RECLAMATION FEASIBILITY REPORT

VIRGINIA CANYON

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Colorado Division of Minerals and Geology

Funded Through Regional Geographic Initiative

December 2001
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INTRODUCTION

This report is intended to be a guidance document for use in reclaiming mining sites in Virginia Canyon. The Colorado Division of Minerals and Geology (DMG) inspected approximately 200 mine waste piles in this study. DMG also sampled water quality in 2000 during spring snowmelt and during a summer thunderstorm. In 1999, the Colorado School of Mines (CSM) sampled stream sediments and collected water quality samples during spring snowmelt, low-flow, and following a summer thunderstorm. The water quality, mine waste and sediment data were used in conjunction with site observations to prioritize mining sites for reclamation. The ultimate goal of this work is to reduce metals loading to Clear Creek from Virginia Canyon by reclaiming the mining sites contributing the largest metal load.

GENERAL SITE DESCRIPTION

LOCATION

Virginia Canyon is located in Clear Creek County immediately north of the town of Idaho Springs. Virginia Canyon begins approximately 2 miles north of Idaho Springs. Figure 1 is a general location map of the area.

Mining began in Virginia Canyon in 1860 following the discovery of Placer Gold by George Jackson near present day Idaho Springs and the discovery of lode gold by John Gregory near present day Central City. Gold was the principal product mined in Virginia Canyon; although the mines in the Seaton Mountain area were principally silver. Most of the ores were hauled by wagon to the Idaho Springs area for milling. Most of the larger mines operated until World War II, when a presidential order required cessation of all mines not mining “strategic metals”.

Investigation of the water quality of Virginia Canyon was initiated as part of an effort to improve the water quality of Clear Creek. Virginia Canyon is one of the largest sources of heavy metals to Clear Creek. The lower portion of Virginia Canyon has perennial flow most years, while the mid-elevations are intermittent, and the upper reaches are ephemeral. Most of the flow from Virginia Canyon enters Clear Creek as ground water. Heavy metals in the flow from Virginia Canyon originate from leaching of eroded mine waste in the stream channel, direct leaching of mine waste piles, and leaching of un-mined sources.

BASELINE DATA COLLECTION

WATER QUALITY SAMPLING

The DMG sampled along Virginia Canyon during a snowmelt event and a thunderstorm event. Twenty-four stream sites and 4 draining mine adits were planned to be sampled (Figure 2). Snowmelt was sampled on May 9, 2000. Because the snow pack was lower than normal, there was very little runoff during May of 2000. A total of 14 stream sites and 3 draining mine adits were sampled. Stream flow was measured using one-inch and four-inch Baski cutthroat flumes. Field measurements included pH and electrical conductivity. Water samples were collected at each site in 250 ml pre-acidified HDPE bottles. Total recoverable metals and dissolved metals samples were collected. The dissolved metals samples were filtered through 0.45 micron filters in the field.
Figure 1. Virginia Canyon General Location Map
Sixteen stream sites were sampled during a summer thunderstorm on August 17, 2000. Two draining mine adits were subsequently sampled the following day. There were no rain gauges in Virginia Canyon, but, based upon measurements in Idaho Springs, the thunderstorm was estimated to be approximately 1 inch. One of the stream samples was an opportunistic sample taken directly below a mine waste pile. Stream flow less than 1 cfs was measured using one-inch and four-inch Basket cutthroat flumes. Stream flow over 1 cfs was measured with a current meter. Field measurements included pH and electrical conductivity. Water samples were collected at each site in 250 ml pre-acidified HDPE bottles. Total recoverable metals and dissolved metals samples were collected. The dissolved metals samples were filtered through 0.45-micron filters in the field.

The May 2000 water quality data is presented in Appendix 1. The August 2000 storm flow data is presented in Appendix 2. It should be noted that metals loading data in the appendices is reported in grams per day, whereas throughout the text, the data is presented in pounds per day. This was done to enable the reader to visualize the amounts better. To convert pounds to grams, multiply the number of pounds by 454. Conversely, to convert grams to pounds, divide the number of grams by 454.

Water samples were collected by CSM three different times in 1999. The water samples were collected along with sediment samples to compare the chemistry of the two mediums. Water samples were collected in 1999 during spring run-off in May, during low-flow drainage in August, and after a 0.5 – 1 inch summer thunderstorm in August. Only dissolved metals samples were collected. Flows were not measured. The pH, Eh, ionic conductivity, and water temperature were recorded. The water samples were filtered, then acidified for later analysis using the ICP-AES. The spring 1999 data is presented in Appendix 3. The 1999 low-flow data is presented in Appendix 4. The data following a summer thunderstorm is presented in Appendix 5.

MINE WASTE SAMPLING

Mining waste samples were collected at 74 different locations in Virginia Canyon. All the mine waste samples were waste rock. No mill tailings were observed in Virginia Canyon. Vegetated and unvegetated soils and alluvium were also collected at 5 locations. The vegetated soils included one near the headwaters and one near the two brothers mine. Alluvium samples were collected in a recent 16-foot high head-cut in Boomerang Gulch and a manganeous debris flow near the mouth of Robinson Gulch. One sample of a naturally denuded soil, near the Comstock Mine, was sampled. The locations of the sampling sites are shown on Figure 3.

Waste rock and soil samples were collected from a minimum of ten and maximum of thirty locations at each site. Acid-washed plastic 100 ml beakers were used to remove the top two inches of material. The 10+ sub-samples from each site were composited in a 1-gallon re-closeable plastic bag. The composited samples were thoroughly mixed by inverting the plastic bag numerous times.

The soil and waste rock samples were analyzed by two different methods. A portion of the composited sample was sent to Analytica Laboratory as a solid sample. Another portion of the composite sample was leached with deionized water, then the filtered leachate was sent to Analytica Laboratory.
The solid samples were screened through a ¼ inch stainless steel sieve, then placed in pre-cleaned 125 ml glass jars. The solid samples were analyzed for total metals following method SW 6010B. Arsenic, Cadmium, Copper, Lead, Iron and Zinc were measured in each sample.

The deionized water leachate was collected by the following method: 150 ml of sample was removed and placed in a 1-liter plastic beaker along with 300 ml of deionized water. The wetted sample was then vigorously mixed for 15 seconds; plastic wrap was placed over the top, then left to settle for 90 minutes. Ninety minutes was the amount of time it took for the clay fraction to settle to the bottom of the beaker. After 90 minutes, the liquid was filtered through very fine grade soil filters (approximately 2 micron). A portion of the liquid was then used to measure the total acidity, pH, and specific conductance. The remaining liquid was acidified with nitric acid for lab analysis. Total acidity was determined using a Hach digital titrator to reach a phenolphthalein end-point.

The results from the solid sample and leachate analysis are presented in Appendix 6. The 2:1 deionized water method provides information on the amount of leachable metals in the waste sample. The solid sample total metals analysis provides information on the total amount of metal in the waste sample. In general, there was a poor correlation between the results of the two testing methods. The total metals analysis of the solid samples resulted in a much smaller relative range in concentrations than the 2:1 deionized water leachate analysis. This probably indicates that the metals in some samples are in a different crystalline form than others. The crystalline form of the mineral is partially responsible for the rate of weathering.

At all the sampling sites, measurements and observations were recorded, including:

1. Latitude/Longitude (uncorrected)
2. Major mineralogy and abundance of major sulfides
3. Approximate distance from a defined drainage channel
4. Degree of erosion (0-4) (0=no erosion, 4=Gullies over 12” deep)
5. Volumetric measurements
6. Presence and approximate size of a vegetation kill zone
7. Presence of vegetation on waste pile
8. Texture (fine = <2mm, medium = mostly gravel size, coarse = mostly cobble size)
9. Equipment access description
10. Feasibility of reclamation measures

A synopsis of the measurements and observations is presented in Appendix 7.

Visual observations were made of 126 other mine sites (Figure 4). These mine sites were viewed from a distance. Observations included approximate volume of mine waste, degree of erosion, presence of a vegetation kill zone, equipment access, and distance from a defined drainage. A synopsis of the observations is presented in Appendix 8.

