Arizona Department of Environmental Quality

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# TMDL IMPLEMENTATION PLAN

For

## Cadmium, Copper, Zinc and Acidity

# ALUM GULCH

## HUC #15050301-561A & B

Arizona Department of Environmental Quality

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# 1.0 INTRODUCTION

## 1.1 Total Maximum Daily Load Implementation Plan

Pursuant to Arizona Revised Statute § 49-234 (G), (H), & (J), the Arizona Department of Environmental Quality (ADEQ), in collaboration with interested stakeholders, is required to develop and establish a Total Maximum Daily Load (TMDL) implementation plan for those impaired surface waters requiring TMDL analysis in accordance with Section 303(d) of the federal Clean Water Act. The TMDL implementation plan explains how the allocations and any reductions in existing pollutant loadings will be achieved and the time frame in which attainment of applicable surface water quality standards is expected to be achieved.

The purpose of the Alum Gulch TMDL Implementation Plan is to provide an action plan for the implementation of removal and remediation actions designed to achieve the pollutant load reductions identified in the Alum Gulch TMDL for cadmium, copper, zinc and acidity. This implementation plan is a dynamic document that supports revision and improvements of implementation actions based on applied lessons learned. Plan revisions will be administered by ADEQ staff with stakeholder involvement and contribution.

## 1.2 Summary of the TMDL Process

Section 305(b) of the federal Clean Water Act requires each state to submit a water quality assessment report describing the status of state waterbodies in relation to state water quality standards. Based upon review of the 305(b) Report, states generate a list, 303(d) List, of surface waters identified as impaired due to exceedances of applicable surface water quality standards. TMDL analyses are required for waters identified as impaired on the 303(d) List. TMDLs determine the amount or load of a pollutant that a waterbody can receive without exceeding surface water quality standards. TMDLs are pollutant specific and identify source and critical conditions which cause exceedances. For waterbodies with multiple parameter exceedances, TMDLs for each parameter will be developed. Review of TMDL analyses and watershed characteristics aid in determining efficient and effective implementation actions.

## 2.0 BACKGROUND

### 2.1 Alum Gulch Location and Land Use

The Alum Gulch watershed is located approximately 60 miles southeast of Tucson, Arizona and approximately 4 miles south of the town of Patagonia in Santa Cruz County (Figure 1). Contained within the Coronado National Forest, the watershed drains an approximate 10.7 square mile area of the Patagonia and Santa Rita Mountains from Alum Gulch's confluence with Sonoita Creek to its headwaters. Alum Gulch flows generally north-northwest. Sonoita Creek eventually discharges to Patagonia Lake. The watershed elevations range from 4,600 feet to 6,300 feet.

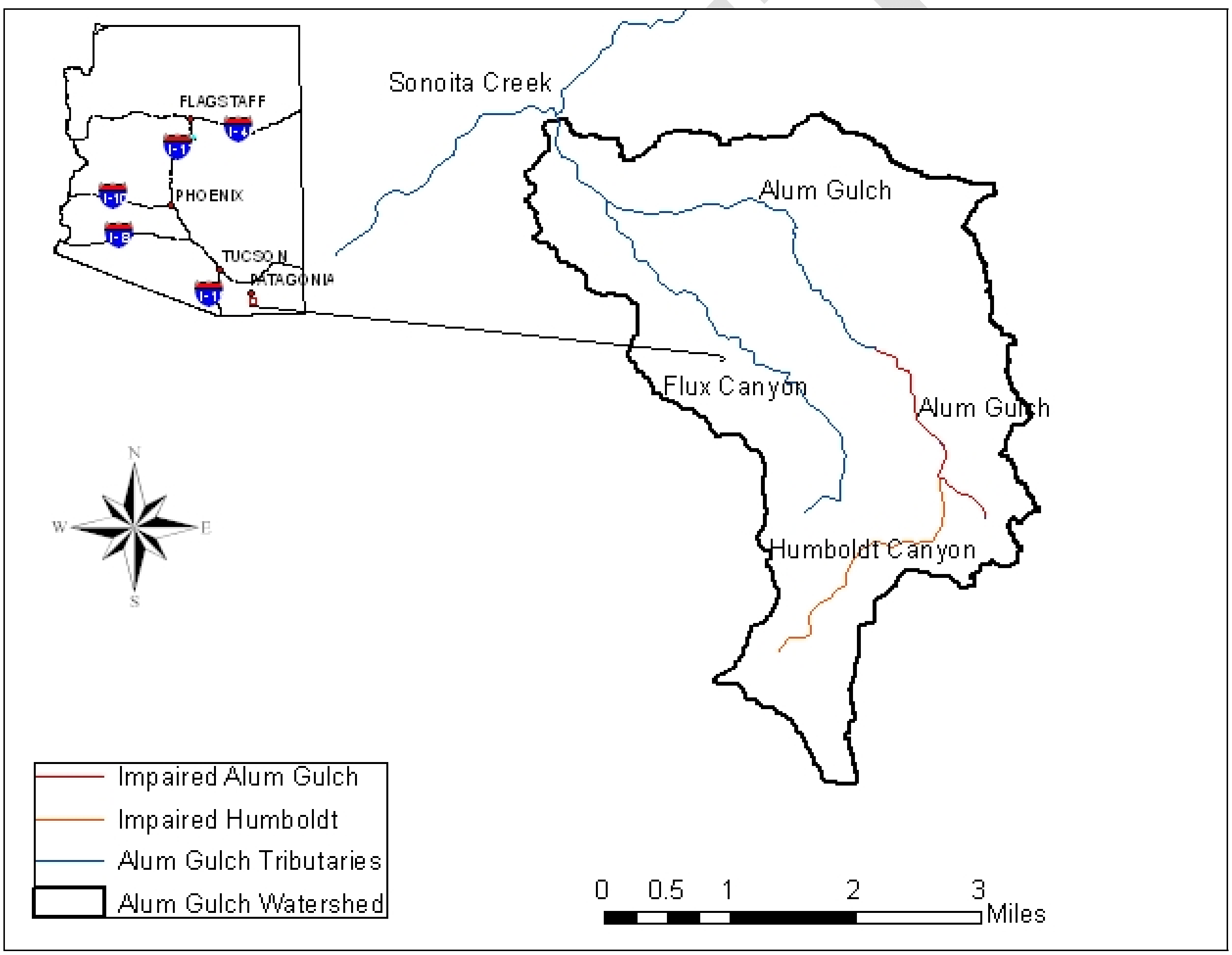


Figure 1. Alum Gulch watershed and reach location

The Alum Gulch watershed contains areas of high mineralization, primarily zinc, lead and copper. These important metals are present in the Alum Gulch watershed combined with sulfur as metal sulfides. Historical mining activities (mining, milling and smelting processes) have left metal sulfide bearing tailings and waste rock behind, often near surface drainages. Ore removed from mine shafts or drifts, dug along rich veins of ore, was generally processed in a mill located onsite. The milling process separated valuable minerals from the ore or base rock. Minerals of value were directed to a smelter for refined extraction (through chemical reduction).

Waste rock and mill tailings, the fine waste rock slurry generated from the milling process, were usually piled downslope of the shaft opening (adit) and often in a streambed. Waste tailing piles are highly susceptible to erosion by wind and water due to the fine particle size of the tailings. Additionally, precipitation and weathering of the sulfide bearing waste rock and tailings piles produces sulfuric acid (through oxidation of sulfide minerals). Sulfuric acid leaches metals from mineralized rock and keeps the metals dissolved which makes them available for transport. The acidic runoff and metals contamination from abandoned mines threaten the Alum Gulch plant, wildlife, aquatic resources and pose significant human health risks.

Current land use activities within the Alum Gulch watershed include recreational use and livestock grazing. Recreational activities include hiking, camping, picnicking, and off-road vehicle riding.



## 2.2 Alum Gulch Impaired Reach

Upper Alum Gulch is impaired due to dissolved and total cadmium, copper, zinc, and acidity (excessively low pH). The pollutants of concern result from the chemical weathering of sulfide mineralized rock which produces sulfuric acid. Sulfuric acid acts to dissociate metals from the mineral matrix and make them available for transport, in the dissolved form, in the water column.

The two mile long impaired reach of Alum Gulch is identified by Hydrologic Unit Code (HUC) and described as headwaters to 31°28'20"/11043'51" (HUC #15050301-561A) and from 31°28'20"/110°43'51" to 31°29'17"/110°44'25" (HUC #15050301-561B). Lower Alum Gulch, beginning at the downstream location of the impaired reach continuing approximately 4 ½ miles to its mouth with Sonoita Creek, is not currently listed as impaired.

