of 4 composite samples. Two laboratories will be used each receiving 4 composite samples, 2 from each basin.

In order to determine precision and accuracy the labs will prepare and evaluate spiked samples. We are going to compare the values based on the known value of the spiked sample, which will help to determine the degree of accuracy in our analytical procedures.

Matrix

Matrix	Parameter	Measurement Range	Accuracy	Precision
Sediment	Selected Metals	ppb	Parameter Dependent	To be determined based on comparative analysis of 4 duplicate samples, 2 from each basin

b. Data Representativeness:

The composite analysis of multiple sub-samples is designed to maximize data representativeness.

c. Data Comparability:

The Toxicity and Metals Leaching Assessment methodology is based on a sampling design used repeatedly by DRMS, CSM, CCWF and others.

d. Data Completeness:

Quality Control check analyses to verify precision and accuracy for the analytical protocol will be assured through comparison of 2 duplicate composites for each basin, analyzed by two separate laboratories.

Key Parameters	No. Valid Samples Anticipated	No. Valid Samples Collected and Analyzed	Percent Complete
Al, Cd, Cu, Fe, Pb, Mn, Zn	2 samples from each basin provided to 2 labs	4 Anticipated	100% Anticipated

A-6 -- Training Requirements and Certification

Senior engineering students will be used through the Colorado School of Mines Department of Civil and Environmental Engineering (CEE). The students will be participating in a faculty supervised CEE Field Session for academic credit.

A6a - Training Logistical Arrangements

Student Training	Frequency of Training / Certification
CSM Field Team Sampling Protocol	2 Pre-sampling site visits
CSM Laboratory Protocol	CSM Campus Laboratory

A6b - Description of Training and Trainer Qualifications

Thomas Wildeman, Dept. of Chemistry & Geochemistry, Professor Emeritus
Jonathan O. (Josh) Sharp, PhD, Associate Professor

A6c - Documentation and Records

Field data sheets chain of custody forms are provided by Colorado Analytical Laboratories, Inc. Chain of custody will follow criteria used by Colorado Analytical Laboratories, Inc. Holding Times and Preservatives will be as required in EPA method SW-846-6020, which is readily available online: <https://www.epa.gov/sites/production/files/2015-07/documents/epa-6020a.pdf>.

B - Measurement / Data Generation and Acquisition

B-1 -- Sampling Process Design

a. Rationale for Selection of Sampling Sites:

Hoosac Gulch and the Unnamed Tributary located near Dumont at I-70 milepost 235.5 are mining impacted tributaries coming into Clear Creek from the North. The detention basins put in place at these locations were designed to facilitate efficient maintenance operations to allow the captured contaminated mine waste sediment to be removed entirely from the drainage area. The

measurable results for this SAPP will be used to determine how much of the contaminated mine waste metals are being prevented from going into Clear Creek.

Figure 1 - Hoosac Gulch Grid Diagram

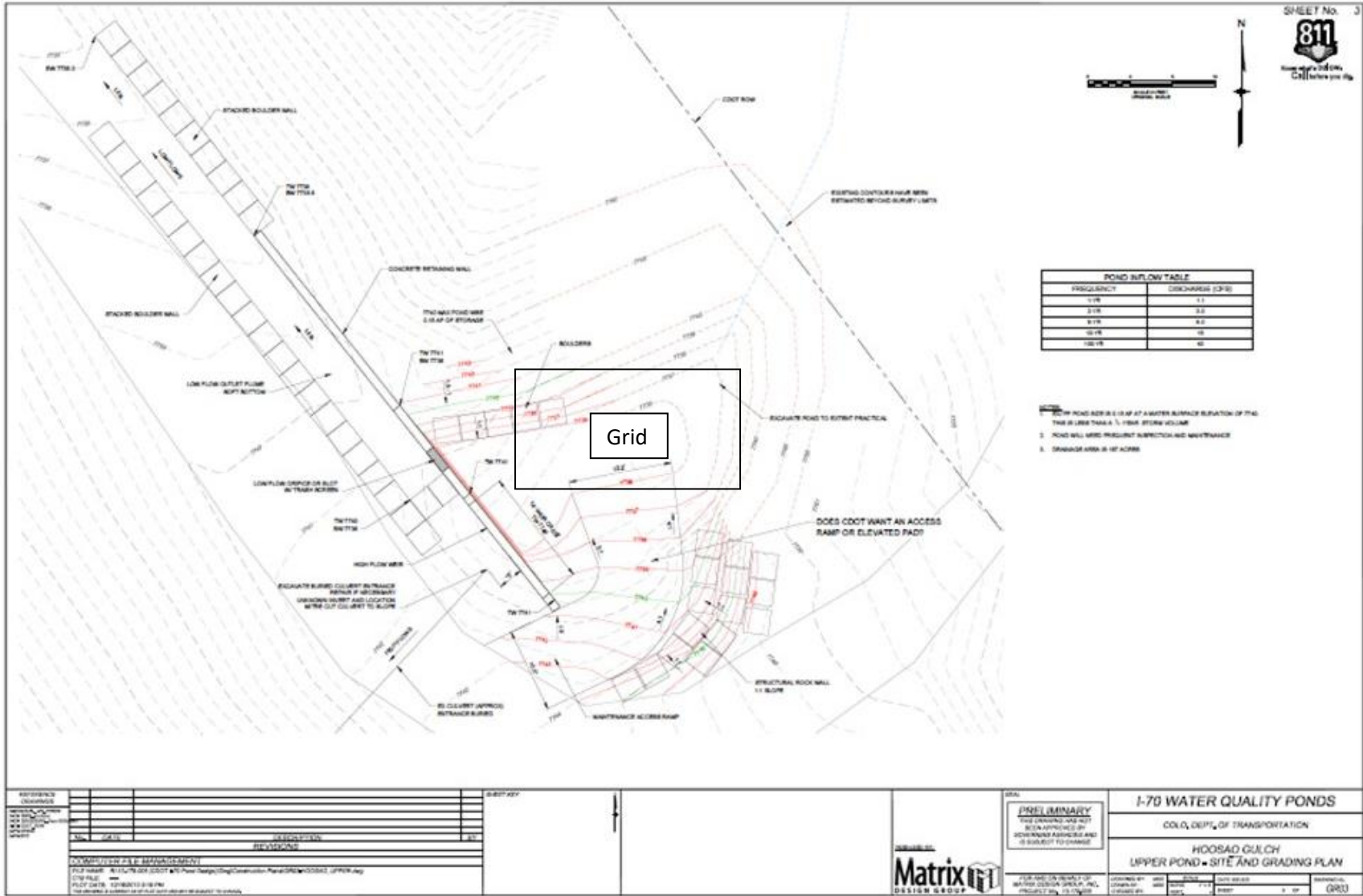
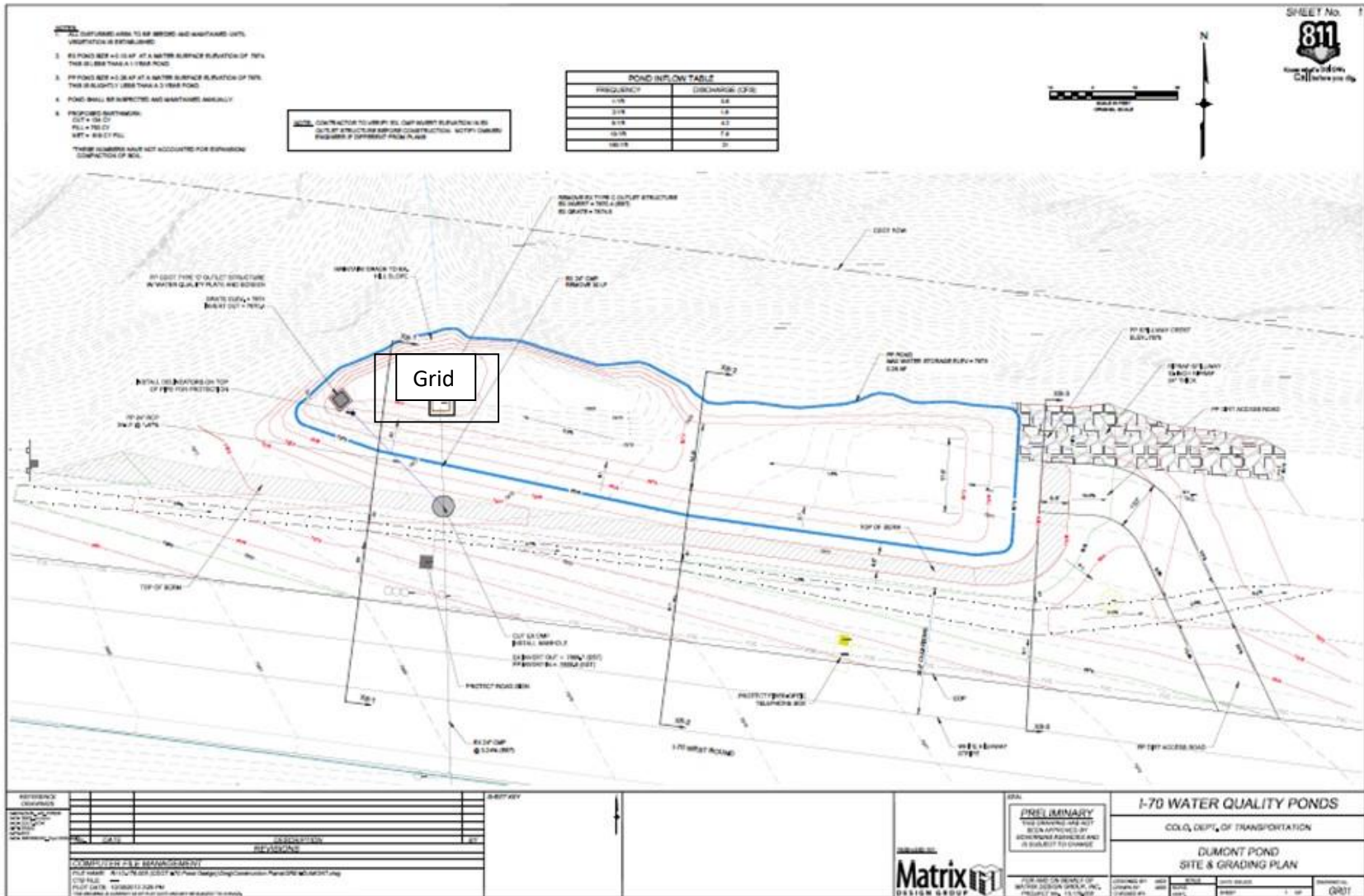


Figure 2 - Dumont Basin Grid Diagram



b. Sample Design Logistics:

B-2 -- Sampling Methods

This section summarizes the sampling and field quality assurance methods.