**STREAM SEDIMENT SAMPLING**

Stream sediments were sampled at 28 locations during the summer of 1999 (Figure 5). The data from sediment sampling is presented in Appendix 9. Sediment samples were collected at the same sampling locations as the water quality samples collected by CSM and transported to the Colorado School of Mines for analysis (1). The sediment samples were analyzed by five different procedures ranging from mild dissolution to aggressive digestion as follows:
Figure 4. Waste Rock Site Location Map
Figure 5. Stream Sediment Sampling Sites
DMG Procedure
This extraction is a 2:1 by volume deionized water extraction process described above for waste rock analysis.

Total Characteristic Leaching Procedure (Modified EPA Method 1311) (5)
The Toxicity Characteristic Leaching Procedure (TCLP) is the standard procedure used by the EPA to classify solid materials as hazardous wastes.

The extraction solution was prepared by adding 5.7 ml of glacial acetic acid to 500 ml of water. 64.3 ml of 1 N NaOH was added to the solution that was then brought to a volume of 1L. 40 ml of this extraction solution were then added to 2 g of < 80-mesh sediment in a 125 ml bottle. The bottles were then agitated end over end using a rotary tumbler for 24 hours. Samples were filtered with a 0.45 μm syringe filter, acidified with nitric acid, and analyzed using ICP-AES

Modified Synthetic Precipitation Leaching Procedure (EPA Method 1312) (4)
The Synthetic Precipitation Leaching Procedure (SPLP), in its unmodified form, is used to by the EPA to determine the mobility of metals in a solid if exposed to acid rain.

A solution of 60% H₂SO₄: 40% HNO₃ by weight was prepared. Distilled water was then brought to a pH of 5.0 using the 60% H₂SO₄: 40% HNO₃ solution. 2 g of <80 mesh sediment was placed into a 125 ml bottle and 40 ml of the extraction solution were added. The bottles were then agitated end over end using a rotary tumbler for 18 hours. Samples were filtered with a 0.45 μm syringe filter, acidified with nitric acid, and analyzed using ICP-AES.

H₂O₂ Acid Potential Test (EPA Field and Lab Methods 3.2.11) (2)
The H₂O₂ Acid Producing Potential Test (APP) is procedure that can be used to predict if a mine waste material will be an acid producer or a neutralizer. The APP releases sulfide materials and the extraction fluid will indicate what metal sulfides can be found in a solid.

1g of < 80 mesh sediment was placed into a Teflon beaker, 12 ml of 30% H₂O₂ was added, and heated to 40°C. The beaker was removed from heat and the reaction was allowed to go to completion as shown when bubbling ceased. An additional 6 ml of 30% H₂O₂ was added to the beaker and the reaction was once again allowed to go to completion. The beaker was then heated to 90°C and was allowed to react until any unreacted H₂O₂ in the beaker was destroyed. Beakers were not allowed to go to dryness. The sides of the beaker were washed down with 50 ml of distilled water, and then were heated to boiling to drive off any dissolved CO₂. The beaker was then cooled to room temperature and titrated with 0.0100 N NaOH that was free of CO₂ to a pH of 7.0 using a pH meter. The procedure was repeated to collect a sample for analysis on the ICP-AES.

Amorphous Digestion (6)
An amorphous digestion was carried out in order to determine if iron and manganese oxides were present in the sediments analyzed (6). Like the APP, this procedure tests for specific species within a sediment.

An extraction solution was prepared containing 0.2 M (NH₄)₂C₂O₄, 0.2 M H₂C₂O₄•2H₂O, and 0.1 M Ascorbic Acid. 80 ml of the extraction solution was then added to 2 g <80-mesh sediment in a Teflon beaker. The beaker was heated to 90°C for 30 minutes. Samples were filtered with a 0.45 μm syringe filter, acidified with nitric acid, and analyzed using ICP-AES.
Heavy Metals in Sediments
The sediment analysis shows that mine waste eroded into the stream channel is a major source of metals. In general, the sediments contain 2 to 3 orders of magnitude more metals than the soils. Heavy metals concentrations of the sediment leachate are often comparable to the concentrations from the mine waste piles. The average zinc concentration from the sediments is approximately half the average of the mine waste piles. The average manganese concentration from the sediments is approximately 90% of the average from the mine waste piles. In comparison, the iron and copper concentrations from the sediments are only 2% and 40% of the average concentrations from the waste rock piles, respectively.

The sediment sampling does not provide an indication of the sources of mining waste to Virginia Canyon. The metals concentrations in sediments above and below and at the bottom of the tributaries are approximately equal. Even sediments from Buttermilk Gulch and Robinson Gulch had high metals concentrations. In general, the concentrations of heavy metals in the stream sediments are higher in the upper portions of the tributaries below the waste piles exhibiting the severe erosion.

WATERSHED CHEMISTRY

Virginia Canyon is an intermittent stream throughout most of the watershed. The upper reaches of the stream are ephemeral, while lower Virginia Canyon is perennial. As such, flow in Virginia Canyon generally occurs during spring snowmelt and summer thunderstorms. There is some flow following snowstorms during the winter, because much of Virginia Canyon is south facing. During spring snowmelt, a portion of the flow infiltrates into the alluvium, then periodically resurfaces. Because of the losing and gaining reaches of the stream, mass loading analysis is difficult. Virginia Canyon contributes many heavy metals to Clear Creek. The main metals of concern include cadmium, copper, iron, manganese and zinc.

Spring Snowmelt

Virginia Canyon was sampled during snowmelt on May 9, 2000. The winter of 1999-2000 was drier than normal, so flow in the stream was lower than normal. During a normal snowmelt runoff event, all the 24 stream stations planned to be sampled would be flowing, based upon 15 years of observation. However, only 14 of the 24 stations were flowing. Measured flows at the sites were erratic, with some upstream sites having higher flow than the downstream sites. To better determine where metals loading was occurring, the flows were “Normalized”. Where measured inflows occurred, the flow was added to the upstream site resulting in a “Normalized” flow measurement. The Normalized flows and loadings are presented in Appendix 1.

During the spring snowmelt event, the majority of the heavy metals loading occurred in the area of the Two Brother/Bald Eagle mine. Minor loading of heavy metals was measured from Robinson Gulch and Seaton Gulch. Buttermilk Gulch had no flow at the time of sampling. The second largest source of heavy metals was Boomerang Gulch. There was no stream flow above the Crown Point and Virginia Mine area.

The highest concentration of aluminum was measured at sampling site VC-2 below the Crown Point and Virginia Mine. The highest concentration of iron, cadmium, copper, arsenic and zinc was measured at site VC-6 above Robinson Gulch. The highest concentration of manganese and silver was measured at site VC-18 at the mouth of Seaton Gulch. The highest concentration of lead was measured at site VC-11 at the mouth of Boomerang Gulch.
Based upon normalized flows, the total heavy metals loading at the mouth of Virginia Canyon from surface drainage was approximately 40 pounds per day. The majority of the load is comprised of manganese and zinc. Manganese and zinc comprise more than half of the heavy metals in the snowmelt drainage. Although there is considerable iron in the upper half of the watershed, most appears to precipitate before reaching the confluence with Clear Creek.

**Storm Flow**

Water quality samples were collected during a summer thunderstorm on August 7, 2000. The thunderstorm was estimated to produce approximately 1 inch of precipitation. The thunderstorm initially was of high intensity, followed by two hours of steady rain. Runoff from this storm was more than normal because of light rain showers two days prior to the sampled thunderstorm and a similar thunderstorm the previous day. The lowest sampling site (station VC-24) could not be sampled safely because of large rock carried by the flowing water. Measured total loading during this thunderstorm was 4 orders of magnitude higher than measured during spring snowmelt. The loading rate measured at sampling site VC-22 was about 195,000 pound of total metals per day, or about 8,100 pounds of total metals per hour. Most of this metals load was carried in the sediments. The dissolved metals loading measured at sampling site VC-22 was approximately 2,350 pound per day or about 100 pounds per hour.

This thunderstorm was between a 2-year (0.89”) and 5-year (1.21”) 2-hour duration storm event. This thunderstorm caused minor mudflows onto the Virginia Canyon roads and resulted in no flooding near the confluence with Clear Creek. In recent years there have been several thunderstorms that have resulted in flooding of the housing area near the confluence.

The largest increase in total metals loading (approximately 44,000 lbs./day) came from Boomerang Gulch. This is followed by a total metal loading of approximately 36,000 lbs./day from the Two Brothers/Bald Eagle area and approximately 21,000 lbs./day from Seaton Gulch. Of the approximately 36,000 lbs./day from the Two Brothers/ Bald Eagle area, a total metals loading of about 21,000 lbs./day was measured from mine waste sampling sites 13 and 14.