Flow within the impaired reach of Alum Gulch occurs below 5,000 feet elevation. Groundwater from springs and effluent from mine adits provide intermittent flow to the stream. Beginning at the January Adit, stream flow is intermittent to the downstream end of the impaired reach. Measured baseflow during the TMDL investigation (2003) ranged from 0.001 to 3 cubic feet per second (cfs) at various points along the impaired reach.

TMDL field observations confirmed that all of the tributaries to upper Alum Gulch are ephemeral. The primary tributary to the impaired portion of Alum Gulch is Humboldt Canyon, the mouth of which is between January Adit and World's Fair Mine (Figure 2).

### 2.3 Alum Gulch Mines

The major mine sites contributing to the impairment of Alum Gulch identified during the TMDL investigation and addressed in this document include the Trench Camp Mine, January Adit, Humboldt Mine, and World's Fair Mine. Trench Camp Mine and January Adit are both privately owned by ASARCO. Humboldt Mine and World's Fair Mine are abandoned mines on Coronado National Forest land. There are no active mines in the Alum Gulch watershed. Figure 2 depicts the location of each mine site along Alum Gulch.

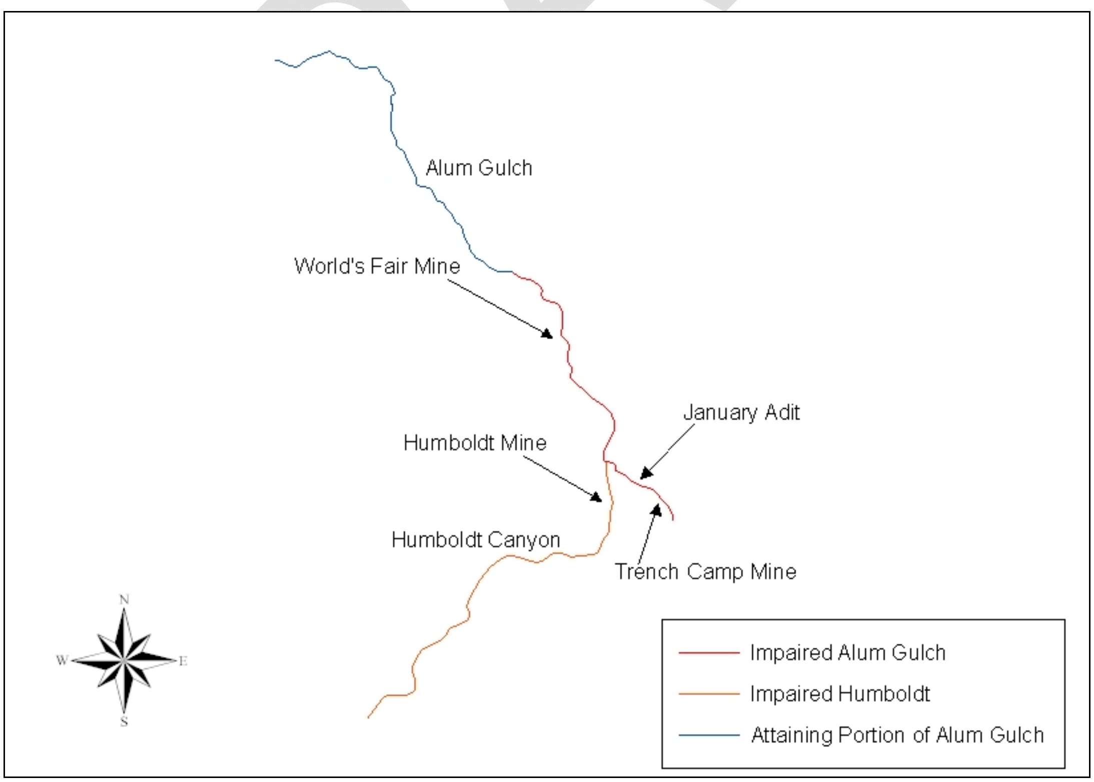


Figure 2. Mine sites located along Alum Gulch

## 3.0 REVIEW OF WATER QUALITY

### 3.1 Designated Uses

Surface water quality standards for the state of Arizona are established to protect each waterbody's designated use(s) (A.A.C. R18-11-101 through R18-11-123). During the 2002 triennial review of surface water quality standards, ADEQ modified designated uses for several segments along Alum Gulch. A flow-related designated use change, from perennial to ephemeral, was adopted for the portion of Alum Gulch upstream from the January Adit (within the impaired reach) and approximately 800 meters downstream from the World's Fair Mine (below the impaired reach). The State also repealed the chronic water quality standards on ephemeral waters; therefore, only the acute standards apply to ephemeral waters. The revised standards were approved by the EPA on October 22, 2002. The designated uses for Alum Gulch are listed below:

Alum Gulch – Two ephemeral reaches: 1) Headwaters to 31°28'20" / 110°43'51" (upstream of January Adit); 2) From a point 800 meters downstream of World's Fair Mine to the confluence with Sonoita Creek:

- Aquatic and Wildlife ephemeral (A&We),
- Partial Body Contact (PBC), and
- Agricultural Livestock Watering (AgL)

Alum Gulch – From January Adit to 800 meters downstream of World's Fair Mine (from 31°28'20" / 110°43'51" to 31°29'17" / 110°44'25"):

- Aquatic and Wildlife warm water (A&Ww) (below 5,000′ elevation),
- Full Body Contact (FBC),
- Fish Consumption (FC), and
- Agricultural Livestock Watering (AgL)

Humboldt Canyon – headwaters to Alum Gulch:

- Aquatic and Wildlife ephemeral (A&We) and
- Partial Body Contact (PBC)

Humboldt Canyon, an unlisted ephemeral tributary to Alum Gulch, is designated A&We and PBC according to the tributary rule (R18-11-105) within the surface water quality standards.

### 3.2 Surface Water Quality Standards

The numeric targets for each pollutant impairing Alum Gulch were selected for the purposes of achieving the most stringent water quality standards for each designated use (Table 1). The dissolved cadmium, copper and zinc standards for the listed Aquatic and Wildlife uses vary with hardness (range of 25 to 400 mg/L as $CaCO_3$) (A.A.C. Title 18, Chapter 11, Article 1, App. A).

**Table 1. Surface Water Quality Standards (basis for numeric targets)**

| Designated Use | pH | Cadmium (µg/L [a]) | | Copper (µg/L) | | Zinc (µg/L) | |
|---|---|---|---|---|---|---|---|
| | | Total | Dissolved | Total | Dissolved | Total | Dissolved |
| A&Ww (chronic) | 6.5 – 9.0 | | 0.8 – 6.2 | | 2.7 – 29 | | 36 – 379 |
| A&Ww (chronic) | 6.5 – 9.0 | | 0.95 – 19 | | 3.6 – 50 | | 36 – 379 |
| A&We (acute) | 6.5 – 9.0 | | 14 – 290 | | 6.3 – 86 | | 344 – 3,599 |
| AgL | 6.5 – 9.0 | 50 | | 500 | | 25,000 | |
| FBC/PBC | 6.5 – 9.0 | 700 | | 1,300 | | 420,000 | |
| FC | 6.5 – 9.0 | 84 | | | | 69,000 | |

[a] µg/L – micrograms per liter

Refer to the TMDL document (ADEQ, 2003) to review the collected water quality data concentrations compared to applicable surface water quality standards.

### 3.3 303(d) Listing History

As previously mentioned, Section 303(d) of the federal Clean Water Act requires states to submit a list of its impaired surface waters, where one or more surface water quality standards are not being met. Each state must submit this updated list every two years to the United States Environmental Protection Agency (EPA). Alum Gulch (HUC #15050301-561A & -561B) was listed on the 1996, 1998, 2002 and currently listed on the 2004 303(d) List due to exceedances of surface water quality standards for cadmium, copper, zinc and acidity. TMDL analysis was completed and approved by the EPA in August 2003.

Alum Gulch is one of three waters impaired within the Sonoita Basin. The other waters are Harshaw Creek and Three R Canyon (Figure 3). Harshaw Creek is impaired due to exceedances of copper and pH standards. Three R Canyon is impaired due to exceedances of cadmium, copper, zinc and pH. All three waters are in areas of high mineralization and share similar historic mining practices.