B2a - Sampling Methods

The methods developed by the USGS will be used to obtain a representative sample of the sediment contained in the basins. For obtaining solid samples sediments (and of mine waste piles) , the general guideline used is that sampling material of small grain size (<2 mm) reduces sampling error and generally incorporates the material that is most chemically reactive. The sampling scheme involves dividing the pile into at least 30 areas of roughly equal surface area and randomly securing a sample of at least 100 g from the surficial material (top 15 cm) of each area. These samples are combined and dry-sieved so that a combined sample of at least one kilogram of <2 mm (minus 10 mesh) particles is obtained.

If the sample is moist, it is air dried before sieving. To eliminate contamination, plastic containers are used for obtaining the 100 g samples and for storing the combined sample. If nearby stream sediment is being sampled, an effort is made to obtain a combined sample consisting of at least 30 subsamples of material whose grain size is <5 mm. This material is air dried before being sieved for total metal analysis by Colorado Analytical or for the leaching tests performed by CSM.

Paste pH is determined on sediment samples by mixing the sample with deionized water to the consistency of a thin paste. The pH of the paste is measured using a pH electrode after one hour.

B2b - Sampling Strategy

A ranking system was developed using four chemical criteria. The first criterion, based on acidity titration (mg/L CaCO₃) is: 1) 0–500, 2) 500–1000, 3) 1000–2500, 4) 2500–7500, and 5) above 7500. The paste or leachate pH provides the next criterion: 1) 4.0–5.0, 2) 3.5–3.9, 3) 3.0–3.4, 4) 2.5–2.9, and 5) below 2.5. Specific conductance is (mScm⁻¹), the third criterion: 1) below 0.5, 2) 0.5–1, 3) 1–2, 4) 2–3, and 5) above 3. The fourth and final criterion compares the leachate composition to water-quality criteria for the protection of aquatic life (U.S. EPA, 2004).

B2c - Field Quality Assurance and Decontamination

After each sample is excavated and the material placed into the respective sample containers, the shovel used to dig and transfer the soil will be decontaminated with a dilute solution of distilled water and tri-sodium phosphate, scrubbed with a brush and rinsed with distilled water to prevent cross contamination among sample points.

B2d - Testing Procedures

Waste rock and soil samples will be collected and transported back to each lab (CSM and Colorado Analytical Laboratories) where they will be allowed to dry overnight. They will then be sieved to achieve the desired grain size for each test.

On each composited sample, two leachate tests will be performed.

Test 1-- Colorado Division of Minerals and Geology (CDMG)

Jim Herron of the Colorado Division of Minerals and Geology (CDMG) developed this test (Herron, Stover, and Krabacher, 1999; Herron, Jordet, and Wildeman, 2001). It uses a volume basis to determine the potential for metal release from soils when exposed to natural waters. The procedure is as follows:

A total of 150 mL of whole sediment sample is placed into an 800 ml plastic beaker and 300 ml of deionized water is added. The sample was stirred vigorously for 15 seconds and then the beaker is covered with Parafilm. The contents are allowed to settle for 90 minutes. After this time, approximately 10 ml of leachate is filtered with a 0.45- μ m syringe filter, acidified with nitric acid, and analyzed using ICP-AES. Also after 90 minutes, the pH, Eh, ionic conductivity (specific conductance, or SC), and acidity or alkalinity are measured on the leachate

Test 2 -- Toxicity Characteristic Leaching Procedure (TCLP)

This test is a modified version of Method 1311 developed by the U.S. Environmental Protection Agency (U.S. EPA, 2002a). The test determines the mobility of metal in the presence of acidic waters.

An extraction fluid is prepared by adding 5.7 mL of concentrated glacial acetic acid to 500 ml of water. 64.3 ml of 1 N NaOH is added to the solution and then the solution is brought to a volume of 1 liter (L) using deionized water. The pH of this solution should be 4.93 ± 0.05 S.U. Then, 40 mL of this extraction fluid is added to 2 g of less-than (<) 80 mesh sediment sample in a 125 ml Nalgene® bottle. The bottles are then agitated end over end using a rotary tumbler for 24 hours. The leachate is then filtered with a 0.45- μ m syringe-filter, acidified with nitric acid, and analyzed using ICP-AES.

a. Sampling Needs- Colorado Analytical Laboratory

Parameter / Matrix	Sampling Method	Sampling Fraction
Al/Soil	SW-846-6020	Total metal
Cd/Soil	SW-846-6020	Total metal
Cu/Soil	SW-846-6020	Total metal
Fe/Soil	SW-846-6020	Total metal
Pb/Soil	SW-846-6020	Total metal
Mn/Soil	SW-846-6020	Total metal
Zn/Soil	SW-846-6020	Total metal

b. Equipment Needs

For sediment volume a distometer and tape measure will be used in addition to the as built deign plans for the basins to determine their maximum capacity. A plastic cup and/or plastic spade will be used to collect samples for pH and Conductivity

B-3 -- Sample Handling and Custody

Sampling instructions for trace metals will be followed as per the sampling instructions provided by Colorado Analytical Laboratories, Inc. and the preceding methodologies. Each sample will be labeled with the test to be performed and any preservative present. Safety glasses and phthalate-free gloves will be worn.

B-4 -- Analytical Methods Requirements

Prior to Colorado Analytical Lab's analysis, samples that require total ("acid-leachable") values must be digested using appropriate sample preparation methods (such as Methods 3005 - 3052). Method 6020 describes the multi-elemental determination of analytes by ICP-MS in environmental samples. The method measures ions produced by a radio frequency inductively coupled plasma. Analyte species originating in a liquid are nebulized and the resulting aerosol is transported by argon gas into the plasma torch. The ions produced by high temperatures are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions produced in the plasma are sorted according to their mass-to-charge ratios and quantified with a channel electron multiplier. Interferences must be assessed and valid corrections applied or the data flagged to indicate problems. Interference correction must

include compensation for background ions contributed by the plasma gas, reagents, and constituents of the sample matrix.

Because CSM is not a commercial laboratory and the instrument is not operated daily, not all elements of EPA Method 6010B can be conducted for metal analyses. The concentration of thirty-one cations and trace metals will be analyzed (Table B-1) with an emphasis on analyzing data associated with the following contaminants of concern and major cations: aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), selenium (Se), silver (Ag), sodium (Na), sulfate (recorded as sulfur rather than as SO₄), uranium (U), and zinc (Zn).

Two leaching tests will be performed on the combined, sieved sample: the CDMG field-leach test (CDMG) (Herron et al., 2001), and a modified toxicity characteristic leaching procedure (TCLP) test (U.S. EPA, 2002). Since this is a preliminary assessment rather than regulatory work, three different leaching tests are usually performed to provide an indication of the concentration range of contaminants in water that comes in contact with the material. If possible, a water sample related to the solid sample (such as a seep, storm water runoff, or other associated water) will be collected, and field tests for pH, Eh, specific conductance, and alkalinity or mineral acidity made. For the CDMG and the USGS leaching tests, a large enough volume of water is sampled so that pH, Eh, specific conductance, and alkalinity or mineral acidity analyses can be made on the excess water. The specific directions for each leaching test are presented here.

Colorado Division of Minerals and Geology Test

James Herron developed this test (Herron et al., 2001). It uses a volume basis to determine the potential for metal release from solids when exposed to natural waters. The procedure is as follows: 150 mL of whole, solid sample is placed into an 800-mL plastic beaker, and 300 mL of deionized water is added. The sample is stirred vigorously for 15 seconds, and then the beaker is covered with polystyrene film. The contents are allowed to settle for 90 min. After this time, approximately 10 mL of leachate is filtered using a 0.45- μ m syringe-filter and acidified with nitric acid, for analysis by inductively coupled plasma-atomic emission spectrometer (ICP-AES). Also after 90 min, the pH, Eh, specific conductance, and alkalinity are measured on the leachate.