In contrast, the largest dissolved metals loading occurred in the Two Brothers/Bald Eagle Mine area (approximately 5,000 lbs./day). Most of the dissolved load from this area (over 3,500 lbs./day) evidently precipitated or was adsorbed to the sediments by the time the flow reached Robinson Gulch. The second and third largest dissolved loading was from Boomerang Gulch and the headwaters above the Crown Point and Virginia.

There was minor total and dissolved loading from Robinson Gulch, Buttermilk Gulch and Seaton Gulch below the Seaton Mine. Most of the storm loading from Seaton Gulch evidently occurs below sampling site #20.

In general, the highest dissolved metals concentrations were measured at sampling site VC-6 below the Two Brothers/Bald Eagle Mine. High dissolved metals concentrations were also found in direct runoff from mine waste piles at sampling sites VC-14 and VC-25.

**Mine Drainage**

There have been 4 mines that historically have drained in Virginia Canyon. The draining mines were sampled on May 9, 2000 and August 8, 2000. The Clarissa Mine (sampling site DM-1) did
not drain during 1999 or 2000. This mine adit has been observed to drain occasionally following snowmelt but is dry during most of the year.

Sampling site DM-2 is believed to be called the Lake Tunnel. Sampling site DM-2 is located on the east side of the road across from the Two Brothers/Bald Eagle Mine. This mine was sampled during the May 2000 event, but was only seeping the morning after the August 2000 thunderstorm. However, two days after the thunderstorm, there was visible flow from the adit. It is theorized that at least part of the mine drainage is due to storm flow into the shaft at mine waste sampling site #13. Gullies leading to this shaft, and debris around the wooden collar indicate that water flows into the shaft during precipitation events. During the May 2000 sampling event, the measured metals loading from this site was slightly less than 4 pounds per day, comprised of about 1 pound of zinc and 2 pounds or iron per day.

Sampling site DM-3 is known as the Rattler Tunnel, Idaho Tunnel and Idaho-Bride Tunnel. The collapsed tunnel drains iron-rich water directly onto the mine waste pile. The Rattler Tunnel generally flows throughout the year. During May 2000, the measured dissolved metals load was approximately 8 lbs./day, which was comprised of about 1.5 pounds of zinc, 2.4 pounds of manganese and 3.75 pounds or iron per day. Following the August 2000 thunderstorm, the flow from the adit had increased by an order of magnitude, with little change in the concentration. This resulted in a measured dissolved metals loading of 88 lbs./day. The majority of the heavy metals in the drainage were zinc, manganese, and iron in a similar ratio to the May 2000 measurement.

Sampling site DM-4 is known as the Crystal Mine. Mine drainage emits from a filled stope in the road drainage ditch. The crystal mine generally flows throughout the year, but flow increases following snowmelt and precipitation events. Drainage from the road above flows into the mine through a stope. During the May 2000 sampling event, the measured dissolved metals load was approximately 1.6 pounds per day, comprised of mostly iron. Following the August 2000 thunderstorm, the measured dissolved metals load was about 9 lbs./day comprised of about 1.5 pounds of zinc, 1.5 pounds of manganese, and 4.5 pounds or iron per day.

**MINE SITE CHARACTERIZATION**

Two hundred mining sites were evaluated to determine the major mining sources of heavy metals in Virginia Canyon. One of the major disturbances in Virginia Canyon is the network of roads. Road drainage was not evaluated in this study. In some cases, the roads concentrate the drainage onto waste rock piles. Also, mining occurred in Virginia Canyon in areas enriched with heavy metals. The areas not mined also contain some heavy metals. Based upon the analysis of five soil and alluvium samples, there is undoubtedly some contribution of heavy metals from non-mining sources. Quantification of the non-mining related sources would require considerably more sampling and modeling. If water quality data can be collected from areas with little mining, such as Delaney Gulch and other small tributaries, some delineation of the mining versus non-mining sources could be made. The original sampling plan allowed for collection of samples from the relatively undisturbed drainages, but there was no flow from those drainages during the spring snowmelt event and the summer thunderstorm event. Following heavy snowfalls, in the past, the relatively undisturbed drainages have been observed to flow.

The 200 mining sites evaluated were prioritized as part of this investigation. The 74 mining sites that were sampled were prioritized on the basis of their chemical and physical characteristics, proximity to a stream course and historic erosion. The 126 mining sites that were qualitatively evaluated were prioritized on the basis of their proximity to a stream course, historic erosion, and visual indicators of the chemical and physical characteristics such as the presence or absence of
vegetation on the waste piles and the presence or absence of a vegetation kill zone below the pile. The characteristics given the most weight in prioritization were proximity to a stream course and historic erosion. Intuitively, the waste rock pile contributing the largest quantity of heavy metals would be those nearest to the major streams, and those exhibiting the most erosion. Also, based upon the water quality sampling, the mine sites in Robinson Gulch and Buttermilk Gulch were given a much lower priority. The water quality from both of these drainages was significantly better than found in the main stem of Virginia Canyon, Boomerang Gulch and Seaton Gulch. In addition, there was significantly less flow from these drainages during both sampling events. Although there are several mine waste piles in Robinson Gulch and Buttermilk Gulch exhibiting severe erosion, and high metals contents, these piles occur near the headwaters, and appear to have a minor effect on water chemistry near their confluence with the mainstem.

The mining sites evaluated were prioritized using a rating between 1 and 4. Mining sites given a rating of 1 are the highest priorities for reclamation. The mining sites given a rating of 4 are the lowest priorities and were evaluated as minor sources of heavy metals. Seventeen mine sites were given a rating of 1. These included 12 sites sampled and 5 sites not sampled. Twenty-two sites were given a rating of 2. Seventeen of these sites were sampled. Sixty-six sites were given a rating of 3 and 91 sites were given a rating of 4. Table 1 is a synopsis of the rankings. Where mine names are given, the names are based upon Geological Survey Bulletin 1208 (7). The mining sites are shown on Figures 3 and 4.

The mining sites were evaluated for possible reclamation measures. In general, most of the mining sites evaluated did not exhibit drainage from the mine workings. The reclamation measures considered for the mine waste piles are classified as hydrologic controls. A brief synopsis of the hydrologic controls follows:

Diversion ditches are effective where run-on water is degraded by flowing over or through mine waste, or into mine workings. Diversion ditches can also be used to intercept shallow ground water that may enter mine waste.

Mine waste removal and consolidation is effective where there are several small mining waste piles in an area, or where there is a large pile in direct contact with flowing water. The method is simply to move reactive material away from water sources.

Stream diversion is similar to mine waste removal and consolidation. It involves moving the water sources away from reactive materials. In most cases, it is usually preferable to move mining waste rather than move the stream, since the relocated stream can require considerable maintenance, particularly following high flow events.

Revegetation is often used in combination with other hydrologic controls above. Revegetation by itself can be a very effective method of reducing heavy metals concentrations, particularly where much of the metals come from erosion of mining waste into a stream. Revegetation also reduces the amount of water that infiltrates a waste pile, thereby reducing leachate production. Additionally, the roots of growing plants have been shown to produce carbonates through respiration.

Reclamation of the mining sites in Virginia Canyon will require sources of soil for revegetation. Even where a waste pile is removed, the underlying soils are often highly acidic and contain high concentrations of heavy metals due to leaching. There are very few areas in Virginia Canyon where topsoil could be “borrowed”. The majority of the soils are very shallow. The terrace deposit below Delaney Gulch is one of the largest potential sources of topsoil in Virginia Canyon. There is
also a moderately deep deposit of topsoil in the headwaters of the mainstem of Virginia Canyon, and a large source of topsoil in the Gilson Gulch drainage west of the Gem Mine.

Table 1. Final ranking of evaluated mining sites.
Table 1 (Cont.) Final ranking of evaluated mining sites.
A few of the waste rock piles sampled could be used as subsoil or a capping material. These include sampling sites #32, #33, and #81. In addition, the debris material at the mouth of Seaton Gulch and Boomerang Gulch can be used as subsoil or capping material.

In situ cementation can be used at historic sites. There are several methods that can be used including a high-pressure water jet, compaction grouting and permeation grouting. Cementing agents are injected into the waste rock to cement and neutralize the material. Cementing material include ordinary cement, phosphates, and sodium silicate.