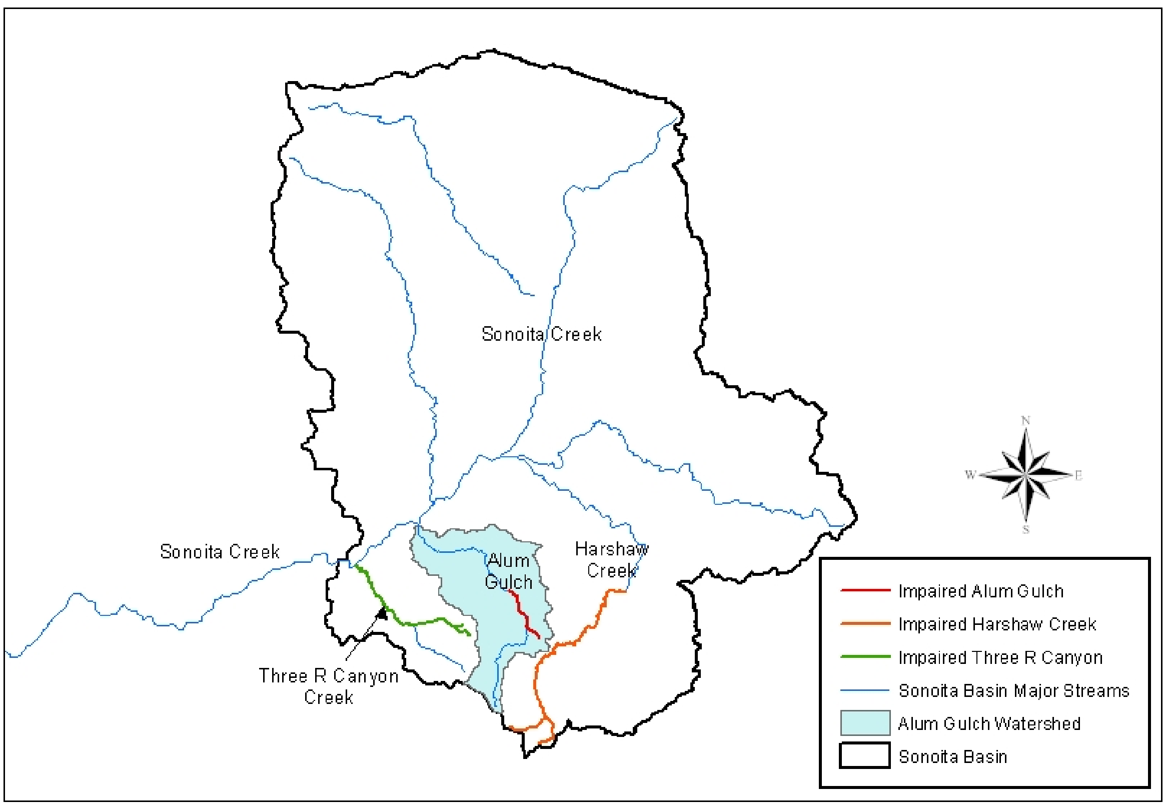


Figure 3. Location of three impaired waters within Sonoita Basin.

# 4.0 SOURCES OF WATER QUALITY IMPAIRMENT

## 4.1 General Sources of Impairment

General sources of pollutant (cadmium, copper, zinc and acidity) impairment to Alum Gulch include adit drainage, waste rock and tailings piles, and sediments. Acidic adit drainage containing heavy metals adversely affects aquatic life and human health when it enters surface streams and groundwater systems. Tailings piles consisting of small particles of heavy metals are easily eroded by wind and rain into nearby streams and rivers. Contaminated sediment enters streams and destroys aquatic habitat by covering stream bottoms. Historic mining activities have severely impacted streams and water quality.

### 4.1.1 Natural Background

The Alum Gulch watershed contains naturally occurring iron sulfide minerals such as pyrite. Natural weathering of pyrite by air and water produces iron oxides and sulfuric acid. However, natural weathering processes occur slowly. Natural background concentrations obtained from averaged United States Geological Survey (USGS) measurements were used to determine TMDLs for dissolved and total metals (Table 2).



**Table 2. USGS natural background concentrations for Alum Gulch**

| Metals (dissolved & total) | Background Concentration (µg/L) |
|---|---|
| Cadmium | 0.14 |
| Copper | 5 |
| Zinc | 28 |

### 4.1.2 Adit Drainage

January Adit and World's Fair Mine have the only observed constant drainages in the Alum Gulch watershed. The January Adit discharge flows through a constructed wetland, infiltrates, and a portion of the infiltrate seeps into the groundwater and stream. Discharge from January Adit is regulated through an Arizona Discharge Elimination System (AZPDES) permit issued in 2003 (AZ0025054).

The USGS determined that one or more discharges exist beneath the World's Fair Mine tailings pile and is a major source of acidity and metals, with equivalent concentrations and proportions as the World's Fair Adit drainage. This suggests that groundwater is impacted by the underground mine workings. The adit drainage in the World's Fair Mine study area is typically very acidic, pH of 2 to 3, and carries a variety of metals. Corresponding flow rates into the stream during the TMDL investigation (1997 – 2000) fluctuated but generally were extremely low, barely a trickle. During dry periods the drainage from the World's Fair Mine adit evaporated or entered the interstitial spaces of the tailings pile before mixing with other discharges beneath the tailings pile and entering the stream.

### 4.1.3 Waste Rock and Tailings Piles

In addition to adit drainage, tailings and waste rock piles are a significant source of pollutants and consist of three major categories of material:

- Waste rock - removed to gain access to the ore. Potential for leachable metals.
- Low grade ore waste - uneconomical to extract at the time of mining. Leachable metals present.
- Mill tailings - the finely ground waste after separation from the economically useful minerals. Potential for leachable metals.

The waste rock, low grade ore waste and mill tailings are typically mixed or layered in the same waste pile site, dependent upon mine or mill activities at the time of dumping. These waste pile sites are subject to erosion which potentially contributes contaminated sediment directly to surface waters. The mine sites within the Alum Gulch watershed typically include adits and shafts, waste rock, and waste piles. Larger mine sites additionally include the remains of mills or other ore-handling fixtures, all of which rest on the steep, rocky slopes of Alum Gulch.



### 4.1.4 Sediments

Streambed sediments contain material from the waste piles and evaporative deposits from groundwater discharges (both vary in composition). Following the Sonoita Basin study, the USGS suggested that streambed sediments are the primary source of pollutant loading to Alum Gulch. Streambed sediments were not directly addressed by the TMDL due to a lack of data that could be used to associate sediment concentrations with water column concentrations at various discharges. However, if waste and tailings piles are removed or stabilized, they would no longer add sediment to the streambed.

### 4.2 Known Sources of Impairment

The known sources of metal pollutant contributions to Alum Gulch are the major mines: Trench Camp, January Adit, Humboldt Canyon, and World's Fair Mine (Figure 2).

### 4.2.1 Trench Camp Mine

Trench Camp Mine, formerly occupied by a mine, mill and smelter, was largely remediated by ASARCO, during the 1980's and 1990's. Implementation actions included sediment removal, limestone addition, capping of the four tailings piles and creation of diversion ditches around the tailings piles (Figures 4 & 5). TMDL sample results showed that Trench Camp Mine contributes minor amounts of zinc and acidity to the water column.

**Figure 4. Trench Camp Mine remediated tailings pile No. 1.**

**Figure 5. Trench Camp Mine remediated tailings pile No. 4.**

### 4.2.2 January Adit

January Adit, located 200 meters downstream from Trench Camp Mine, was plugged in the late 1990's by ASARCO. January Adit discharge flows through a collection system created and buried to convey adit drainage to the pilot wetland treatment system. Once the collection system reaches capacity, excess drainage seeps into the stream (Figures 6-9). ASARCO plans to expand the wetland system in 2007.

During the TMDL investigation, January Adit was found to be a minor contributor of cadmium, copper and acidity and a major contributor of zinc to the water column. Its load contributions of acid and copper were less than that of the World’s Fair Mine and Humboldt Canyon.