Modified Toxicity Characteristic Leaching Procedure

This test is a modified version of method 1311 TCLP developed by the United States Environmental Protection Agency (U.S. EPA, 2002). As originally conceived by the EPA, it was used to assess organic compound and metal mobility in landfills. Here, the test determines the mobility of metals in the presence

of mildly acidic waters containing low-molecular-weight organic acids. It also closely approximates the carbonate extraction step commonly performed in sequential leaching studies (Tessier et al., 1979). An extraction fluid is prepared by adding 5.7 mL of concentrated glacial acetic acid to 500 mL of deionized water. A volume of 64.3 mL of 1 N NaOH is added, and then the solution is brought to a volume of 1 L using deionized water. The pH of this solution should be 4.93 ± 0.05 . A volume of 40 mL of this extraction fluid is added to 2.0 g of <80-mesh sample in a 125-mL polyethylene bottle. The bottles are then agitated end over-end using a rotary tumbler for 18 h. The leachate is filtered using a 0.45- μm syringe-filter and acidified with nitric acid for analysis by ICP-AES. (Wildeman)

A scandium spike is added to all samples that are analyzed with the ICP spectrometer at the CSM laboratory. This internal standard helps to account for fluctuations in the flame of the ICP. Results are rejected if scandium counts are 20% off of their true amount. A quality control standard is analyzed before each batch of samples. If in this standard, the analytical results for Cd, Co, Cu, Fe, Pb, Mn, or Zn are more than 15 percent different than the accepted value, then the analysis will be stopped, the reason for the discrepancy determined and corrected, and then the analysis will be resumed.

For pH measurement the meters and probes will be checked the day before a field session to determine that everything is operating properly. For pH, the meter will be checked with pH 4 and 7 buffers before the analysis of the first sample, and then, every thirty minutes after that. For pH, if the duplicate measurements are not within 0.20 standard units (S.U.) of each other, a third measurement will be made.

B-5 -- Quality Control Requirements

Quality Assurance and Quality Control using the analytical procedures at the Colorado School of Mines Chemistry and Geochemistry facilities follow:

Metals shall be measured in water solutions that have been filtered using 0.45-micrometer filters and acidified to below a pH of 2.0 using nitric acid. For field samples, all efforts will be made to keep the samples refrigerated until analysis. All water samples will be analyzed within 30 days of collection. Metals analyses will be conducted by inductively coupled plasma emission atomic spectroscopy (ICP-AES). A Perkin Elmer Optima Model 5300 dual view spectrometer is used. Typical detection limits are contained in a table at the end of this note. Because CSM is not a commercial laboratory and the instrument is not operated daily, not all elements of EPA Method 6010B are conducted for metal analyses. The concentration of the following cations and metals will be reported: Aluminum, Arsenic, Barium, Boron, Beryllium, Cadmium, Calcium, Cobalt, Chromium, Copper, Iron, Potassium, Lithium, Lead, Magnesium, Manganese, Molybdenum, Nickel, Silver, Sodium, Sulfate (as sulfur), Selenium, Strontium, Vanadium, and Zinc. A scandium spike is added to all samples that are analyzed with the ICP spectrometer. This internal standard helps to account for fluctuations in the flame of the ICP. Results are rejected if scandium counts are 20% off of their true amount. A quality control standard (CCV) is analyzed before each batch of samples. If in this standard, the analytical results for Cd, Co, Cu, Fe, Pb, Mn, or Zn are more than 15 % different than the accepted value, then the analysis will be

stopped, the reason for the discrepancy determined and corrected, and then the analysis will be resumed. If a water sample shows considerable precipitate, it will be acidified and refiltered before analysis. This can happen if the water sample has very high concentrations of natural organic matter. Finally, NIST standards 1640a and/or 1643e are run daily to have an accuracy reference.

Concerning errors the precision of the Perkin Elmer ICP is monitored for each sample by taking three emission analyses and using the average of the three. The typical relative standard deviation (RSD) of the average of three analyses is less than 2 %. Accuracy measures the comparison of results between different laboratories that have analyzed the same sample. In accuracy, the preparation as well as instrument error would be included. When the ICP results from CSM are compared with laboratory results from outside laboratories such as the regional EPA lab or the USGS laboratories, the accuracy falls between 5 and 10 % as long as the concentration is 10 times the detection limit. This is daily confirmed using the NIST standards.

Upon special request, other elements can be analyzed. They have special analytical programs for the rare earth metals and the noble metals. Because, check and certified standards are more difficult to obtain for these elements, the precision and accuracy of the analytical results for these elements are more difficult to ascertain. However, it is in the 10 % ballpark.

a. Field QC Checks:

Quality Control in Field Analyses Colorado School of Mines follows:

Waste rock and sediments samples will be collected according to the methods described in the Waste Rock Assessment paper by Wildeman et al., 2003. The methods developed by the USGS to secure a representative sample of the surface of a waste rock pile also will be used.

For pH, Eh, and conductivity measurements, the meters and probes will be checked the day before a field trip to determine that everything is operating properly. For pH, the meter will be checked with pH 4 and 7 buffers before the analysis of the first sample, and then, every thirty minutes after that. The same procedure will be used for Eh measurements only in this case a Light's solution will serve as the standard check. For the conductivity meter, standardization with a 0.100 molal solution of KCl the day before the trip will serve as the calibration check. For pH and conductivity measurements, duplicate measurements will be made for every sample. For pH, if the duplicate measurements are not within 0.20 standard units of each other, a third measurement will be made. For conductivity, if the range between duplicate measurements is greater than + or – 10 %, then a third measurement will be made. For Eh measurements, duplicate measurements will be made on every third sample and if these measurements are beyond + or – 50 millivolts, then a third measurement will be made.

For acidity and alkalinity, Hach digital titrators will be used. As much as possible, these measurements will be made in the field. Duplicate measurements will be made on every fourth sample.

Analysis of sulfate is performed on the ICP using the 180.669 nanometer line. Because this line is close to the operation limits of the spectrometer, results can deviate if the windows are not clean or if the spectrometer is not completely flushed with nitrogen. We closely monitor the quality control check sample to make certain that the sulfur results are reasonable. One issue that

may skew the results is the question of whether there is considerable sulfide sulfur in the water sample. However, if the sample is acidified and exposed to the air, most of the sulfide sulfur will vaporize as hydrogen sulfide. Three other methods are available for sulfate analysis: turbidimetry (sometimes called colorimetric), gravimetric analysis, and ion chromatography. The turbidimetric method will have many potential interferences, because calcium sulfate, calcium silicate, and natural organic matter can precipitate and add to the sulfate value. In addition, the turbidimetric method has a precision of between 5-10 %. Ion chromatography would be the other preferred method because interferences can be eliminated before the water is analyzed. There may be an issue of samples being too acidic for analysis by ion chromatography. However, the water can be neutralized with NaOH and the sulfate will remain in solution. Ion chromatography has a precision of between 5 and 10 % and the ICP has a precision between 2 and 5 %. This is why sulfate by ICP is the preferred method even though the analysis is for elemental sulfur and not sulfate. There is a gravimetric method for the analysis, however, it is very time intensive and is not performed by many contract laboratories. Access to an ICP-Mass Spec is available. However, it is used for determinations when it is anticipated that the concentration of an element is around 1 nanogram per liter. Also, many natural water that have total dissolved solids (TDS) values above 2,000 mg/L need to be diluted and that limits the detection limits that can be expected from using ICP-Mass Spec. On the other hand the ICP-AES can be routinely used for analyses of waters up to TDS values 10,000 mg/L before dilution is needed.

Soil leachate digests will be processed using 0.45-micrometer (um) filters and acidified to below a pH of 2.0 using nitric acid prior to metals analysis. Metals analyses will be conducted using inductively coupled plasma emission atomic spectroscopy (ICP-AES). A Perkin Elmer Optima Model-3000 radial viewing spectrometer is used.

Duplicate samples shall be taken and analyzed from a minimum of 10% of the total number of samples collected during the implementation of this SAPP.

Blanks shall be taken and analyzed once per CSM field week that results in <15 routine samples to ensure that equipment decontamination procedures are followed to exact specifications, the trip blank shall be collected even if the field week trip only includes 1 routine sample. Should the field week result in ≥15 routine samples then one trip blank shall be collected at the start of the week and a second trip blank shall be collected at the end of the week to ensure that equipment decontamination procedures are followed to exact specifications during trips of heavy usage.

b. Laboratory QC Checks:

Dr. Thomas Wildeman of CSM will oversee all experiments. Experiments and all analyses will be conducted by undergraduate students trained and under the supervision of Dr. Wildeman. Colorado Analytical Laboratories, Inc Quality Control procedures will comport with EPA Method SW-846-6020, which includes sample preparation, preservation, hold times, detailed analytical procedures including all QA practices.

B-6 -- Instrument / Equipment Calibration and Frequency

Colorado Analytical Lab will use Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) to perform the total metals analysis for this project. This laboratory is certified by EPA and CDPHE to perform these analyses as required under the Safe Drinking Water Act and the Clean Water Act.

B-7 -- Inspection / Acceptance Requirements for Supplies

All supplies such as sample bottles, nets, and reagents are specified in EPA method adequate for your program's needs.

B-8 -- Data Acquisition Requirements

Not applicable

B-9 -- Data Management

CCWF will coordinate data exchange with the Colorado Data Sharing Network via our partner organization, Colorado Watershed Assembly, to conduct data upload into EPA's STORET.

C - Assessment and Oversight

C-1 -- Assessment and Response Actions

Colorado Analytical Laboratory will provide a complete report of results for total metals including all QA procedures.

Evaluation of the student sampling activities will be performed through final course presentations. All data compiled and evaluated will be provided in CSM student reports, which will involve instructor and CCWF feedback and revisions prior to a final NPS Project Report. Any problems or discrepancies identified will be addressed by corrective actions, which may include additional collection, sampling and laboratory testing. Sampling errors can be categorized into seven major groups: fundamental error, grouping and segregation error, delimitation error, extraction error, preparation error, cycles, and trends.

Fundamental error results from the compositional heterogeneity of particles. Grouping and segregation error is a function of the nonrandom distribution of particles and the fact that particles are collected in groups rather than individually. Delimitation error and extraction error are both related to the choice and use of sampling tools; collectively they are termed the materialization error. Preparation errors take place after sample collection and before analysis; these errors encompass such factors as sample preservation, contamination, loss, sieving, etc. Both cycles and trends relate to changes in the concentration of a constituent of interest with respect to time or space.