Table 2 presents the possible reclamation measures for each of the sites ranked between 1 and 3. Those sites ranked 4 currently require no reclamation.

**Table 2. Reclamation Measures Feasible for Sites Observed (X=Feasible, XX=Preferred)**
Table 2 (Cont.). Reclamation Measures Feasible for Sites Observed
Table 2 (Cont.). Reclamation Measures Feasible for Sites Observed

PRIORITY SITE CHARACTERIZATION

There were 39 mine waste sites ranked 1 or 2. The ranking of the individual sites is given in Table 1 above. These sites are considered the highest priorities for reclamation. In addition, there are two draining mine adits where hydrologic controls should be beneficial, and may stop all drainage. Each of these sites will be discussed in detail below. In general, the sites that received a ranking of 1 are near or in a stream channel, and exhibit the greatest amount of historic erosion.

Williams, Rio Grande and Crown Point & Virginia (Sites #1 and #2)

Location
This site is located near the headwaters of the mainstem of Virginia Canyon (Figures 3 and 6). This group of mine waste piles was sampled as sites 1 and 2. Site #1 consists of the waste rock pile from the Williams and Rio Grande shafts. Site #1 is located at LAT. N39° 46' 16.6", LONG. W105° 32' 22.5". Site #2 consists of the waste rock pile from the Crown Point and Virginia Mine. Site #2 is located at LAT. N39° 46' 14.2", LONG. W105° 32' 22.4".
Historic Structures
A stone building is located adjacent to the capped Williams shaft. A wooden loadout bin is located east of the stone building adjacent to the County road. The wooden collar remains at the Crown Point and Virginia shaft.

Water Quality Impacts
The principal water quality effect from this site is from erosion of the waste rock. The toe of the waste rock pile is in the stream channel, which at this location, is the road drainage ditch. There are deep gullies on the face of the Crown Point and Virginia waste pile. There is probably some leaching of the waste rock that occurs during snowmelt and following long duration, low intensity rainstorms. The estimated volume of the waste piles is 58,000 cubic yards.

The waste rock piles are highly cemented with metal sulfate salts. Upon wetting, these salts are readily dissolved. During dry periods, water moves to the surface, precipitating metal salts on the surface. The waste rock is high in copper, arsenic and iron. The waste rock from both sampling sites had a very low pH and very high total acidity. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #1</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.16</td>
<td>4750</td>
<td>1500</td>
<td>65</td>
<td>14000</td>
<td>93000</td>
<td>1400</td>
</tr>
<tr>
<td>Site #2</td>
<td>pH s.u.</td>
<td>Total Acidity mg/l</td>
<td>As ppb</td>
<td>Cd ppb</td>
<td>Cu ppb</td>
<td>Fe ppb</td>
<td>Mn ppb</td>
<td>Pb ppb</td>
<td>Zn ppb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.25</td>
<td>5660</td>
<td>2600</td>
<td>86</td>
<td>14000</td>
<td>96000</td>
<td>1400</td>
</tr>
</tbody>
</table>
The county road is immediately adjacent to the waste rock piles on the west and north sides. The portion of the road on the north side does direct some concentrated flow onto the piles.

**Reclamation Measures**

This site contains historic structures. The structures and the waste rock pile are heavily visited and photographed because of the close proximity of the County road. Because of the historic nature of this site, removal and capping and revegetation are not feasible options.

The preferred reclamation measure for this site is a combination of diversions and in-situ cementation. Diversion of the runoff from the adjacent road should be done. The road should be sloped to the north to prevent flow onto the waste rock pile. The waste rock at this site could be cemented with sodium silicate or a water jet injection could be tested on this site. If a water jet is used, the top of the pile will have to be neutralized with surface application of lime or limestone. This will change the color of the pile, but should not disturb the historic integrity of the site.

**Castleton Mine (Site #4)**

**Location**

This site is located near the headwaters of the mainstem of Virginia Canyon (Figures 3 and 7). This waste pile was sampled as site #4. Site #4 is located across the County road from site 1 and 2, to the north. Site #4 is located at LAT. N39° 46' 19.2", LONG. W105° 32' 23.9". The estimated volume of waste rock is 7,100 cubic yards.

**Figure 7. Photo of Castleton Mine (Site #4)**

**Historic Structures**

There are no historic structures other than scattered debris at this site.
Water Quality Impacts
The principal water quality effect from this site is from erosion of the waste rock. The waste rock pile is located directly in the stream channel near the headwaters of the mainstem of Virginia Canyon. The presence of sulfate salts on the waste pile indicates that some leaching of the waste rock occurs during snowmelt and following long duration, low intensity rainstorms.

The waste rock piles are highly cemented with metal sulfate salts. Upon wetting, these salts are readily dissolved. During dry periods, water moves to the surface, precipitating metal salts on the surface. The waste rock is high in copper. The waste rock had a very low pH and very high total acidity. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #4</th>
<th>pH (s.u.)</th>
<th>Total Acidity (mg/l)</th>
<th>As (ppb)</th>
<th>Cd (ppb)</th>
<th>Cu (ppb)</th>
<th>Fe (ppb)</th>
<th>Mn (ppb)</th>
<th>Pb (ppb)</th>
<th>Zn (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.33</td>
<td>1820</td>
<td>660</td>
<td>78</td>
<td>6200</td>
<td>360000</td>
<td>400</td>
<td>4500</td>
<td>15000</td>
<td></td>
</tr>
</tbody>
</table>

Reclamation Measures
Removal of the waste rock is the preferred reclamation alternative. However, the waste rock pile may be considered a contributing historic resource to the area. If the waste rock pile cannot be removed, it is recommended that the waste in the stream and the scattered waste to the south and east be consolidated with the main part of the waste pile. Diversion ditches could then be constructed to direct upland runoff around the pile, and a small catchment basin can be constructed to intercept eroded material from the waste rock pile.

Trio Tunnel (Site #9)
Location
This site is located approximately 2.6 miles up the mainstem of Virginia Canyon (Figures 3 and 8). This mine waste pile was sampled as site #9. Site #9 is located at a curve in the road, where the stream channel changes from the east side of the County road to the west side. Site #9 is located at LAT. N39° 46' 05.1", LONG. W105° 32' 22.4". The estimated volume of waste rock at site #9 is 8,000 cubic yards.

Historic Structures
A sheet iron clad powder magazine is located west of the waste rock pile. There are no historic structures other than scattered debris at the waste rock pile.

Water Quality Impacts
The principal water quality effect from this site is from erosion of the waste rock. The waste rock pile is located directly in the historic stream channel. In fact, a stream channel has been excavated through the waste pile to accommodate a culvert that directs the drainage from the east side of the road into the historic channel on the west side of the road. There is probably some leaching of the waste rock as ground water follows the flow path of the historic channel through the waste rock. However, there were no visible indications of leaching at the site.
Some erosion of the mine waste also occurs from drainage flowing down the adjacent gravel road. The stream flow and drainage from the road has eroded deep gullies in the face of the waste pile. The deionized water extract of the waste rock indicates that the material is not particularly high in soluble metals, but the location of the waste rock makes the site a high priority. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #9</th>
<th>pH</th>
<th>Total Acidity (mg/l)</th>
<th>As (ppb)</th>
<th>Cd (ppb)</th>
<th>Cu (ppb)</th>
<th>Fe (ppb)</th>
<th>Mn (ppb)</th>
<th>Pb (ppb)</th>
<th>Zn (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.68</td>
<td>940</td>
<td>BDL</td>
<td>49</td>
<td>5900</td>
<td>91000</td>
<td>BDL</td>
<td>7600</td>
<td>8400</td>
</tr>
</tbody>
</table>

Reclamation Measures
Removal of the waste rock is the preferred reclamation alternative. The only other feasible alternative for this site is to construct a stream channel around the site. The material generated during excavation of a new stream channel could be used to cap the waste rock. If a new stream channel is constructed, bedrock should be removed to a level equal to the bedrock in the historic channel to minimize ground water flow through the historic channel.