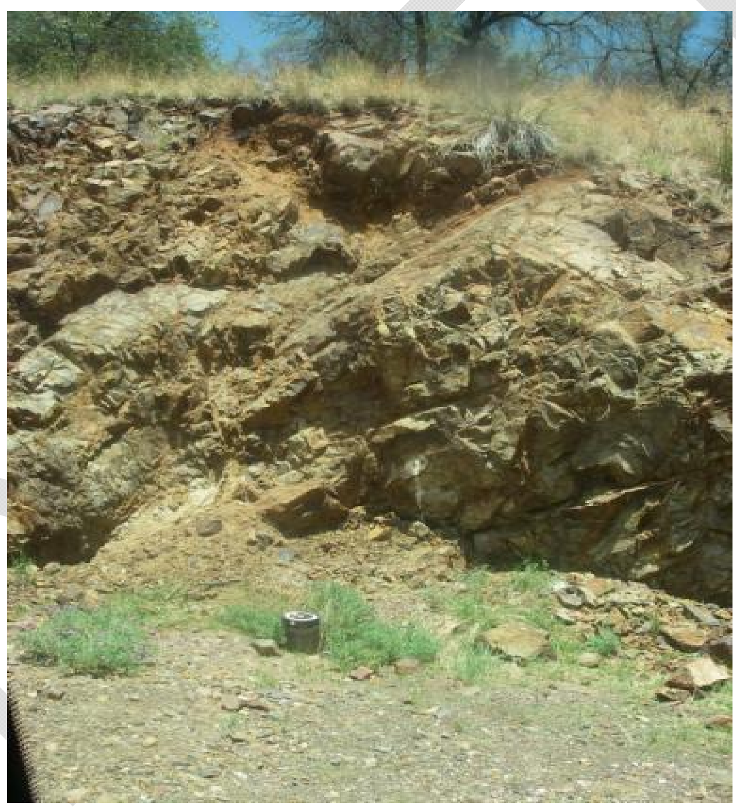

**Figure 6. January Adit after remediation efforts.**

Figure 7. January Adit discharge through treatment system.

Figure 8. January Adit discharge continuing through treatment system.

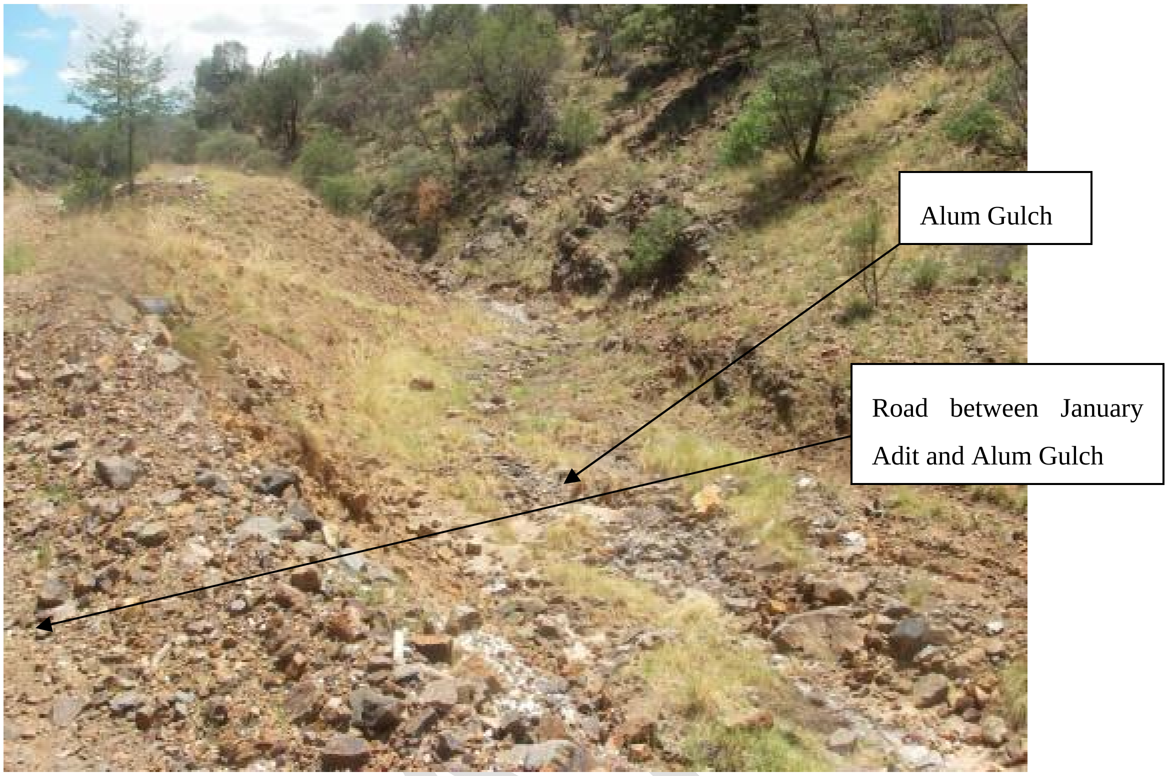


**Figure 9. View upstream of Alum Gulch beside January Adit.**

### 4.2.3 Humboldt Canyon Mines

The headwaters of Humboldt Canyon contain Thunder Mine and several un-named mines of sufficient size with easily observable waste piles and spoils. Between the headwaters portion and the lower portion of Humboldt Canyon is an approximately 500 meter segment of drops (falls) and a small basin. There are no larger mines in this middle portion, only small workings and prospect pits.

Humboldt Well, located in the middle portion of Humboldt Canyon, was a 5,000 foot exploration hole (now steel-cased to about 2,000 feet below ground). Because Humboldt Well is an artesian well, it has been capped and equipped with a small, garden-hose sized valve. During the TMDL study, measurements of the well water pH ranged from 2.8 to 3.8.

The lower portion of Humboldt Canyon has many small prospect pits, several small adit or shaft mines with observable waste piles and spills, and the Humboldt Mine, a cluster of shafts and adits with waste piles large enough to occupy part of the stream channel.

### 4.2.4 World's Fair Mine

The World's Fair Mine, an abandoned claim, is a complex of shafts and adits and a former mill site. The main adit releases continual low flow adit drainage (Figures 10-12) directly to Alum Gulch. Currently, no AZPDES permit exists for the World's Fair Mine main adit discharge.