The fundamental error (FE) is often the main source of sampling error (Pitard, 1993). It cannot be eliminated, but it can be estimated prior to sampling. Based on estimates of FE, steps can be taken to minimize it and thus minimize the overall sampling error. Important factors in the FE include heterogeneity, particle size, and sample mass.

The other main sampling error of concern is the grouping and segregation error (GSE). To minimize the grouping factor of the GSE, it is necessary to collect as many small increments as practically possible, assuming that sample collection and preparation are properly carried out. An increment is a group of particles collected from a population with a single operation of the sampling device. Minimizing the segregation factor of the GSE is much more difficult. Complete homogenization of the target population prior to sampling is the solution, but generally is impractical.

C-2 -- Reports

We anticipate one report to be produced for CDPHE NPS from this single sampling effort. Reports received from student volunteers will be based on the number of CSM student groups assigned to the field session. Data will be entered into the Colorado Data Share Network once a final report is approved by CDPHE NPS.

D - Data Validation and Usability

D-1 -- Data Review, Validation and Verification

We will employ Tim Steele, PhD to perform a data quality review in accordance with USGS practices, with which he is well familiar having spent much of his career in the water resources division of that agency.

D-2 -- Validation and Verification Methods

The following steps describe the validation and verification methods that the WQCD Environmental Data Unit uses to verify precision and accuracy and are presented here as a suggestion. We will abide by these same procedures

“Unless otherwise specified, acceptable precision for each analytical parameter (e.g., zinc) for a pair of split samples will be < 30%, expressed as relative percent difference (RPD).

$$\text{Precision} = \text{RPD} = \frac{(C - C)}{(C + C)} \times \frac{1}{2} \times 100\%$$

In the event that the difference between split samples is > 30%, data from that site/time will be considered qualified and either deleted or interpreted with caution. Qualified data will be clearly denoted as such in the database.

Estimates of overall precision of a parameter (e.g., zinc) will be derived from the pooled standard deviations (SD) from all individual split pairs. The pooled standard deviation statistic is termed the root mean square and is calculated as:

$$\text{Percent relative standard deviation} = \%RSD = (\text{SD} / \text{Mean}) \times 100\%$$

$$\text{Root mean square} = \text{RMS} = \sqrt{\%RSD^{0.5} + \%RSD^{0.5} \dots + \text{etc.}^{0.5}}$$

N

Unless otherwise specified, acceptable RMS for each parameter is < 30%. If RMS is > 30%, then the analysis for that parameter will be deleted from the database or considered as qualified data and interpreted with caution. Qualified data will be clearly denoted in the database.

Concentration of contaminants allowable in field blanks will be project specific. Data from field blanks will be tabulated, reviewed, and interpreted in project reports. If contamination of field blanks occurs, corrective action will be initiated.

The decision process for determining the significance of blank contamination in terms of project and data quality objectives is presented in the following decision criteria:

<u>Field Blank</u>	Reported <u>Analytical Blank</u>	Outcome to <u>Database</u>
1. < Detection limit	> detection limit	no change
2. > Detection limit	< detection limit	no change
3. > Detection limit	< detection limit	no change
4. > Detection limit	> detection limit	qualified data (See below)

The decision to accept or reject qualified data will be based on the following criteria:

- If, after downward adjustment for possible contamination, the analytical values reported for ambient sites still exceed the designated standard (e.g., the stream standard for zinc), then no change in the data base is required.
- If downward adjustment of the ambient site values eliminates exceedance of the designated standards, then the data point(s) are interpreted with caution and re-sampling at the site(s) is appropriate.”

D-3 -- Reconciliation with Data Quality Objectives

Once the analytical results are provided by the laboratory along with the meta-data pertaining to quality assurance, CCWF will prepare a data quality report that reconciles the sampling results with the data quality objectives.

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Hoosac Gulch
and
Dumont Basins:
Sediment Sampling and Analysis Project Plan

Clear Creek Watershed Foundation
Contracting Entity

June 7, 2017

Bonie Pate
Nonpoint Source Project Manager

Date

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A - Sampling Project Management

A-3 -- Distribution List

NAME	Project Title/Responsibility
Ben Moline (CCWF Board President)	Stakeholder Group
Dave Holm (CCWF Executive Director)	Project Manager
Diane Kielty (KDP Consultant)	Project Team
Tim Steele, PhD	Data Quality Officer
Bonie Pate	NPS Project Manager and NPS Quality Control Officer

A-4 -- Sampling Project or Task Organization

Name	Project Title / Responsibility
Bonie Pate	NPS Quality Control Officer
Dave Holm (CCWF Executive Director)	Project Manager
Jonathan O. (Josh) Sharp, PhD, Associate Professor	Colorado School of Mines Field Session Supervisor
Thomas Wildman	CSM Project QA Officer – SAPP responsibilities
Diane Kielty	Field / Sampling Leader
Colorado Analytical	Laboratory Manager / Leader

A-5 -- Problem Definition / Background – Sampling Needs

The Clear Creek Tributaries Sediment Control and Metal Removal Project is located alongside Clear Creek (segment COSPCL02c) in Clear Creek County, a short distance upstream of Idaho Springs. Clear Creek crosses the Colorado Mineral Belt from Silver Plume through Idaho Springs. There are a number of small watersheds (ranging in size from ~ 1/8 mi. to >2 mi) draining from the north side of I-70 into Clear Creek that have experienced significant mining in the past. These are steep side-tributaries with a southern aspect that typically have intermittent flows. Frontal weather systems and intense, short duration thunderstorms can mobilize substantial loads of contaminated sediments from mine waste and mill tailings in the drainage ways. Access to many of these previously mined areas is difficult and even impossible for vehicles in some cases. Therefore, many of these areas will not be reclaimed and will be ongoing sources of metals, acidity and nutrients- that is, unless the runoff is captured and detained, so that contaminated solids can be removed and prevented from entering Clear Creek. Hoosac Gulch and the Unnamed Tributary located near Dumont at I-70 milepost 235.5. are examples of such mining impacted tributaries coming into Clear Creek from the North.

Hoosac Gulch is a direct tributary of segment COSPCL02c of Clear Creek, located 1 1/4 mile west of Idaho Springs, Lat: 39° 45' 11.43028" N / Long: 105° 33' 14.47675 W. It is a prime example of an inaccessible drainage with an abundance of mine waste in the upper (roadless) portion of the watershed and a large mill tailings pile near its mouth. The Unnamed Tributary located at milepost 235.5, about 0.7

miles east of the confluence of Mill Creek with Clear Creek at Dumont Colorado, Lat: 39° 45' 52.26428" N / Long: 105° 35' 20.29804" W, also has numerous inaccessible mine waste piles in its drainage way.

The primary goal of the Hoosac Gulch and Dumont drainage contaminated mine waste sediment control and metal removal projects is to significantly reduce the loading of particulate metals, including the TMDL target metals cadmium, copper and zinc, from reaching Clear Creek. Important secondary goals in these project areas include reduction of total phosphorus and sediment loading to Clear Creek. Construction of sediment control basins was a high priority, as reflected in CDOT's Sediment Control Action Plan for the I-70 corridor between the Eisenhower Tunnel and the bottom of Floyd Hill.

The overarching environmental goal of this project is to improve water quality in Clear Creek Segment 2c to become fully supporting for Aquatic Life Use. While this project will not achieve that goal on its own, it will contribute to the required loading reductions that have been established to meet that goal.

I – Problem Statement:

The detention basins put in place at these locations were designed to facilitate efficient maintenance operations to allow the captured contaminated mine waste sediment to be removed entirely from the drainage area.

II – Intended Use of Data: the quantity (mass loading) of contaminated mine waste metals being prevented from going into Clear Creek by the detention basins.

A-6 -- Sampling Project or Task Description

The measurable results for this SAPP will be used to determine the effectiveness of the sediment Basins constructed as part of the Clear Creek Tributaries Sediment Control and Metal Removal Project

I – General Overview of Project

The project will focus on a chemical characterization and loading assessment for sediment in Hoosac Gulch and Dumont sediment basins.

Soil samples will be collected for total metals analysis by Colorado analytical Lab. The results from this sampling effort will provide the most direct answer to the fundamental question: How much metal is being prevented from reaching Clear Creek as a result of being trapped in the Hoosac Gulch and Dumont sediment basins? The answer will require a computation of the volume of sediment stored in the basin plus the total metals analytical results.

The Colorado School of Mines chemical characterization of the contained sediment will include a modified Toxicity and Metals Leaching Assessment (TCLP) with a focus on metals including Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg 279.553-R, Mg 285.213-R, Mn, Na, Ni, P, Pb, S, Se, Si, Sr, Tl, V, Zn, Sn, Mo, Sb, Ti plus acidity/pH, conductivity and volume determination. If possible, a water sample related to the solid samples (such as a seep, storm water runoff, or other associated water) will be collected, and field tested for pH, Eh, specific conductance, and alkalinity or mineral acidity. It is expected that most this data can be provided by early Summer 2017.

Simple systematic random sampling will be used to evaluate the average concentrations of chemical constituents of concern (COC) in the surficial soils. To implement the sampling, a geo-referenced systematic grid will be established over the entire surface area of each sediment basin dividing each site into 30 cells of equal area. (Please see Figures 1 and 2). We will scale each grid to the size of the basin. There will be 30 sub-samples per basin where surface samples (15 cm depth) will be collected of at least 100 g from each cell. There will be one composited sample by combining the sub-samples which will be duplicated for analysis. We will sieve the composite to <2 mm for at least 1 kg of final composite sample. Two leaching tests are performed on the combined, sieved sample: the CDMG field leach test (CDMG) (Herron et al., 2001), and a modified toxicity characteristic leaching procedure (TCLP) test (U.S. EPA, 2002).