**Windsor Castle Shaft and Upper Lake Adit (Sites #13 and #14)**

**Location**
This site is located approximately 2.1 miles up the mainstem of Virginia Canyon (Figures 3, 9 and 10). The site is located across the County road to the east from the Two Brothers/Bald Eagle mine. The mine waste piles were sampled as site 13 and 14. Site #13 (Windsor Castle) is the lower of the contiguous waste piles. Site #13 was mined from a shaft while site #14 (Upper Lake) was mined from an adit. Site #13 is located at LAT. N39° 45’ 51.4”, LONG. W105° 31’ 59.9”. The estimated volume of waste rock at site #13 is 5,000 cubic yards. Site #14 is located at LAT. N39° 45’ 51.5”,
LONG. W105° 31' 58.4". The estimated volume of waste rock at site #14 is 13,100 cubic yards. Access to the site is currently poor. An old narrow overgrown road leads to site #13. There is no road to site #14.

Figure 9. Photo of Windsor Castle Mine (Site #13) on Left and Upper Lake Adit (Site #14)

Figure 10. Photo of Upper Lake Adit (Site #14) with site #15 in background
Historic Structures
There are no historic structures other than scattered debris at site #13. The wooden collar of the shaft is intact. There are the remains of a loadout and several small buildings at site #14.

Water Quality Impacts
The principal water quality effect from this site is from erosion of the waste rock. Road drainage from the paved road above passes through a culvert and is directed onto the two waste rock piles. A water quality sample (station #25) was collected from this site during the August 2000 thunderstorm. The drainage from this pile was producing a total metals load of 862 pounds per hour and a dissolved metals load of almost 35 pounds per hour. The drainage from the waste rock pile was high in dissolved arsenic, zinc, manganese, lead, iron, copper and cadmium. Deep gullies have been cut in both piles, but more gullying is present at site #14.

The waste rock analysis shows similar results to the water quality results. However, the dissolved metals concentrations were much higher in the runoff than found in the leachate. Site #13 had the highest total acidity of all the piles tested, and the second lowest pH. Overall, site #13 had the second highest heavy metal content and site #14 had the fifth highest metal content of the 79 sites sampled. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>6350</td>
<td>6700</td>
<td>580</td>
<td>11000</td>
<td>300000</td>
<td>2600</td>
<td>3200</td>
<td>130000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>2140</td>
<td>200</td>
<td>520</td>
<td>7700</td>
<td>290000</td>
<td>2300</td>
<td>39000</td>
<td>87000</td>
</tr>
</tbody>
</table>

An erosion channel and debris around the shaft at site #13 indicates that a portion of the drainage from the road above flows into the shaft. Furthermore, it appears from a debris ring around the shaft that the shaft totally fills with water at times. Prior to the August 2000 thunderstorm, there was only seepage coming from the adit sampled as Station DM-2. Within 48 hours of the storm, the adit was flowing again. This indicates that there may be some connection between the workings of the two mines.

Reclamation Measures
These two waste rock piles are over 500 feet from the nearest stream channel. The majority of the waste piles that ranked 1 or 2 are near or in the stream channels. If the drainage from the road above is diverted around the waste pile, the contribution from these two waste piles should be virtually eliminated. It would be preferable to divert the drainage from the road above through several culverts rather than the one culvert. The location for the culverts would have to be investigated to avoid causing erosion of one of the other waste rock piles in the area.

Regardless of the reclamation method chosen, an access road will have to be cut into this site. The existing road could be improved with minimal disturbance to the surrounding area, then small track-mounted equipment could be used to access the top of site #14. The gullying that has occurred below the piles should be repaired. A portion of this could be done with equipment, but some of the work will have to be completed by hand methods because of steep slopes.
A structural cap should be place over the shaft at site #13. The cap should be designed to prevent most water from entering the shaft. It is believed that most if not all of the drainage from sampling site DM-2 would be eliminated.

**Two Brothers/Bald Eagle Mine (Site #15)**

**Location**
This site is located approximately 2.0 miles up the mainstem of Virginia Canyon (Figures 3, 11 and 12). The mine was recently operated under a DMG permit. The waste pile is the largest and one of the most prominent in Virginia Canyon. The waste pile was sampled as sites 15A and 15B. The pile was sampled as two separate units because there were visible differences between the newer waste rock on the top of the pile and the older material on the outslope of the pile. Sample #15A was collected from the top of the pile and #15B was collected from the outslope of the pile. The site is located at LAT. N39° 45' 42.4", LONG. W105° 31' 58.1". The estimated volume of waste rock at the site is 200,000 cubic yards.

![Figure 11. Two Brothers/Bald Eagle (Site #15) looking north](image)

**Historic Structures**
The structures at the site are mostly associated with the recent mining. There are two wooden structures near the portals that may be near 50 years old; the minimum age to be considered historic.

**Water Quality Impacts**
This site is perhaps the most complex in the Virginia Canyon watershed. Water quality sampling indicates that a large heavy metals load comes from this area. This mine site is bracketed by water quality stations VC-4 and VC-6. A large part of the increased loading measured in the August 2000 thunderstorm likely comes from the waste rock piles sampled as sites 13 and 14. However, during the spring 2000 sampling, there was no visible flow from waste piles 13 and 14 and the mine drainage from sampling site DM-2 accounts for a small portion of the increase in loading.
Figure 12. Two Brothers/Bald Eagle Mine (Site #15) looking south

Most of the loading from this site is thought to occur from leaching of the mine waste in the northern part of the waste rock pile. That portion of the waste rock is located north of the recently constructed mill building. A portion of the mine waste blocks the flow from an ephemeral channel draining Bellevue Mountain. Water has been observed to pond behind the mine waste during spring snowmelt and following summer thunderstorms. In addition, the waste rock pile is located in the thalweg of the old stream channel and forces the stream to flow onto the road during summer thunderstorms. During the spring 2000 water quality sampling, the flow at station VC-4 quickly infiltrated the mine waste/alluvium above the mine, then surfaced below the mill building.

The waste rock analysis shows that the material at this site is highly acid forming. The waste rock from the top of the pile had the highest heavy metal content from the deionized water leach test and the second highest heavy metal content from the total digestion. The highest concentration of soluble arsenic, cadmium, copper and zinc was found at this site. The waste rock pile was observed to be highly cemented with metal sulfates and secondary metal sulfides. There was a prevalent layer of sulfate salts near the toe of the pile. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #15A</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.56</td>
<td>5250</td>
<td>9200</td>
<td>3900</td>
<td>12000</td>
<td>790000</td>
<td>2300</td>
<td>130000</td>
<td>890000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site #15B</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.55</td>
<td>1740</td>
<td>2900</td>
<td>600</td>
<td>21000</td>
<td>300000</td>
<td>74</td>
<td>19000</td>
<td>130000</td>
</tr>
</tbody>
</table>
Reclamation Measures
Reclamation required by the DMG permit has to be completed before any further remediation can be done at this site. It is unknown at this time what the extent of reclamation will be.

To reduce leaching of heavy metals from the waste rock, the waste rock above the mill building should be removed. This waste rock can be consolidated at the main pile. A stream channel should be constructed through the mine site. Currently, the County road is the stream channel during high flows. It is suggested that the current road be excavated and placed on the side of the waste rock pile. This will form a stream channel in the present roadbed.

Rattler Tunnel (Site #25 and #26)

Location
This site is located in Boomerang Gulch approximately ¼ mile above the confluence with Virginia Canyon (Figures 3 and 13). This mine site is also known as the Idaho Tunnel and the Idaho-Bride Tunnel. There are two distinct waste rock piles at the site, separated by the county road through the site. The main waste pile was sampled as site #25. The waste pile below the road was sampled as site #26. Site #25 is located at LAT. N39° 45' 24.3", LONG. W105° 31' 20.0". Site #26 is located at LAT. N39° 45' 22.5", LONG. W105° 31' 19.9". The estimated volume of waste rock at site #25 is 15,000 cubic yards. The estimated volume of mine waste at site #26 is 12,500 cubic yards.

Figure 13. Rattler Tunnel (Site #25)

Historic Structures
The only structure at this site is a loadout adjacent to the county road passing through this site. This loadout is one of the two most photographed and most visited historic sights in Virginia Canyon.
Water Quality Impacts
The principal water quality effect from this site is probably from leaching of the mine waste. The collapsed adit drains perennially onto the waste rock, infiltrates the waste rock, and emits as a series of springs below the county road. In addition, the waste rock pile completely blocks Boomerang Gulch. During small runoff events, all the flow in Boomerang Gulch infiltrates the pile and emits as springs below the road. During larger events, some of the flow passes through a channel on the northwest side of the pile, while some flows over the pile, eroding the face.