**Figure 10. World's Fair Mine main adit and drainage.**

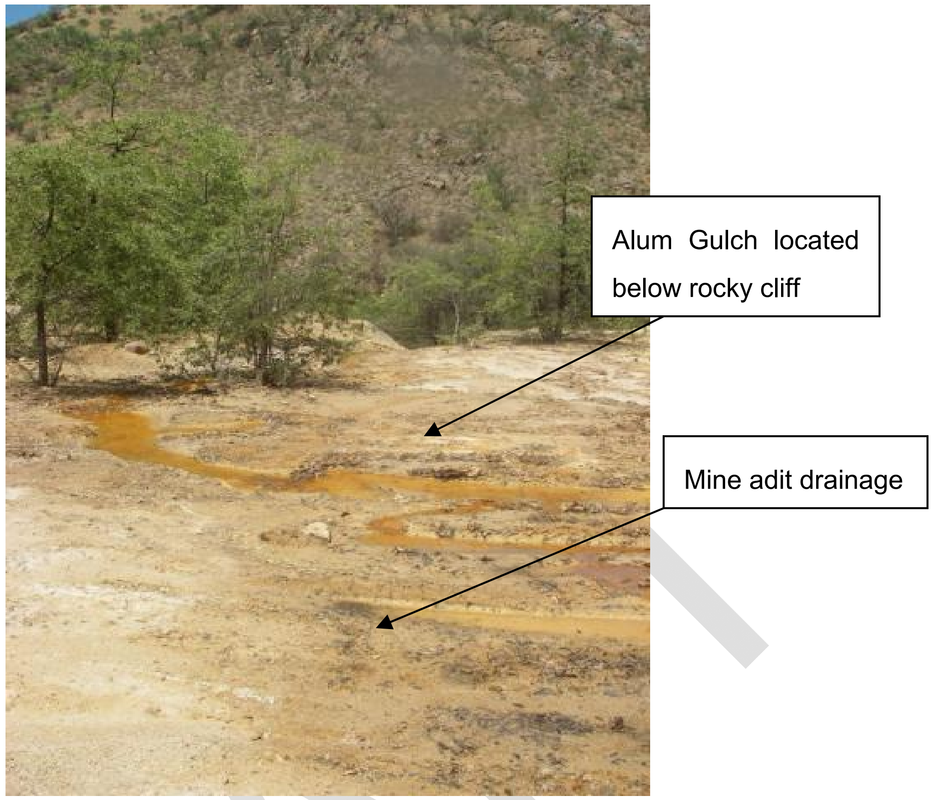


**Figure 11. World's Fair Mine adit drainage.**

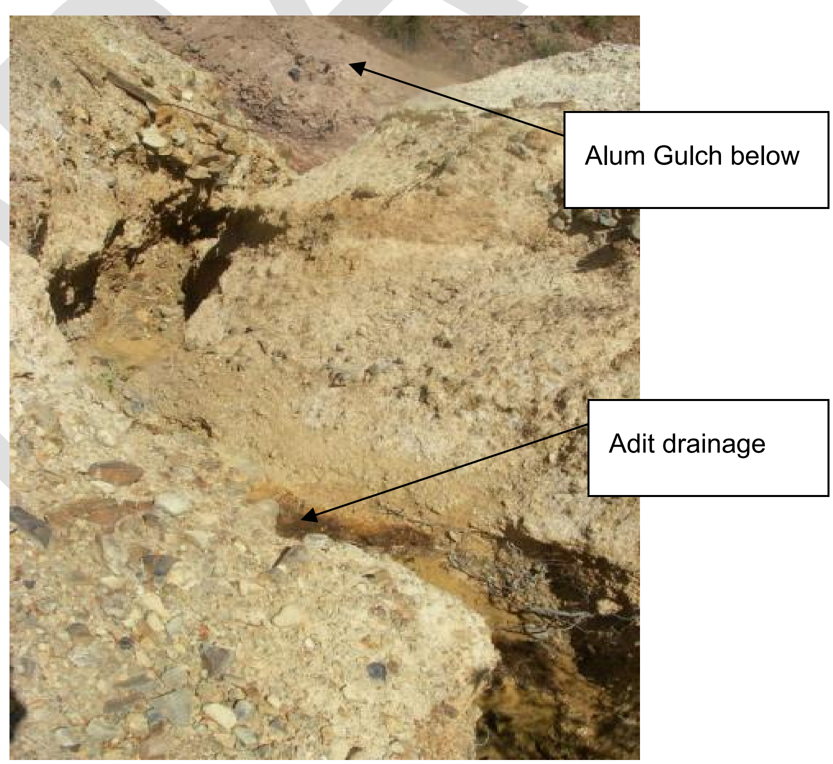


**Figure 12. World's Fair Mine adit drainage into Alum Gulch**

The waste pile located at World's Fair Mine is a large exposure of material and includes tailings that fill a tributary draw and a portion of Alum Gulch (Figure 13). The left stream bank of Alum Gulch is defined by the waste pile as evidenced through undercutting of the pile by the stream flow. As previously mentioned, the USGS determined that one or more discharges exist beneath the tailings pile and is a major source of acidity and metals. During dry periods, the adit drainage evaporates or enters the interstitial spaces of the tailings pile and mixes with the tailings drainages prior to entering Alum Gulch.

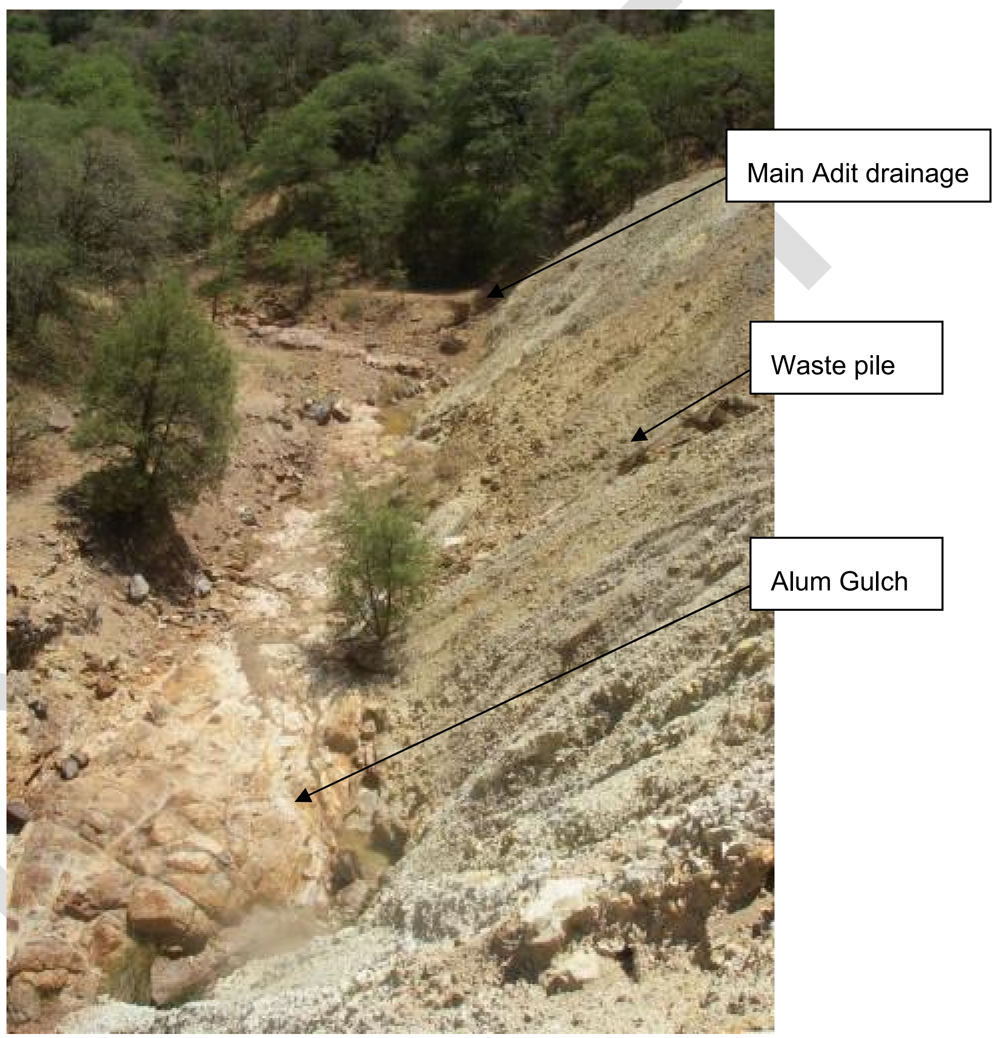


**Figure 13. View upstream (southerly) of waste rock and tailings pile**

TMDL sample results indicated the World's Fair Mine site is a major contributor to loading of all the pollutants of concern. The World's Fair Mine is approximately 300 meters upstream from the bottom of the 303(d) listed reach and there are no significant additional sources of pollutant loading in this lowest segment downstream of the mine.

### 4.3 Summary of Sources of Impairment

Based upon results of the TMDL field measurements, the major portion of the loading originates from the World's Fair Mine and Humboldt Canyon areas with relatively minor contributions from Trench Camp Mine and January Adit. Remediation efforts at Trench Camp have been relatively successful. January Adit requires further treatment system upgrades (to meet permit requirements). Contributions of acidity and copper from Trench Camp Mine and January Adit were one to two orders of magnitude less than samples collected from World's Fair Mine and Humboldt Canyon. There appeared to be little change in cadmium levels among the various sites and all sites except Trench Camp site were major contributors of zinc.

## 5.0 EXPECTED LOAD REDUCTIONS

The cadmium, copper and zinc load reductions calculated during the TMDL process were assigned to segments of Alum Gulch under critical flow regimes. TMDLs and subsequent load reductions determined for the purposes of achieving the TMDLs were calculated based on water quality standards, flow, load allocation (non-point source), waste load allocation (point source), natural background, and margin of safety. The general method for calculating load reduction is described below:

- TMDL = ∑load allocations + ∑waste load allocations + margin of safety + natural background
- Load Reduction = Existing load - TMDL

Refer to the TMDL study for a complete description of the load calculating process (ADEQ, 2003). The targeted load reductions for specific locations along Alum Gulch are listed in the following tables (3-10). As load reductions are achieved, water quality standards will be met.