A field survey and sampling trip will be made 3-weeks after the SAPP has been approved by CDPHE/NPS. In addition to the volumetric measurement of the sediment in each gulch basin, to the extent possible, pH and conductivity measurements will be made in the laboratory.

Pre-field activities involve the following:

- Preparing the work plan and data quality objectives (DQOs) for field sampling, sample analyses, and data reporting
- Procuring the field sampling equipment
- Coordinating site access and scheduling field sampling

Information inputs include:

- Coordinate maps for the Hoosac Gulch and Dumont Basins
- Obtaining the list of Colorado's "risk-based" concentrations for metals of concern in Clear Creek.

Field Activities include:

- Randomized grid sampling of surficial soils for metals.
- Field Sieving of samples unless samples are sand-sized or smaller particles. Any further required sieving will be performed by the lab.
- Preparation of composite samples of surficial soils subjected to the Total Metals analysis by Colorado Analytical Lab and the Toxicity Characteristic Leaching Procedure to be performed by CSM

TCLP and subsequent analysis of the leachate for metals to evaluate the potential leachability of metals from contaminated sediment to groundwater and surface water in concentrations that exceed levels of concern.

Spatial Boundaries: Samples to be collected within the boundary of the sediment basins are designed to characterize the average concentration for each regulated metal in surface sediments within each basin.

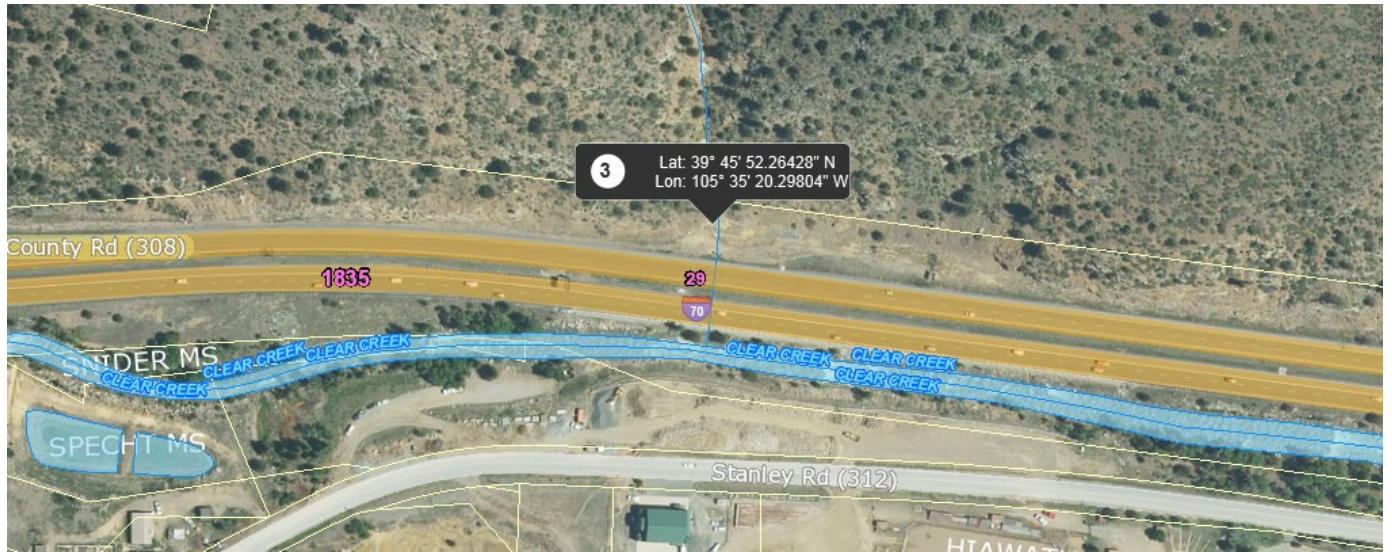
Temporal Boundaries: The samples will be collected as grab samples at one point in time. There are no plans to conduct temporal or time-weighted sampling because the conservative nature of the analytes of concern (metals) render them unlikely to change quickly in concentration over time.

Chemical constituents: Metals for which there are corresponding Colorado risk-based standards promulgated. These metals include: aluminum, cadmium, copper, iron, lead, manganese, and zinc.

II – Sampling Project Locations
Map 1 - Hoosac Gulch Coordinates



Map 2 - Dumont Sediment Basin Coordinates



Sampling Timeline Overview & Responsibilities							
Goal	Activity	Method	Location(s)	Projected Start Date	Reoccurrence	Anticipated Date of Completion	Responsible Party

Sediment Quality	Sediment Chemistry Sampling (metals)	EPA SW-846-6020	Hoosac Gulch & Dumont Basin	July 2017	None	July 2017	CCWF
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Sampling Locations			
Site #	Description	Latitude	Longitude
1	Hoosac Gulch	39° 45' 11.43028" N	105° 33' 14.47675" W
2	Dumont Basin	39° 45' 52.26428" N	105° 35' 20.29804" W

III – Sampling Project Timetable

Major Tasks	J	F	M	A	M	J	J	A	S	O	N	D
Training Field Sampling Team					x	x						
Field Sampling Event					x							
Sample Preparation (Compositing, etc...)					x							
Lab analysis (CSM & Colorado Analytical)					x							
Data processing, analysis & reporting						x						

A-7 -- Data Quality Objectives for Measurement Data

a. Data Precision, Accuracy and Measurement Range:

Precision will be determined by comparison of the analytical results for duplicate samples. There will be 2 composite samples from each basin for a total of 4 composite samples. Two laboratories will be used each receiving 4 composite samples, 2 from each basin.

In order to determine precision and accuracy the labs will prepare and evaluate spiked samples. We are going to compare the values based on the known value of the spiked sample, which will help to determine the degree of accuracy in our analytical procedures.

Matrix

Matrix	Parameter	Measurement Range	Accuracy	Precision
Sediment	Selected Metals	ppb	Parameter Dependent	To be determined based on comparative analysis of 8 duplicate samples, 4 from each basin

b. Data Representativeness:

The composite analysis of multiple sub-samples is designed to maximize data representativeness.

c. Data Comparability:

The Toxicity and Metals Leaching Assessment methodology is based on a sampling design used repeatedly by DRMS, CSM, CCWF and others.

d. Data Completeness:

Quality Control check analyses to verify precision and accuracy for the analytical protocol will be assured through comparison of 2 duplicate composites for each basin, analyzed by two separate laboratories.

Key Parameters	No. Valid Samples Anticipated	No. Valid Samples Collected and Analyzed	Percent Complete
Al, Cd, Cu, Fe, Pb, Mn, Zn	2 samples from each basin provided to 2 labs	8 Anticipated	100% Anticipated

A-8 -- Training Requirements and Certification

Senior engineering students will be used through the Colorado School of Mines Department of Civil and Environmental Engineering (CEE). The students will be participating in a faculty supervised CEE Field Session for academic credit.

a. Training Logistical Arrangements:

Student Training	Frequency of Training / Certification
CSM Field Team Sampling Protocol	2 Pre-sampling site visits
CSM Laboratory Protocol	CSM Campus Laboratory

b. Description of Training and Trainer Qualifications:

Thomas Wildeman, Dept. of Chemistry & Geochemistry, Professor Emeritus
Jonathan O. (Josh) Sharp, PhD, Associate Professor

c. Documentation and Records

Field data sheets chain of custody forms are provided by Colorado Analytical Laboratories, Inc. Chain of custody will follow criteria used by Colorado Analytical Laboratories, Inc. Holding Times and Preservatives will be as required in EPA method SW-846-6020, which is readily available online: <https://www.epa.gov/sites/production/files/2015-07/documents/epa-6020a.pdf>

B - Measurement / Data Generation and Acquisition

B-1 -- Sampling Process Design

a. Rationale for Selection of Sampling Sites:

Hoosac Gulch and the Unnamed Tributary located near Dumont at I-70 milepost 235.5 are mining impacted tributaries coming into Clear Creek from the North. The detention basins put in place at these locations were designed to facilitate efficient maintenance operations to allow the captured contaminated mine waste sediment to be removed entirely from the drainage area. The measurable results for this

SAPP will be used to determine how much of the contaminated mine waste metals are being prevented from going into Clear Creek.