All the flow sampled at water quality station VC-18 during May of 2000 can be attributed to the mine drainage. The water quality at station VC-18 generally had significantly higher heavy metal concentrations than the mine drainage at station DM-3. During the thunderstorm in August of 2000, virtually all the flow was passing over the waste rock pile.

The waste rock had the second highest concentrations of soluble cadmium and zinc of the 79 sites sampled. It is thought that the metals concentrations inside the pile will be significantly less than found on the surface. Leaching by the perennial mine drainage appears to precipitate metals on the top and outslope of the waste rock pile. The common flow path for the mine drainage is coated with secondary metal sulfides and sulfate salts. This portion of the waste rock was not sampled. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #25</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.59</td>
<td>1700</td>
<td>1500</td>
<td>840</td>
<td>12000</td>
<td>19000</td>
<td>1800</td>
<td>6500</td>
<td>14000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site #26</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.66</td>
<td>660</td>
<td>220</td>
<td>110</td>
<td>2700</td>
<td>89000</td>
<td>240</td>
<td>13000</td>
<td>18000</td>
</tr>
</tbody>
</table>

Reclamation Measures
The recommended reclamation measure for this site is partial removal, with in-situ cementation of the remainder of the pile. The loadout structure is supported by the waste rock pile. Because of the historic nature of this structure, that portion holding up the loadout must remain. The eastern side of the pile can be removed to allow free flow down Boomerang Gulch. Although the waste rock at site #26 does exhibit better chemical characteristics than the main pile, this material would also have to be removed or partially removed to construct a stream channel around the remaining portion of the pile. As an alternative, an engineered concrete channel can be constructed over the pile. If this option is chosen, the ground water flow path must be cut off by constructing a grout curtain.

The mine drainage from the collapsed adit can be partially treated using a sulfate reducing wetland. The pH of the mine drainage is favorable, but the iron and aluminum content may be high enough to shorten the life of the treatment system. This can be partially offset by constructing an anoxic limestone drain and small settling pond in the collapsed adit. However, the aluminum in the drainage may result in a plugged drain. There should be sufficient area near the collapsed adit to construct a small passive treatment system.

Foxhall Tunnel (Site #28)

Location
This site is located in Seaton Gulch approximately ½ mile above the confluence with Virginia Canyon (Figures 3 and 14). The mine site is visible from the upper road in Virginia Canyon between...
Boomerang Gulch and the Gilson Gulch turnoff. Access to this mine is by a narrow road starting near the Rattler Tunnel. This mine site was not sampled, but is designated as site #28 on Figure 3. Site #28 is located at LAT. N39° 45' 24.4", LONG. W105° 31' 02.8". The estimated volume of mine waste is 65,000 cubic yards.

Figure 14. Foxhall Tunnel (Site #28)

Historic Structures
The only structure visible at this site is sheet iron sided building that probably housed the compressor and served as the “Dry”.

Water Quality Impacts
The principal water quality effect from this site appears to be from erosion of the mine waste pile. This site was chosen as a high priority because the toe of the waste pile is being eroded by Seaton Gulch and the upper part of the pile is being eroded by an ephemeral drainage off Seaton Mountain. The chemical characteristics of the waste rock are unknown, but a portion of the waste is composed of country rock from the crosscut tunnel.

Reclamation Measures
The recommended reclamation measure for this site is partial removal and construction of diversion ditches. The portion of the waste rock in Seaton Gulch should be removed and consolidated with the main pile. The removal area will have to be amended with ground limestone and lime before revegetation. Diversion ditches should be constructed to divert upland flow away from the waste pile. One of these diversions should also divert the ephemeral drainage. The site should be investigated in detail before choosing the final reclamation method.
Brighton Mine and Little Emma Mine (Sites #41 and #108)

Location
These two sites are located approximately midway up Boomerang Gulch (Figures 3 and 15). The county road system bisects Boomerang Gulch in three locations. The mine sites are located between the upper and middle bisection. The mine waste piles are located adjacent to each other on both sides of Boomerang Gulch. Some waste rock remains in the drainage channel. The mine waste piles were not sampled. The Brighton is designated site #41 on Figure 3. The Brighton Mine is located at LAT. N39° 45' 38.1", LONG. W105° 31' 24.0". The Little Emma adit is designated site #108 on Figure 4 and is located at LAT. N39° 45' 38.6", LONG. W105° 31' 20.5". The estimated volume of waste rock at site #41 is 11,000 cubic yards. The estimated volume of waste rock at site #108 is 1,000 cubic yards. Access to the site is by an old road. The road is severely eroded in places.

Figure 15. Brighton Mine (Site #41) on Right and Little Emma Mine (Site #108) on left

Historic Structures
The remains of a loadout at the Brighton mine and the remains of a building at the Little Emma mine are visible from the road.

Water Quality Impacts
The principal water quality effect from these sites is from erosion of the waste rock. Severe erosion of the waste rock has occurred adjacent to the stream channel. The access road to these two sites is constructed of mine waste, and the road crosses the streambed. The waste rock at both sites is likely similar to that from sampled sites 42, 43, and 68 nearby.
Reclamation Measures
The portion of these two waste rock piles that is located in the stream channel should be removed. The removed waste rock can be hauled off-site or can be consolidated with the main pile of the Brighton mine. Virtually all the mine waste at site #108 will have to be removed. The removal area will have to be amended with ground limestone and lime before revegetation. Diversion ditches should be constructed to intercept upland runoff from the steep slopes above the mine sites. The site should be investigated in detail before choosing the final reclamation method.

Inter Ocean Mine (Sites #45 and #144)

Location
This site is located in Boomerang gulch immediately below the middle road bisecting the stream. This site consists of two waste rock piles designated as sites 45 and 144 (Figures 3, 4 and 16). Site #45, lower pile, was sampled. Site #144 was not sampled. Site #45 is located at LAT. N39° 45' 28.9", LONG. W105° 31' 15.9". The estimated volume of waste rock at site #45 is 4,600 cubic yards. The estimated volume of waste rock at site #144 is 3,200 cubic yards.

Figure 16. Inter Ocean Mine (Site #45-Lower, Site #144-Upper)

Historic Structures
No historic structures or debris was observed at these sites. This waste pile is very visible from the main Virginia Canyon road.

Water Quality Impacts
Both waste rock piles are severely eroded. The principal source of water that erodes these waste piles is road drainage. The road ditch has been observed to carry water from the road above, around the nearby curve, then a portion of the flow crosses the road and flows down the mine waste pile. Gullies up to 12 feet in depth have been cut in the waste piles. The mine waste is eroded directly into Boomerang Gulch. Most of the eroded waste rock settles on the debris fan at the upper end of the Rattler Tunnel waste pile.

The waste rock piles are highly cemented with metal sulfate salts. Upon wetting, these salts are readily dissolved. During dry periods, water moves to the surface, precipitating metal salts on the
The waste rock is not particularly high in soluble heavy metals compared to other piles in Virginia Canyon, but erosion of the waste into Boomerang Gulch subjects the eroded material to frequent leaching. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #45</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.43</td>
<td>108</td>
<td>BDL</td>
<td>76</td>
<td>590</td>
<td>50</td>
<td>400</td>
<td>5800</td>
<td>13000</td>
</tr>
</tbody>
</table>

Reclamation Measures
Because of the high visibility of this waste pile, removal is not recommended. This waste pile and others like it contribute to the historic mining flavor of Virginia Canyon.

The preferred alternative is to direct the road drainage away from the waste rock. A portion of the road drainage should be culverted into the small ephemeral drainage around the corner to the east. The remaining drainage should be taken directly to the Boomerang Gulch channel crossing. The road drainage should not be culverted at the small drainage to the northwest because the road outslope contains mine waste from sites 43, 140 and 141.

**Casino Mine (Site #53)**

**Location**
This site is located near the headwaters of Seaton Gulch approximately 200 yards below the Gilson Gulch turnoff (Figures 3 and 17). The waste pile is located in the drainage immediately below the county road. This waste pile was sampled as site #53. Site #53 is located at LAT. N39° 45’ 29.1”, LONG. W105° 30’ 51.1”. The estimated volume of waste rock is 5,500 cubic yards.
Historic Structures
There are no historic structures other than scattered debris at this site.