**Table 3. Targeted Load Reductions for Trench Camp Mine site (point source)**
Sample point: SCALG005.66, ADEQ# 100839. Bankfull discharge = 8.7 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.21 | 1.5 | 0 |
| Cd (total) | 0.21 | 1.1 | 0 |
| Cu (diss) | 0.28 | 0.54 | 0 |
| Cu (total) | 1.3 | 11 | 0 |
| Zn (diss) | 53 | 26 | 32 |
| Zn (total) | 62 | 532 | 0 |
| H+ (pH) | 0.000016 | 0.0000054 | 0.00001 |

**Table 4. Targeted Load Reductions for site between January Adit & Humboldt Canyon (point source)**
Sample point: SCALG005.35, ADEQ# 100838. Baseflow discharge = 0.04 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.014 | 0.0006 | 0.014 |
| Cd (total) | 0.016 | 0.005 | 0.012 |
| Cu (diss) | 0.011 | 0.003 | 0.009 |
| Cu (total) | 0.011 | 0.05 | 0 |
| Zn (diss) | 4.6 | 0.04 | 4.6 |
| Zn (total) | 4.8 | 2.4 | 3 |
| H+ (pH) | 0.000002 | 0.00000003 | 0.000002 |

**Table 5. Targeted Load Reductions for site between January Adit & Humboldt Canyon (non-point source)**
Sample point: SCALG005.35, ADEQ# 100838. Bankfull discharge = 12.6 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.65 | 0.16 | 0.5 |
| Cd (total) | 0.74 | 1.5 | 0 |
| Cu (diss) | 3.5 | 0.73 | 3 |
| Cu (total) | 3.5 | 15 | 0 |
| Zn (diss) | 192 | 9.5 | 186 |
| Zn (total) | 192 | 771 | 0 |
| H+ (pH) | 0.0004 | 0.00001 | 0.0004 |

**Table 6. Targeted Load Reductions for Upper Humboldt Canyon (headwaters) (non-point source)**
Sample point: SCHMC002.41, ADEQ# 100841. Bankfull discharge = 12.7 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.012 | 2 | 0 |
| Cd (total) | 0.012 | 22 | 0 |
| Cu (diss) | 7.4 | 0.72 | 6.8 |
| Cu (total) | 7.3 | 40 | 0 |
| Zn (diss) | 0.9 | 35 | 0 |
| Zn (total) | 0.8 | 13,050 | 0 |
| H+ (pH) | 0.009 | 0.00001 | 0.009 |

**Table 7. Targeted Load Reductions for Upper Humboldt Canyon at Falls (non-point source)**
Sample point: SCHMC001.27, ADEQ# 100840. Baseflow discharge = 38.6 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.47 | 1.4 | 0 |
| Cd (total) | 0.47 | 66 | 0 |
| Cu (diss) | 5.9 | 0.6 | 5.4 |
| Cu (total) | 6.4 | 123 | 0 |
| Zn (diss) | 8 | 32 | 0 |
| Zn (total) | 10 | 39,663 | 0 |
| H+ (pH) | 0.014 | 0.00003 | 0.014 |

**Table 8. Targeted Load Reductions for site below Humboldt Canyon above Alum Falls (non-point source)**
Sample point: SCHMC005.15, ADEQ# 100837. Baseflow discharge = 0.06 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.02 | 0.0009 | 0.02 |
| Cd (total) | 0.03 | 0.007 | 0.02 |
| Cu (diss) | 0.18 | 0.004 | 0.18 |
| Cu (total) | 0.18 | 0.07 | 0.12 |
| Zn (diss) | 6.5 | 0.06 | 6.5 |
| Zn (total) | 6 | 3.7 | 3 |
| H+ (pH) | 0.00004 | 0.00000005 | 0.00004 |

**Table 9. Targeted Load Reductions for site below Humboldt Canyon above Alum Falls (non-point source)**
Sample point: SCHMC005.15, ADEQ# 100837. Bankfull discharge = 68.5 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 3.5 | 0.7 | 3 |
| Cd (total) | 4.7 | 8.4 | 0 |
| Cu (diss) | 89 | 3.1 | 87 |
| Cu (total) | 86 | 84 | 20 |
| Zn (diss) | 973 | 40 | 946 |
| Zn (total) | 873 | 4,190 | 0 |
| H+ (pH) | 0.025 | 0.000054 | 0.025 |

**Table 10. Targeted Load Reductions for Alum Gulch above World's Fair Mine (non-point source)**
Sample point: SCALG004.72, ADEQ# 100836. Bankfull discharge = 74.8 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 4.2 | 0.7 | 3.7 |
| Cd (total) | 4.4 | 9.1 | 0 |
| Cu (diss) | 121 | 3 | 119.5 |
| Cu (total) | 109 | 91 | 36.9 |
| Zn (diss) | 1,111 | 39 | 1,085 |
| Zn (total) | 1,139 | 4,575 | 0 |
| H+ (pH) | 0.035 | 0.00006 | 0.035 |

**Table 11. Targeted Load Reductions for World's Fair Mine (point source)**
Sample point: SCAL004.67, ADEQ# 100317. Baseflow discharge = 0.01 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.005 | 0.0002 | 0.005 |
| Cd (total) | 0.005 | 0.001 | 0.004 |
| Cu (diss) | 0.05 | 0.0007 | 0.05 |
| Cu (total) | 0.05 | 0.01 | 0.04 |
| Zn (diss) | 1.3 | 0.009 | 1.3 |
| Zn (total) | 1.3 | 0.6 | 0.8 |
| H+ (pH) | 0.00001 | 0.00000001 | 0.00001 |

**Table 12. Targeted Load Reductions for World's Fair Mine**
Sample point: SCAL004.67, ADEQ# 100317. Bankfull discharge = 75.9 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 5.4 | 1.1 | 4.5 |
| Cd (total) | 5.2 | 9.3 | 0 |
| Cu (diss) | 172 | 5.3 | 167 |
| Cu (total) | 159 | 93 | 85 |
| Zn (diss) | 1,347 | 69 | 1,292 |
| Zn (total) | 1,245 | 4,642 | 0 |
| H+ (pH) | 0.06 | 0.00006 | 0.06 |

**Table 13. Targeted Load Reductions for World's Fair Mine and basin downstream (point source)**
Sample point: SCAL004.45, ADEQ# 100870. Baseflow discharge = 0.19 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 0.1 | 0.03 | 0.07 |
| Cd (total) | 0.13 | 0.03 | 0.1 |
| Cu (diss) | 0.93 | 0.014 | 0.9 |
| Cu (total) | 0.98 | 0.2 | 0.8 |
| Zn (diss) | 25 | 0.18 | 25 |
| Zn (total) | 25 | 12 | 15.3 |
| H+ (pH) | 0.0003 | 0.0000002 | 0.0003 |

**Table 14. Targeted Load Reductions for World's Fair Mine and basin downstream (non-point source)**
Sample point: SCAL004.45, ADEQ# 100870. Bankfull discharge = 93.2 cfs

| Parameter | Existing Load (kg/day) | TMDL (kg/day) | Load Reduction (kg/day) |
|---|---|---|---|
| Cd (diss) | 39 | 1.4 | 37.7 |
| Cd (total) | 39 | 11 | 30 |
| Cu (diss) | 251 | 6.7 | 247 |
| Cu (total) | 433 | 114 | 343 |
| Zn (diss) | 11,173 | 86 | 11,110 |
| Zn (total) | 10,261 | 5,700 | 5,707 |
| H+ (pH) | 0.09 | 0.00007 | 0.09 |

## 6.0 IMPLEMENTATION ACTIONS

The Alum Gulch TMDL Implementation Plan outlines removal and remediation implementation actions for abandoned and inactive mines within the Alum Gulch watershed based on the targeted TMDLs for cadmium, copper, zinc and acidity. General implementation actions for cleanup of the mines are described followed by specific actions (either previously, currently or proposed) for January Adit (ASARCO) and World's Fair Mine (USFS).

### 6.1 General Mine Reclamation Implementation Actions

The general implementation actions for abandoned and inactive mines in the Alum Gulch watershed are the use of hydrologic controls or passive treatment. Best Management Practices in Abandoned Mine Land Reclamation (2002) developed by the Colorado Division of Minerals and Geology describes feasible solutions for the removal and remediation of contaminated mine workings and waste through hydrologic and passive controls including implementation, costs and maintenance.

#### 6.1.1 Hydrologic Controls

Hydrologic controls are preventative measures intended to reduce or eliminate acid production and metal dissolution processes by minimizing or eliminating water from entering a mine or making contact with sulfide rocks and waste rock/tailings piles. Common hydrologic controls with a brief description of purpose and implementation are listed below:

- Diversion ditches
- Remove/consolidate contaminated material
- Stream diversion
- Erosion control by regrading
- Capping
- Vegetation

*Diversion Ditches*

Diversion ditches divert rainwater, snowmelt or surface flow away from flowing over or through mine workings or mine waste rock and tailings piles. Ditches should be constructed upstream of contaminated mine waste rock and tailings piles to capture and direct flow around contaminated material. Vegetation should be established on ditches to slow water flow and reduce ditch erosion.