Figure 1 - Hoosac Gulch Grid Diagram

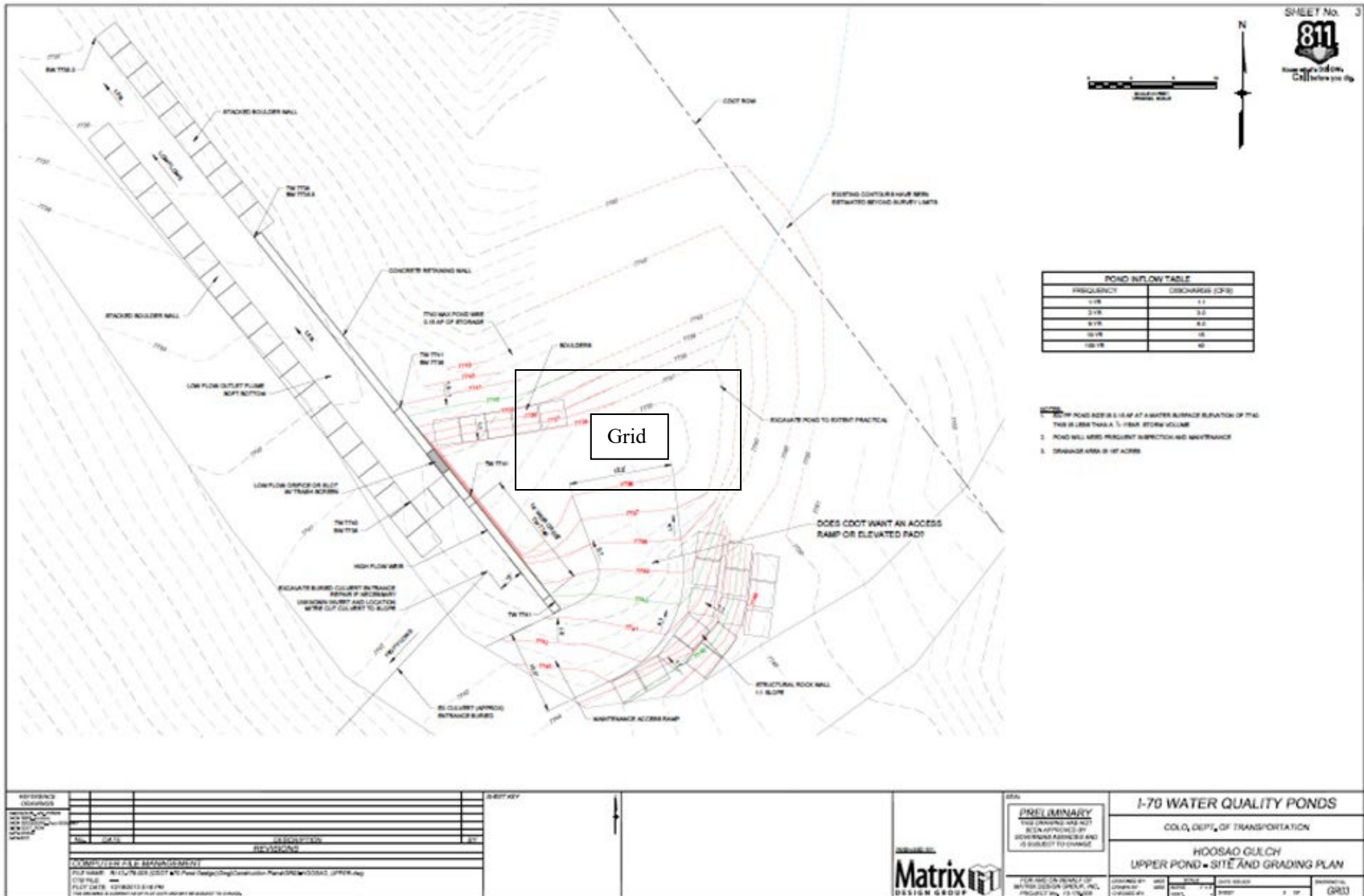
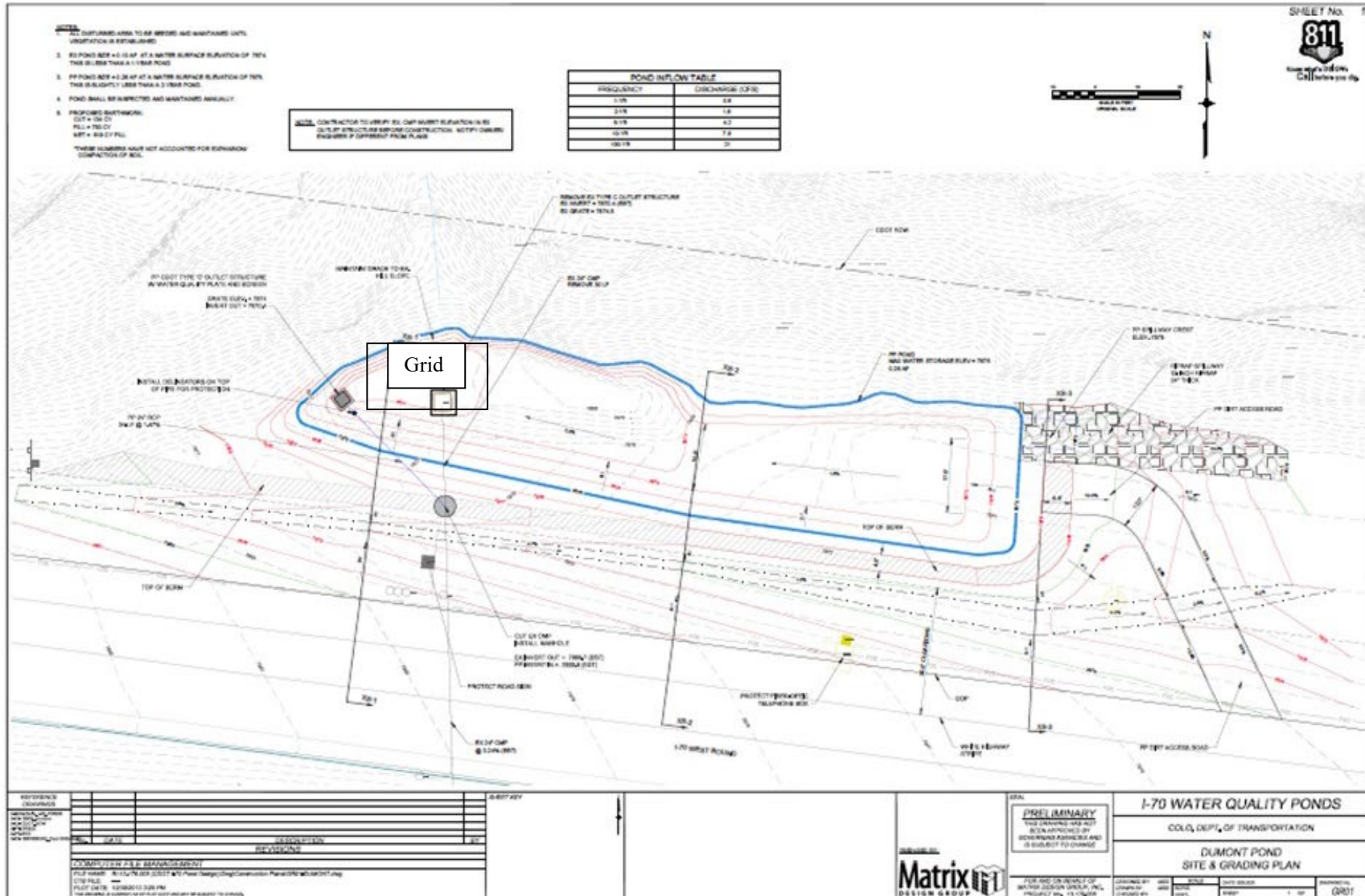


Figure 2 - Dumont Basin Grid Diagram



B-2 -- Sampling Methods

This section summarizes the sampling and field quality assurance methods.

B2a - Sampling Methods

The methods developed by the USGS will be used to obtain a representative sample of the sediment contained in the basins. For obtaining solid samples sediments (and of mine waste piles), the general guideline used is that sampling material of small grain size (<2 mm) reduces sampling error and generally incorporates the material that is most chemically reactive. The sampling scheme involves dividing the pile into at least 30 areas of roughly equal surface area and randomly securing a sample of at least 100 g from the surficial material (top 15 cm) of each area. These samples are combined and dry-sieved so that a combined sample of at least one kilogram of <2 mm (minus 10 mesh) particles is obtained.

If the sample is moist, it is air dried before sieving. To eliminate contamination, plastic containers are used for obtaining the 100-g samples and for storing the combined sample. If nearby stream sediment is being sampled, an effort is made to obtain a combined sample consisting of at least 30 subsamples of material whose grain size is <5 mm. This material is air dried before being sieved for total metal analysis by Colorado Analytical or for the leaching tests performed by CSM.

Paste pH is determined on sediment samples by mixing the sample with deionized water to the consistency of a thin paste. The pH of the paste is measured using a pH electrode after one hour.

B2b - Sampling Strategy

A ranking system was developed using four chemical criteria. The first criterion, based on acidity titration (mg/L CaCO₃) is: 1) 0–500, 2) 500–1000, 3) 1000–2500, 4) 2500–7500, and 5) above 7500. The paste or leachate pH provides the next criterion: 1) 4.0–5.0, 2) 3.5–3.9, 3) 3.0–3.4, 4) 2.5–2.9, and 5) below 2.5. Specific conductance is (mScm⁻¹), the third criterion: 1) below 0.5, 2) 0.5–1, 3) 1–2, 4) 2–3, and 5) above 3. The fourth and final criterion compares the leachate composition to water-quality criteria for the protection of aquatic life (U.S. EPA, 2004).

B2c - Field Quality Assurance and Decontamination

After each sample is excavated and the material placed into the respective sample containers, the shovel used to dig and transfer the soil will be decontaminated with a dilute solution of distilled water and tri-sodium phosphate, scrubbed with a brush and rinsed with distilled water to prevent cross contamination among sample points.

B2d - Testing Procedures

Waste rock and soil samples will be collected and transported back to each lab (CSM and Colorado Analytical Laboratories) where they will be allowed to dry overnight. They will then be sieved to achieve the desired grain size for each test.

On each sediment basin composited sample two leachate tests will be performed.