Water Quality Impacts
This waste pile is located directly in Seaton Gulch below a road culvert that directs road drainage onto the pile. There is very little runoff from the headwaters of Seaton Gulch above. The drainage from the headwaters is collected by the road ditches and conveyed onto the waste pile. Deep gullies have been cut in the face of this pile. Where soil has eroded onto the waste, there is some vegetation.

The waste rock at this site had the highest soluble manganese of all the sites tested, with high cadmium, copper and zinc concentrations. Sulfate salts and secondary sulfates were present at the toe of the pile, indicating that some leaching of heavy metals from this pile occurs. This is probably principally during snowmelt. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #53</th>
<th>pH</th>
<th>Total Acidity</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>s.u.</td>
<td>mg/l</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
</tr>
<tr>
<td>2.82</td>
<td>577</td>
<td>BDL</td>
<td>360</td>
<td>6300</td>
<td>6200</td>
<td>180000</td>
<td>53</td>
<td>53000</td>
<td></td>
</tr>
</tbody>
</table>

Reclamation Measures
Removal of the waste rock is the preferred reclamation alternative. The only other alternative would be to construct a drainage over the pile, such as a concrete flume. In order for removal to be cost-effective, a nearby disposal site would have to be available. The removal area will have to be amended with ground limestone and lime before revegetation. As an alternative, an engineered concrete channel can be constructed over and around the waste rock pile.

Doves Nest Mine (Site #67)

Location
This site is located near the headwaters of Boomerang Gulch directly above the upper road bisection of the stream channel (Figures 3 and 18). This waste pile was sampled as site #67. Water quality station VC-14 is located at the bottom of this waste pile. Site #67 is located at LAT. N39° 45’ 46.1” , LONG. W105° 31’ 17.7” . The estimated volume of waste rock is 12,800 cubic yards.

Historic Structures
There are no historic structures or debris at this site. Most of the waste rock pile was pushed down to the county road in the recent past.

Water Quality Impacts
The waste rock from the Doves Nest mine was pushed into the headwaters drainage of Boomerang Gulch in the recent past. As a result, much of the waste is eroded and leached by runoff from above the site. A water quality sample was collected at station VC-14 in August of 2000. Over 40 pounds of total metals per hour were coming from this site. The dissolved metals loading rate was almost 9 pounds per hour. The majority of the heavy metals loading was composed of zinc, iron and aluminum.

The waste rock at this site had a very low pH and was highly acid forming. The deionized water extract showed much lower metals content relative to the other mine sites, than the total digestion. This tends to indicate that some of the metal sulfides are in a relatively insoluble form. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #67</th>
<th>pH</th>
<th>Total Acidity</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>s.u.</td>
<td>mg/l</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
</tr>
<tr>
<td>2.31</td>
<td>5070</td>
<td>BDL</td>
<td>13</td>
<td>170</td>
<td>220000</td>
<td>2200</td>
<td>180</td>
<td>2100</td>
<td></td>
</tr>
</tbody>
</table>
Reclamation Measures
Removal of the waste rock is the preferred reclamation alternative. The mine waste in the stream channel will have to be pushed down to the road for loading. If a disposal site is not available for the waste, the removed material can be consolidated at the original pile location on the east side of the drainage. There is good road access to this site. As another alternative, the mine waste can be removed to the old Doves Nest heap leach site. The removal area will have to be amended with ground limestone and lime before revegetation.

Crystal Mine (Sites #23 and #24)

Location
This Crystal Mine is located in the mainstem of Virginia Canyon approximately 1.2 miles above Clear Creek. This site consists of an adit and stope between the upper and lower roads, a stope in the upper road, and a shaft and two waste rock piles above the upper road. The waste rock pile between the roads was sampled as site #23 (Figures 3 and 19). Site #23 is located at LAT. N39° 45' 22.4", LONG. W105° 31' 30.7". The estimated volume of waste rock at site #23 is 6,900 cubic yards. The adit between the roads was sampled as water quality station DM-4. The waste pile at the shaft was sampled as site #24 (Figures 3 and 20). Site #24 is located at LAT. N39° 45' 24.1",
LONG. W105° 31' 26.2". The estimated volume of waste rock at site #24 is 1,800 cubic yards. A larger waste rock pile shown as site #163 on Figure 4 is also associated with the Crystal mine. The waste pile at site #163 is estimated to contain 600 cubic yards.

Historic Structures
The remains of the shafthouse are on waste pile #24. A concrete foundation rests on pile #23. There is scattered debris throughout this site,

Water Quality Impacts
Water quality impacts from this site are the result of waste rock erosion and mine drainage. The waste rock pile at site #24 is located in a small ephemeral drainage. Gullies about one-foot in depth have been eroded in the pile. The waste rock pile at site #23 is highly eroded by road drainage. A portion of the road drainage crosses the road and flows down the waste pile. Most of the eroded waste from site #23 flows down the road ditch into Virginia Canyon.

The waste rock piles are highly cemented with metal sulfate salts. Upon wetting, these salts are readily dissolved. During dry periods, water moves to the surface, precipitating metal salts on the surface. The waste rock is not particularly high in soluble heavy metals compared to other piles in Virginia Canyon, but erosion of the waste into Virginia Canyon subjects the eroded material to frequent leaching. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #23</th>
<th>pH</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.01</td>
<td>376</td>
<td>BDL</td>
<td>240</td>
<td>2400</td>
<td>5300</td>
<td>BDL</td>
<td>25000</td>
<td>48000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site #24</th>
<th>pH</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.95</td>
<td>574</td>
<td>BDL</td>
<td>350</td>
<td>3000</td>
<td>6200</td>
<td>240</td>
<td>39000</td>
<td>53000</td>
</tr>
</tbody>
</table>

In addition to the waste rock, there is drainage from the adit or stope at station DM-4. Most if not all of this mine drainage is due to road drainage that flows into a stope under the upper road. Following thunderstorms, the amount of mine drainage from station DM-4 had been observed to increase. It is believed that the mine drainage actually emits from a collapsed or filled stope. This stope is also believed to extend under the lower road into the stream channel. During the winter there is considerable ice buildup where the stope would cross the stream channel.
Figure 19. Lower Waste Pile of Crystal Mine (Site #23) Showing Mine Drainage
There may be additional water that infiltrates into the mine workings from a collapsed stope near the uppermost shaft of the Crystal mine. This stope collapsed in the road drainage ditch during the spring of 1996. The stope has subsequently filled with sediments, but there may be some infiltration into the mine workings.

Reclamation Measures
There are several reclamation measures that should be done at this site. The highest priority should be placed upon stopping the road drainage from entering the open stope under the upper road. Currently, the road crosses this stope on a bridge. A structural closure that will prevent water inflows should be constructed over the stope. In addition, the road drainage at this location should be improved to prevent runoff from flowing across the road onto waste pile #23. As a preventative measure, it is suggested that limestone be placed in the stope to help neutralize mine drainage due to infiltration of local groundwater.

The collapsed stope in the road below the upper shaft should be excavated, then the excavated material should be mixed with fly ash and kiln dust to form a cemented plug. This should reduce infiltration from the road drainage ditch.

If the road drainage issues are addressed, waste pile #23 should require no action.

Waste Pile #24 is located in an ephemeral drainage. The recommended reclamation measure is to construct diversion ditches on both sides of the pile. In addition, a small catchment pond should be constructed at the base to settle out erosion from incidental precipitation.
Lower Clarissa Tunnel (Site #10)

Location
The Clarissa Tunnel is located in the mainstem of Virginia Canyon approximately 2.5 miles above Clear Creek (Figures 3 and 21). The mine waste pile was sampled as site #10. Site #10 is located at LAT. N39° 46’ 02.7”, LONG. W105° 32’ 14.6”. The adit of the Clarissa Tunnel is designated as water quality station DM-1. The adit has been observed to drain during wet years. No drainage was observed in 2000. The estimated volume of mine waste is 2,300 cubic yards.

Figure 21. Lower Clarissa Tunnel (Site #10)

Historic Structures
The remains of a loadout structure is located on the waste pile. The timbered adit is intact.