*Remove/Consolidate Contaminated Material*

The purpose of this method is to remove and consolidate contaminated material while preventing water flow through mine waste and contaminating nearby waterbodies. A consolidation area to contain the removed material must be located away from the waterbody. A berm should be constructed around the consolidation area if the removed material is saturated with a tendency to flow downstream. All waste rock and tailings piles should be removed from the streambanks and all mine-waste originated sediments should be removed from the streambed.

*Stream Diversion*

Stream diversion involves relocating a stream away from waste rock and tailings piles when the pile is in direct contact with a flowing stream and there is no place to remove and consolidate waste.

*Erosion Control by Regrading*

Barren areas and steep slopes of waste rock piles and tailings piles are susceptible to wind and water erosion causing rills and unfavorable conditions for vegetation growth. Regrading barren areas and steep slopes to create a uniform surface with a gentle ($\leq$3:1) slope provides a stable environment for vegetation growth and minimizes erosion.

*Capping*

Capping waste rock or tailings piles provides a protective layer of soil on top of the contaminated piles which minimizes infiltration of water into the pile, and the potential for transport of pollutants to nearby surface waters. The pile should be graded then capped with material. Caps may consist of 1) soil obtained from the site and may be a mixture of soils if clay and sand are available; 2) layered soils: the lower layer, directly on top of the pile, should be composed of fine (high density), low permeable soil to prevent infiltration and the upper layer should be composed of coarse (low density) soil to promote vegetation growth; or 3) synthetic filter fabric material and fine and coarse material to prevent water infiltration and promote vegetation growth on top. The final soil cover should be a minimum of 6” – 12” to provide an adequate root zone.

*Vegetation*
Planting a graded or capped waste rock or tailings pile with vegetation minimizes water infiltration into the contaminated pile. Additionally, vegetated piles create habitat for various wildlife.

### 6.1.2 Passive Treatment

Passive methods treat mine waste through drainage treatment techniques such as aeration and settling ponds, sulfate-reducing wetlands, and oxidation wetlands. Additionally, limestone or other neutralizing agents may be used to directly or passively treat acid-mine drainage.

*Aeration and Settling Ponds*
Aeration and settling ponds promote precipitation of heavy metals such as cadmium, copper and zinc through oxidation processes. This process is especially effective for treating neutral (pH = 7) mine drainage that is high in suspended solids. This type of drainage may be directed through a series of small drops to increase oxygen content of the drainage that eventually collects in a settling pond where heavy metals precipitate out.

*Sulfate-Reducing Wetlands*
Specialized sulfate-reducing bacteria (SRB) found in decomposing organics within sulfate-reducing wetlands remove heavy metals from acid-mine drainage. During respiration, SRB obtain oxygen from sulfates, producing sulfides. Sulfides combine with heavy metals in the drainage to form insoluble metal sulfides, which precipitate out and settle.

*Oxidation Wetlands*
Oxidation by aquatic plants and algae precipitate heavy metals such as cadmium, copper, and zinc. The plant materials provide an oxidizing environment and upon senescence, the decaying plants provide adsorption surfaces for the metals and sites for algal growth. Algae may remove cadmium, copper, and zinc.

*Limestone Addition*
Limestone (high alkalinity) may be used to neutralize highly acidic mine drainage. Limestone can be crushed and deposited in a trench designed to receive and neutralize acid-mine drainage as it is released. Aqueous lime may be mixed with acid mine drainage before it enters a settling pond, where metals will precipitate out.

Achieving targeted TMDL load reductions through controlling exposure of the source material to weathering, treating the runoff, and removing mine-waste originated stream sediments, will reduce the pollutants evaluated and water quality standards will be met.

### 6.2 January Adit Remediation Actions

January Adit was plugged in the late 1990's by ASARCO and the adit drainage discharge was piped to artificial wetlands created to treat the discharge before entering Alum Gulch. In 1996, ASARCO began remediation of the Alum Gulch segment near January Adit between the Trench Camp Mine site and the confluence with Humboldt Canyon for a total distance of approximately 2,536 feet (0.5 mile). The primary objective of the project was to remove as much of the stream run sediments as possible from the affected Alum Gulch channel.

900 cubic yards of sediment were removed from Alum Gulch then hauled and buried in an open pit, excavated in solid rock, located west of the Trench Camp main shaft. 270 cubic yards of limestone were deposited along the channel. Upon completion of the project, the waste was covered with 4 feet of soil/rock and contoured to prevent erosion. The banks of Alum Gulch were kept as close to the original contours as possible with only the addition of sufficient soil material to promote grasses and other plant development.

In 2003, ASARCO obtained an Arizona Pollutant Discharge Elimination System (AZPDES) permit (AZ0025054) from ADEQ to allow discharge from January Adit which flows through a wetland, and then seeps into Alum Gulch. The wetland was artificially created for the purposes of treating the acid mine drainage. Unfortunately, the treatment system is not treating the discharge effectively to meet permit concentration limits. ASARCO is currently conducting a pilot test project for a treatment alternative. Completion of this pilot project will result in the recommended treatment alternative designed to achieve permit discharge limits. Installation of the treatment system is scheduled to be completed and permit concentrations achieved by December 30, 2006, the deadline established in the compliance schedule within the January Adit AZPDES permit. However, ASARCO has indicated they need more time to complete the pilot project and construct the full-scale wetlands with additional treatment.

### 6.3 Trench Camp Mine Remediation Actions

ASARCO performed removal/remediation actions at Trench Camp Mine during the 1980's and 1990's. Remediation included the removal of structures, filling the main shaft, leveling and vegetating the four waste material (waste rock and tailings) piles, and creation of diversion ditches around the tailings piles. The Trench Camp mining waste piles Numbers (No.) 1, 2, and 4 fill the upper portion of Alum Gulch, and pile No. 3 is in the Harshaw Creek basin.

ASARCO removed 900 cubic yards of stream bottom sediments from an approximate 400 meter reach of Alum Gulch running from the bottom of the Trench Camp Mine to below the created wetlands that capture the January Adit discharge. The sediments were replaced with crushed limestone to act as a neutralizing agent for acid drainage.

### 6.4 World's Fair Mine Remediation Actions

The World's Fair Mine, an abandoned mine located on USFS Coronado National Forest land, has been named a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. As a CERCLA site, funds are available to support USFS remediation or reclamation of abandoned mine sites causing harm to the ecosystem. In efforts to begin reclamation of abandoned mines within the Alum Gulch watershed, the USFS Coronado National Forest contracted Science Applications International Corporation to develop an Engineering Evaluation/ Cost Analysis (EE/CA) for evaluation of technical alternatives or remediation strategies for the cleanup of mine waste.

The EE/CA, completed May 2006, evaluated the effectiveness of mine waste removal action alternatives based on the overall protection of public health and the environment, compliance with applicable or relevant and appropriate requirements (ARARs), long-term effectiveness, reduction of toxicity, mobility, or volume through treatment, and short-term effectiveness. Finally, the implementability of each alternative was evaluated based on technical feasibility at the site, availability of services and materials, administrative feasibility, and state/community acceptance cost.

The recommended removal actions for the World's Fair Mine, as described in the final EE/CA Report, are the passive treatment of acid mine drainage and an on-site repository. These alternatives call for an anoxic drain, constructed wetlands, modifying the waste rock pile in place with a reclamation cover, and surface water diversion.

The USFS evaluated the EE/CA recommendations, future land use, and public comments. In August 2006, a final decision was made to perform excavation and onsite consolidation of approximately 26,000 cubic yards of waste rock located adjacent to drainages at the Humboldt Mine, South Chief Mine and World's Fair Mine. The proposed removal action for the World's Fair Mine site specifically, as stated in the USFS Removal Action and Approval Memorandum (August 15, 2006), includes:

1) Excavating approximately 12,000 cubic yards of waste rock containing lead and arsenic,
2) Blasting bedrock from the existing stream channel and reshaping the drainage to the east;
3) Reshaping the existing waste rock material with a milder slope of 3:1 or 4:1;
4) Using the existing bench to place material to achieve the milder slope,
5) Protecting the toe of the new slope using rock riprap generated from blasting bedrock in the adjacent stream channel;
6) Constructing a rock riprap French drain from the mouth of the main adit to Alum Gulch drainage bottom and the installation of a 36 inch bat culvert gate.