Test 1-- Colorado Division of Minerals and Geology (CDMG)

Jim Herron of the Colorado Division of Minerals and Geology (CDMG) developed this test (Herron, Stover, and Krabacher, 1999; Herron, Jordet, and Wildeman, 2001). It uses a volume basis to determine the potential for metal release from soils when exposed to natural waters. The procedure is as follows:

A total of 150 mL of whole sediment sample is placed into an 800 ml plastic beaker and 300 ml of deionized water is added. The sample was stirred vigorously for 15 seconds and then the beaker is covered with Parafilm. The contents are allowed to settle for 90 minutes. After this time, approximately 10 ml of leachate is filtered with a 0.45-µm syringe filter, acidified with nitric acid, and analyzed using ICP-AES. Also after 90 minutes, the pH, Eh, ionic conductivity (specific conductance, or SC), and acidity or alkalinity are measured on the leachate

Test 2 -- Toxicity Characteristic Leaching Procedure (TCLP)

This test is a modified version of Method 1311 developed by the U.S. Environmental Protection Agency (U.S. EPA, 2002a). The test determines the mobility of metal in the presence of acidic waters.

An extraction fluid is prepared by adding 5.7 mL of concentrated glacial acetic acid to 500 ml of water. 64.3 ml of 1N NaOH is added to the solution and then the solution is brought to a volume of 1 liter (L) using deionized water. The pH of this solution should be 4.93 ± 0.05 S.U. Then, 40 mL of this extraction fluid is added to 2 g of less-than (<) 80 mesh sediment sample in a 125 ml Nalgene® bottle. The bottles are then agitated end over end using a rotary tumbler for 24 hours. The leachate is then filtered with a 0.45-µm syringe filter, acidified with nitric acid, and analyzed using ICP-AES.

a. Sampling Needs- Colorado Analytical Laboratory

Parameter / Matrix	Sampling Method	Sampling Fraction
Al/Soil	SW-846-6020	Total metal
Cd/Soil	SW-846-6020	Total metal
Cu/Soil	SW-846-6020	Total metal
Fe/Soil	SW-846-6020	Total metal
Pb/Soil	SW-846-6020	Total metal
Mn/Soil	SW-846-6020	Total metal
Zn/Soil	SW-846-6020	Total metal

b. Equipment Needs

For sediment volume a distometer and tape measure will be used in addition to the as built design plans for the basins to determine their maximum capacity. multimeter. a plastic cup and/or plastic spade will be used to collect samples for pH and Conductivity

B-3 -- Sample Handling and Custody

Sampling instructions for trace metals will be followed as per the sampling instructions provided by Colorado Analytical Laboratories, Inc. and the preceding methodologies. Each sample will be labeled with the test to be performed and any preservative present. Safety glasses and phthalate-free gloves will be worn.

B-4 -- Analytical Methods Requirements

Prior to Colorado Analytical Lab's analysis, samples which require total ("acid-leachable") values must be digested using appropriate sample preparation methods (such as Methods 3005 - 3052). Method 6020 describes the multi-elemental determination of analytes by ICP-MS in environmental samples. The method measures ions produced by a radiofrequency inductively coupled plasma. Analyte species originating in a liquid are nebulized and the resulting aerosol is transported by argon gas into the plasma torch. The ions produced by high temperatures are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions produced in the plasma are sorted according to their mass-to-charge ratios and quantified with a channel electron multiplier. Interferences must be assessed and valid corrections applied or the data flagged to indicate problems. Interference correction must include compensation for background ions contributed by the plasma gas, reagents, and constituents of the sample matrix.

Because CSM is not a commercial laboratory and the instrument is not operated daily, not all elements of EPA Method 6010B can be conducted for metal analyses. The concentration of thirty-one cations and trace metals will be analyzed (Table B-1) with an emphasis on analyzing data associated with the following contaminants of concern and major cations: aluminum (Al), arsenic (As), barium (Ba), cadmium (Cd), calcium (Ca), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), nickel (Ni), potassium (K), selenium (Se), silver (Ag), sodium (Na), sulfate (recorded as sulfur rather than as S04), uranium (U), and zinc (Zn).

Two leaching tests are performed on the combined, sieved sample: the CDMG field leach test (CDMG) (Herron et al., 2001), and a modified toxicity characteristic leaching procedure (TCLP) test (U.S. EPA, 2002). Since this is a preliminary assessment rather than regulatory work, three different leaching tests are usually performed to provide an indication of the concentration range of contaminants in water that comes in contact with the material. If possible, a water sample related to the solid sample (such as a seep, storm water runoff, or other associated water) is collected, and field tests for pH, Eh, specific conductance, and alkalinity or mineral acidity are made. For the CDMG and the USGS leaching tests, a large enough volume of water is sampled so that pH, Eh, specific conductance, and alkalinity or mineral acidity analyses can be made on the excess water. The specific directions for each leaching test are presented here.

Colorado Division of Minerals and Geology Test

This test was developed by James Herron of the CDMG (retired) (Herron et al., 2001). It uses a volume basis to determine the potential for metal release from solids when exposed to natural waters. The procedure is as follows: 150 mL of whole, solid sample is placed into an 800-mL plastic beaker, and 300 mL of deionized water is added. The sample is stirred vigorously for 15 seconds, and then the beaker is covered with polystyrene film. The contents are allowed to settle for 90 min. After this time, approximately 10 mL of leachate is filtered using a 0.45- μ m syringe filter and acidified with nitric acid, for analysis by inductively coupled plasma-atomic emission spectrometer (ICP-AES). Also after 90 min, the pH, Eh, specific conductance, and alkalinity are measured on the leachate.

Modified Toxicity Characteristic Leaching Procedure

This test is a modified version of method 1311 TCLP developed by the United States Environmental Protection Agency (U.S. EPA, 2002). As originally conceived by the EPA, it was used to assess organic compound and metal mobility in landfills. Here, the test determines the mobility of metals in the presence of mildly acidic waters containing low-molecular-weight organic acids. It also closely approximates the carbonate extraction step commonly performed in sequential leaching studies (Tessier et al., 1979). An extraction fluid is prepared by adding 5.7 mL of concentrated glacial acetic acid to 500 mL of deionized water. A volume of 64.3 mL of 1 N NaOH is added, and then the solution is brought to a volume of 1 L using deionized water. The pH of this solution should be 4.93 ± 0.05 . A volume of 40 mL of this extraction fluid is added to 2.0 g of <80 mesh sample in a 125-mL polyethylene bottle. The bottles are then agitated end-over-end using a rotary tumbler for 18 h. The leachate is filtered using a 0.45- μ m syringe filter and acidified with nitric acid for analysis by ICP-AES. (Wildeman)

A scandium spike is added to all samples that are analyzed with the ICP spectrometer. This internal standard helps to account for fluctuations in the flame of the ICP. Results are rejected if scandium counts are 20% off of their true amount. A quality control standard is analyzed before each batch of samples. If in this standard, the analytical results for Cd, Co, Cu, Fe, Pb, Mn, or Zn are more than 15 percent different than the accepted value, then the analysis will be stopped, the reason for the discrepancy determined and corrected, and then the analysis will be resumed.

For pH measurement the meters and probes will be checked the day before a field session to determine that everything is operating properly. For pH, the meter will be checked with pH 4 and 7 buffers before the analysis of the first sample, and then, every thirty minutes after that. For pH, if the duplicate measurements are not within 0.20 standard units (S.U.) of each other, a third measurement will be made.

B-5 -- Quality Control Requirements

Quality Assurance and Quality Control using the analytical procedures at the Colorado School of Mines Chemistry and Geochemistry facilities follow:

Metals shall be measured in water solutions that have been filtered using 0.45 micrometer filters and acidified to below a pH of 2.0 using nitric acid. For field samples, all efforts will be made to keep the samples refrigerated until analysis. All water samples will be analyzed within 30 days of collection. Metals analyses will be conducted by inductively coupled plasma emission atomic spectroscopy (ICP-AES). A Perkin Elmer Optima Model 5300 dual view spectrometer is used. Typical detection limits are contained in a table at the end of this note. Because CSM is not a commercial laboratory and the instrument is not operated daily, not all elements of EPA Method 6010B are conducted for metal analyses. The concentration of the following cations and metals will be reported: Aluminum, Arsenic, Barium, Boron, Beryllium, Cadmium, Calcium, Cobalt, Chromium, Copper, Iron, Potassium, Lithium, Lead, Magnesium, Manganese, Molybdenum, Nickel, Silver, Sodium, Sulfate (as sulfur), Selenium, Strontium, Vanadium, and Zinc. A scandium spike is added to all samples that are analyzed with the ICP spectrometer. This internal standard helps to account for fluctuations in the flame of the ICP. Results are rejected if scandium counts are 20% off of their true amount. A quality control standard (CCV) is analyzed before each batch of samples. If in this standard, the analytical results for Cd, Co, Cu, Fe, Pb, Mn, or Zn are more than 15 % different than the accepted value, then the analysis will be stopped, the reason for the discrepancy determined and corrected, and then the analysis will be resumed. If a water sample shows considerable precipitate, it will be acidified and refiltered before analysis. This can happen

if the water sample has very high concentrations of natural organic matter. Finally, NIST standards 1640a and/or 1643e are run daily to have an accuracy reference.

Concerning errors the precision of the Perkin Elmer ICP is monitored for each sample by taking three emission analyses and using the average of the three. The typical relative standard deviation (RSD) of the average of three analyses as seen in Table 1 is less than 2 %. Accuracy measures the comparison of results between different laboratories that have analyzed the same sample. In accuracy, the preparation as well as instrument error would be included. When the ICP results from CSM are compared with laboratory results from outside laboratories such as the regional EPA lab or the USGS laboratories, the accuracy falls between 5 and 10 % as long as the concentration is 10 times the detection limit. This is daily confirmed using the NIST standards.

Upon special request, other elements can be analyzed. They have special analytical programs for the rare earth metals and the noble metals. Because, check and certified standards are more difficult to obtain for these elements, the precision and accuracy of the analytical results for these elements are more difficult to ascertain. However, it is in the 10 % ballpark.

a. Field QC Checks:

Quality Control in Field Analyses Colorado School of Mines follows:

Waste rock and sediments samples will be collected according to the methods described in the Waste Rock Assessment paper by Wildeman et al., 2003. The methods developed by the USGS to secure a representative sample of the surface of a waste rock pile also will be used.

For pH, Eh, and conductivity measurements, the meters and probes will be checked the day before a field trip to determine that everything is operating properly. For pH, the meter will be checked with pH 4 and 7 buffers before the analysis of the first sample, and then, every thirty minutes after that. The same procedure will be used for Eh measurements only in this case a Light's solution will serve as the standard check. For the conductivity meter, standardization with a 0.100 molal solution of KCl the day before the trip will serve as the calibration check. For pH and conductivity measurements, duplicate measurements will be made for every sample. For pH, if the duplicate measurements are not within 0.20 standard units of each other, a third measurement will be made. For conductivity, if the range between duplicate measurements is greater than + or - 10 %, then a third measurement will be made. For Eh measurements, duplicate measurements will be made on every third sample and if these measurements are beyond + or - 50 millivolts, then a third measurement will be made.

For acidity and alkalinity, Hach digital titrators will be used. As much as possible, these measurements will be made in the field. Duplicate measurements will be made on every fourth sample.

Analysis of sulfate is performed on the ICP using the 180.669 nanometer line. Because this line is close to the operation limits of the spectrometer, results can deviate if the windows are not clean or if the spectrometer is not completely flushed with nitrogen. We closely monitor the quality control check sample to make certain that the sulfur results are reasonable. One issue that may skew the results is the question of whether there is considerable sulfide sulfur in the water sample. However, if the sample is acidified and exposed to the air, most of the sulfide sulfur will vaporize as hydrogen sulfide. Three other methods are available for sulfate analysis: turbidimetry (sometimes called colorimetric), gravimetric analysis, and ion chromatography. The turbidimetric method will have many interferences because calcium sulfate, calcium silicate, and natural organic matter can precipitate and add to the sulfate value. In addition, the turbidimetric method has a precision of between 5-10 %. Ion chromatography would be

the other preferred method because interferences can be eliminated before the water is analyzed. There may be an issue of samples being too acidic for analysis by ion chromatography. However, the water can be neutralized with NaOH and the sulfate will remain in solution. Ion chromatography has a precision of between 5 and 10 % and the

ICP has a precision between 2 and 5 %. This is why sulfate by ICP is the preferred method even though the analysis is for elemental sulfur and not sulfate. There is a gravimetric method for the analysis, however, it is very time intensive and is not performed by many contract laboratories.

Access to an ICP-Mass Spec is available. However, it is used for determinations when it is anticipated that the concentration of an element is around 1 nanogram per liter. Also, many natural water that have total dissolved solids (TDS) values above 2,000 mg/L need to be diluted and that limits the detection limits that can be expected from using ICP-Mass Spec. On the other hand the ICP-AES can be routinely used for analyses of waters up to TDS values 10,000 mg/L before dilution is needed.

Soil leachate digests will be processed using 0.45-micrometer (um) filters and acidified to below a pH of 2.0 using nitric acid prior to metals analysis. Metals analyses will be conducted using inductively coupled plasma emission atomic spectroscopy (ICP-AES). A Perkin Elmer Optima Model-3000 radial viewing spectrometer is used.

Duplicate samples shall be taken and analyzed from a minimum of 10% of the total number of samples collected during the implementation of this SAPP.

Blanks shall be taken and analyzed once per field week that results in <15 routine samples to ensure that equipment decontamination procedures are followed to exact specifications, the trip blank shall be collected even if the field week trip only includes 1 routine sample. Should the field week result in ≥15 routine samples then one trip blank shall be collected at the start of the week and a second trip blank shall be collected at the end of the week to ensure that equipment decontamination procedures are followed to exact specifications during trips of heavy usage.

b. Laboratory QC Checks:

Dr. Thomas Wildeman of CSM oversee all experiments. Experiments and all analyses will be conducted by undergraduate students trained and under the supervision of Dr. Wildeman. Colorado Analytics Laboratories, Inc Quality Control procedures will comport with EPA Method SW-846-6020, which includes sample preparation, preservation, hold times, detailed analytical procedures including all QA practices.

B-7 -- Instrument / Equipment Calibration and Frequency

Colorado Analytical Lab will use Inductively coupled plasma-mass spectrometry (ICP-MS) to perform the total metals analysis for this project. This laboratory is certified by EPA and CDPHE to perform these analyses as required under the Safe Drinking Water Act and the Clean Water Act.

B-8 -- Inspection / Acceptance Requirements for Supplies

All supplies such as sample bottles, nets, and reagents are specified in EPA method SWadequate for your program's needs./

B-9 -- Data Acquisition Requirements

Not applicable

B-10 -- Data Management

CCWF will coordinate data exchange with the Colorado Data Sharing Network via our partner organization, Colorado Watershed Assembly, to conduct data upload into EPA's STORET.

C - Assessment and Oversight

C-1 -- Assessment and Response Actions

Colorado Analytical Laboratory will provide a complete report of results for total metals including all QA procedures.

Evaluation of the student sampling activities will be performed through final course presentations. All data compiled and evaluated will be provided in CSM student reports which will involve instructor and CCWF feedback and revisions prior to a final NPS Project Report. Any problems or discrepancies identified will be addressed by corrective actions which may include additional collection, sampling and laboratory testing. Sampling errors can be categorized into seven major groups: fundamental error, grouping and segregation error, delimitation error, extraction error, preparation error, cycles, and trends.

Fundamental error results from the compositional heterogeneity of particles. Grouping and segregation error is a function of the nonrandom distribution of particles and the fact that particles are collected in groups rather than individually. Delimitation error and extraction error are both related to the choice and use of sampling tools; collectively they are termed the materialization error. Preparation errors take place after sample collection and before analysis; these errors encompass such factors as sample preservation, contamination, loss, sieving, etc. Both cycles and trends relate to changes in the concentration of a constituent of interest with respect to time or space.

The fundamental error (FE) is often the main source of sampling error (Pitard, 1993). It cannot be eliminated, but it can be estimated prior to sampling. Based on estimates of FE, steps can be taken to minimize it and thus minimize the overall sampling error. Important factors in the FE include heterogeneity, particle size, and sample mass.

The other main sampling error of concern is the grouping and segregation error (GSE). To minimize the grouping factor of the GSE, it is necessary to collect as many small increments as practically possible, assuming that sample collection and preparation are properly carried out. An increment is a group of particles collected from a population with a single operation of the sampling device. Minimizing the segregation factor of the GSE is much more difficult. Complete homogenization of the target population prior to sampling is the solution, but generally is impractical.

C-2 -- Reports

We anticipate one report to be produced for CDPHE NPS from this single sampling effort. Reports received from student volunteers will be based on the number of CSM student groups assigned to the field session. Data will be entered into the Colorado Data Share Network once a final report is approved by CDPHE NPS.

D - Data Validation and Usability

D-1 -- Data Review, Validation and Verification

We will employ Tim Steele, PhD to perform a data quality review in accordance with USGS practices, with which he is well familiar having spent much of his career in the water resources division of that agency.

D-2 -- Validation and Verification Methods

The following steps describe the validation and verification methods that the WQCD Environmental Data Unit uses to verify precision and accuracy and are presented here as a suggestion. We will abide by these same procedures

“Unless otherwise specified, acceptable precision for each analytical parameter (e.g., zinc) for a pair of split samples will be < 30%, expressed as relative percent difference (RPD).

$$\text{Precision} = \text{RPD} = \frac{(C - C)}{(C + C)} \times \frac{1}{2} \times 100\%$$

In the event that the difference between split samples is > 30%, data from that site/time will be considered qualified and either deleted or interpreted with caution. Qualified data will be clearly denoted as such in the database.

Estimates of overall precision of a parameter (e.g., zinc) will be derived from the pooled standard deviations (SD) from all individual split pairs. The pooled standard deviation statistic is termed the root mean square and is calculated as:

$$\text{Percent relative standard deviation} = \% \text{RSD} = (\text{SD} / \text{Mean}) \times 100\%$$

$$\text{Root mean square} = \text{RMS} = \frac{\% \text{RSD}^{0.5} + \% \text{RSD}^{0.5} \dots + \text{etc.}^{0.5}}{N}$$

Unless otherwise specified, acceptable RMS for each parameter is < 30%. If RMS is > 30%, then the analysis for that parameter will be deleted from the database or considered as qualified data and interpreted with caution. Qualified data will be clearly denoted in the database.

Concentration of contaminants allowable in field blanks will be project specific. Data from field blanks will be tabulated, reviewed, and interpreted in project reports. If contamination of field blanks occurs, corrective action will be initiated.

The decision process for determining the significance of blank contamination in terms of project and data quality objectives is presented in the following decision criteria:

<u>Field Blank</u>	<u>Reported Analytical Blank</u>	<u>Outcome to Database</u>
1. < Detection limit	> detection limit	no change

2. > Detection limit	< detection limit	no change
3. > Detection limit	< detection limit	no change
4. > Detection limit	> detection limit	qualified data (See below)

The decision to accept or reject qualified data will be based on the following criteria:

- If, after downward adjustment for possible contamination, the analytical values reported for ambient sites still exceed the designated standard (e.g., the stream standard for zinc), then no change in the data base is required.
- If downward adjustment of the ambient site values eliminates exceedance of the designated standards, then the data point(s) are interpreted with caution and re-sampling at the site(s) is appropriate.”

D-3 -- Reconciliation with Data Quality Objectives

Once the analytical results are provided by the laboratory along with the meta data pertaining to quality assurance, CWF will prepare data quality report that reconciles the sampling results with the data quality objectives.

Bibliography

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