This proposed action includes reshaping the existing World's Fair waste rock and consolidating it with waste rock hauled from the Humboldt Mine. The consolidated material will be capped with clean fill. Separating the adit water from direct contact with the waste rock will reduce the leaching of the waste rock. The Removal Action is scheduled to commence in the fall of 2006 and completed by the summer of 2007.

The adit discharge itself was not addressed in the remediation plans. According to the Arizona Pollutant Discharge Elimination System (AZPDES) program, the USFS is responsible for applying for an AZPDES permit for the World's Fair Mine adit discharge. ADEQ issued a Notice of Opportunity to Correct (NOC) for the adit discharge. USFS issued a Supplemental Memorandum (December 19, 2006) to the Removal Action Memorandum (August 15, 2006) for the purposes of clarifying the Forest Service's intent to perform additional evaluation of the adit drainage through 1) assessment of background pH for water from springs and seeps in the area; 2) and adit water contribution to degraded pH and metal concentration to Alum Gulch. The USFS proposes to sample upstream and downstream of the World's Fair mine and at the adit discharge point into Alum Gulch biannually for three years assessing pH, cadmium, copper, zinc, lead, arsenic, and basic water quality measurements (dissolved oxygen, conductivity, and alkalinity). The monitoring will provide further characterization proposed to determine the most effective way to treat the adit discharge. On February 7, 2007, ADEQ elevated the NOC to a Notice of Violation (NOV) due to the adit discharge activity without a permit. The NOV provides 120 days for the USFS Coronado National Forest to either submit documentation that the violation never occurred or submit a complete AZPDES permit application to ADEQ. Failure to achieve or document compliance with the NOV may result in a compliance order.

### 6.5 Humboldt Canyon Mines Remediation Actions

The USFS Coronado National Forest Removal Action and Approval Memorandum additionally proposes removal and remediation actions for the Humboldt Canyon mines. The proposed action includes (1) excavation from the site of approximately 8,000 cubic yards of waste rock containing lead and arsenic, (2) loading, hauling, placing and consolidating the waste rock at the World's Fair Mine and (3) containment through surface capping with clean soil. As previously mentioned, the Removal Action is scheduled to commence in the fall of 2006 and completed by the summer of 2007.

## 7.0 INFORMATION AND OUTREACH

The information, education, and outreach component of this implementation plan is an integral part of public relations, understanding, and community involvement for the future of Alum Gulch. Outreach goals will be to provide an information/education component that will be used to enhance public understanding of the project and encourage their participation in selecting, designing, and implementing nonpoint source management measures.

## 8.0 IMPLEMENTATION SCHEDULE

Implementation actions to remediate or remove nonpoint source pollution are strictly voluntary with no regulatory deadlines. Point source remediation or removal implementation efforts are regulated through compliance with the point source discharger's AZPDES permit. Discharges that fail to meet permitted concentration limits (based on water quality standards) are required to complete a compliance schedule for the purposes of attainment of discharge limits (A.A.C. R18-11-121).

Currently there are two point source discharges to Alum Gulch: 1) January Adit discharge; and World's Fair Mine adit discharge. A compliance schedule was developed to bring the January Adit discharge into compliance with water quality standards by December 30, 2006. However, ASARCO, private owner of January Adit, did not meet the deadline. ADEQ will address this matter in accordance with the Compliance and Enforcement Handbook.

On February 7, 2007, a Notice of Violation (NOV) was issued to the USFS Coronado National Forest for the World's Fair Mine adit discharge. The NOV allows 120 days for the Forest Service to comply with AZPDES discharge requirements.

The remediation/removal actions at World's Fair Mine under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), were scheduled to commence in the fall of 2006 and completed by the summer of 2007. The projected timeline for implementation of point and nonpoint sources of pollution at Alum Gulch is outlined in Table 15.

**Table 15. Alum Gulch TMDL Implementation Schedule**

| | Implementation Actions | Year |
|---|---|---|
| January Adit - ASARCO | Evaluation and proposal of preferred alternative treatment technology and control measures | 2004-2005 |
| | Implementation of selected alternative treatment technology and control measures to meet AZPDES permit requirements | 2006-2007 |
| | Water quality implementation monitoring | 2006-2010 |
| | ADEQ TMDL effectiveness monitoring | 2006-2010 |
| World's Fair Mine & Humboldt Canyon – Coronado National Forest | Engineering Evaluation/Cost Analysis Report | 2006 |
| | Removal Action Decision based on EE/CA | 2006 |
| | Implementation of selected alternative treatment technology and control measures | 2006-2007 |
| | AZPDES permit application for World's Fair Mine adit | Pending NOV outcome |
| | Water quality implementation monitoring | 2006-2010 |
| | ADEQ TMDL effectiveness monitoring | 2006-2010 |

## 9.0 MILESTONES

In order to evaluate the effectiveness of TMDL implementation at Alum Gulch, measurable milestones must be tracked. As selected management measures or implementation actions take effect in the Alum Gulch watershed, a routine assessment of the project status and achievements is needed to determine reasonable assurance of successful implementation.

Milestones are interim and contingent on certain measures like funding, coordination, organization, schedules of stakeholders, timelines, communication, staffing/personnel, and temporal patterns. Initiations of some actions are dependent on the delivery of others. Therefore, milestones used to evaluate the Alum Gulch implementation plan will adapt as the project matures and deliverables are processed. The stakeholders and land owners at Alum Gulch will be responsible for tracking and evaluating milestones.

## 10.0 IMPLEMENTATION AND EFFECTIVENESS MONITORING

Establishing a monitoring component to evaluate the effectiveness of the implementation efforts at Alum Gulch will provide assurance of a successful project. Implementation monitoring and effectiveness monitoring provide a comprehensive approach to water quality improvement projects by providing evaluation criteria on the management measures and water quality data.

### 10.1 Implementation Monitoring

Implementation monitoring is used to determine whether activities and management measures are being carried out as planned and how effective the activities have been. This is done by careful tracking and evaluating the execution of the chosen management alternatives. Implementation monitoring will also evaluate progression of management goals, milestones and schedules, among other factors. Tracking and evaluating the information revealed through implementation monitoring provides criteria to measure the effectiveness and progression of water quality improvement projects.

### 10.2 Effectiveness Monitoring

Effectiveness monitoring involves in-stream monitoring to evaluate water quality changes that occur due to implementation of chosen management measures. Effectiveness monitoring will provide water quality data that will assist in evaluating the status of the waters and the management measures implemented towards achieving load reductions and improving water quality.

ADEQ is required to revisit waters in which a TMDL study has been performed within five years (A.R.S. § 49-234(J)) to determine the effectiveness of water quality implementation and to gather additional data for Arizona's 305(b) Water Quality Assessment Report and 303(d) List of Impaired Waters. Assessing water quality data sampled within the Alum Gulch watershed will determine whether the waterbodies are attaining designated uses and meeting applicable water quality standards. This assessment, required under the Clean Water Act, is completed every two years and considers available surface water data collected within the last five years. The effectiveness monitoring data will provide ADEQ with the necessary water quality data to determine the success of implementation initiatives.

## 11.0 PUBLIC PARTICIPATION

Development of the Alum Gulch TMDL included public participation in accordance with 40 CFR Parts 25 & 130.7. Public participation included review and input from stakeholder groups. Multiple presentations and meetings were held by ADEQ in 1997 and 2001. These meeting were attended by owners/operators of mining sites, property owners; environmental groups; representatives of local, state, and federal agencies; and other interested members of the public. A copy of this report is available on the ADEQ TMDL Web site.

www.azdeq.gov/environ/water/assessment/tmdl.html

The development of the TMDL Implementation Plan follows similar review and input from stakeholders through public participation and public comment period.

## REFERENCES


Arizona Administrative Code, Title 18, Chapter 11, Water Quality Standards

Arizona Revised Statute § 49-234 (G), (H), & (J), TMDL Implementation Plan

Arizona Department of Environmental Quality, 1996-2004, Arizona's 1996-2004 305(b) Water Quality Assessment Report

Arizona Department of Environmental Quality, 2003, Alum Gulch Cadmium, Copper, Zinc and acidity TMDL Report

ASARCO, 1996, Memorandum, Alum Gulch Remediation (April 8, 1996)

Code of Federal Regulations Title 40 Part 25, Clean Water Act

USFS, Coronado National Forest, 2006, Removal Action and Approval Memorandum (August 15, 2006)