Water Quality Impacts
The toe of the waste pile is being actively eroded by the stream. There is also some minor erosion from road drainage that flow over the pile. The waste rock contains high concentrations of soluble arsenic, copper and lead. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #10</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.38</td>
<td>1900</td>
<td>2200</td>
<td>260</td>
<td>7500</td>
<td>35000</td>
<td>2200</td>
<td>10000</td>
<td>49000</td>
</tr>
</tbody>
</table>

Reclamation Measures
The recommended reclamation measure for this site is to remove the waste rock near the stream and consolidate on-site. The waste rock within 10 feet of the stream channel should be moved to the main pile toward the county road. The toe of the reclaimed pile should be armored with riprap to
prevent future erosion if the stream meanders. Diversion ditches should also be constructed to convey run-on water around the pile.

**Unknown Mine Site #11**

**Location**

This site is located approximately 150 feet northwest of the Lower Clarissa Tunnel waste pile (Figures 3 and 22). The mine waste pile was sampled as site #11. Site #10 is located at LAT. N39° 46' 02.7", LONG. W105° 32' 16.7". The estimated volume of mine waste at this site is 3,300 cubic yards.

**Historic Structures**

There are no historic structures at this site. The Flues of a boiler are immediately above the waste rock pile.

**Water Quality Impacts**

The toe of the waste pile is being actively eroded by the stream. There is also some erosion from road drainage that flow over the pile. The waste rock does not exhibit high concentration of heavy metals compared to the other piles sampled. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #11</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.72</td>
<td>247</td>
<td>BDL</td>
<td>30</td>
<td>2900</td>
<td>22000</td>
<td>1900</td>
<td>270</td>
<td>5400</td>
</tr>
</tbody>
</table>
Reclamation Measures
The recommended reclamation measure for this site is to remove the waste rock near the stream and consolidate on-site. The waste rock within 10 feet of the stream channel should be moved to the main pile toward the county road. The toe of the reclaimed pile should be armored with riprap to prevent future erosion if the stream meanders. Diversion ditches should also be constructed to convey run-on water around the pile.

Diamond Joe Mine (Site #12)

Location
The Diamond Joe Mine is located in the mainstem of Virginia Canyon approximately 2.4 miles above Clear Creek (Figures 3 and 23). The mine waste pile was sampled as site #12. Site #12 is located at LAT. N39° 45’ 56.8”, LONG. W105° 32’ 09.4. The estimated volume of mine waste is 8,000 cubic yards.

Historic Structures
There has been some recent activity at this site. A portion of the waste rock pile has been pushed out of the stream. There is some scattered debris at the site, including rail. The adit has recently been re-collared.

Water Quality Impacts
The stream bifurcates this waste pile. A portion of the waste rock is mixed with stream-eroded material. Even with some alluvial material in the sample, this waste rock had one of the five highest concentrations of soluble copper. The waste rock has partially dammed the stream. There is likely to be some leaching of the waste rock by ground water, due to the damming. Results from the 2:1 leachate analysis are given below:
Site #12

<table>
<thead>
<tr>
<th>pH</th>
<th>Total Acidity</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.65</td>
<td>733</td>
<td>BDL</td>
<td>160</td>
<td>12000</td>
<td>95000</td>
<td>BDL</td>
<td>9300</td>
<td>30000</td>
</tr>
</tbody>
</table>

Reclamation Measures
The recommended reclamation measure for this site is to remove the waste rock. As an alternative, the waste rock in the streambed can be removed, mixed with fly ash, cement and kiln dust, then stockpiled on the west side of the stream. The addition of the amendments should neutralize and cement the waste rock, making it resistant to leaching and erosion. If cementation is chosen, a new armored stream channel should be constructed east of the stockpiled waste.

Red Jacket Mine (Site #19)

Location
This site is located approximately 200 yards below the confluence of Robinson Gulch and Virginia Canyon (Figures 3 and 24). The mine waste pile was sampled as site #19. Site #19 is located at LAT. N39° 45' 28.8", LONG. W105° 31' 47.3". The estimated volume of mine waste is 700 cubic yards.

Historic Structures
There are no historic structures or artifacts at this site.
**Water Quality Impacts**
The entire length of the waste pile is in the stream channel. In addition, the stream passes through a culvert at this site. The culvert directs stream flow broadside into the waste rock. The original soil layer is exposed in several places along the pile. This indicates that there is probably little leaching of the waste rock. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #19</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5</td>
<td>2090</td>
<td>700</td>
<td>28</td>
<td>2300</td>
<td>410000</td>
<td>190</td>
<td>3000</td>
<td>5800</td>
</tr>
</tbody>
</table>

**Reclamation Measures**
The recommended reclamation measure for this site is to remove the waste rock. As an alternative, the waste rock can be armored with riprap, wooden or concrete cribbing, or other commercial abutment product. At a minimum, a deflector should be place on the end of the culvert to direct flow downstream rather than into the pile. If the pile is left, a diversion ditch should be constructed above the pile.

**Keystone Mine (Site #21)**

**Location**
The Keystone mine is located in the mainstem of Virginia Canyon approximately 1.5 miles above Clear Creek (Figures 3 and 25). The mine waste pile was sampled as site #21. Site #21 is located at LAT. N39° 45' 24.8", LONG. W105° 31' 40.9". The estimated volume of mine waste is 600 cubic yards.
Historic Structures
There are no historic structures or artifacts at this site. The timbered adit and door are intact.

Water Quality Impacts
The waste rock pile at this site has been severely eroded by the stream. Erosion of the waste pile leaves a vertical escarpment, which results in slumping into the stream. This cycle has left only a minor portion of the waste rock in-place. The waste pile also partially blocks an ephemeral tributary. Leaching of the waste rock by surface and groundwater in the ephemeral drainage is likely. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #21</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.72</td>
<td>560</td>
<td>BDL</td>
<td>83</td>
<td>1400</td>
<td>19000</td>
<td>BDL</td>
<td>28000</td>
<td>16000</td>
</tr>
</tbody>
</table>

Reclamation Measures
The recommended reclamation measure for this site is to remove the waste rock. As an alternative, the waste rock can be armored with riprap, wooden or concrete cribbing, or other commercial abutment product. If the pile is left in place, the ephemeral drainage should be conveyed around the pile. The diversion should be deep enough to prevent groundwater flow through the waste rock.

Casino Tunnel (Site #29)

Location
This site is located in Seaton Gulch southeast of and across the stream from the Foxhall Tunnel (Figures 3 and 26). The mine waste pile was not sampled. Site #29 is located at LAT. N39° 45' 24.0", LONG. W105° 31' 00.0". The estimated volume of mine waste is 13,000 cubic yards.
Historic Structures
There are no historic structures or artifacts visible from the roads in Virginia Canyon.

Water Quality Impacts
This waste pile is located in the channel of Seaton Gulch. The stream is actively eroding the waste rock. There is some vegetation on the top of the pile.

Reclamation Measures
The recommended reclamation measure for this site is to remove the waste rock. It may be possible to consolidate this mine waste with the Foxhall Tunnel pile. The site should be investigated in detail before choosing the final reclamation method.

Old Proverb and Early Bird Mines (Sites #34 and #35)

Location
This Old Proverb and Early Bird mines are located in the mainstem of Virginia Canyon approximately 1.1 miles above Clear Creek (Figures 3 and 27). The mine waste piles are contiguous. The Old Proverb waste pile was sampled as site #34. Site #34 is located at LAT. N39° 45' 09.3", LONG. W105° 31' 12.4". The estimated volume of mine waste is 1,900 cubic yards. The Early Bird waste pile, located north of the Old Proverb, was sampled as site #35. Site #35 is located at LAT. N39° 45' 10.5", LONG. W105° 31' 13.6". The estimated volume of mine waste is 500 cubic yards.

Figure 27. Old Proverb and Early Bird Mines (Sites #34 and #35)
Historic Structures
There are no historic structures or artifacts at these sites.

Water Quality Impacts
The chemical and physical characteristics of the waste rock from both mines are very similar. Compared to the other mine sites sampled, metal concentrations are near the median levels. The waste rock piles are directly in the stream channel. The Early Bird waste pile has been mostly eroded away by broadside flow from Boomerang Gulch. Erosion of the waste below the confluence also occurs during high flows. There is some visual evidence to suggest that leaching of the waste rock occurs. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #34</th>
<th>pH</th>
<th>Total Acidity (mg/l)</th>
<th>As (ppb)</th>
<th>Cd (ppb)</th>
<th>Cu (ppb)</th>
<th>Fe (ppb)</th>
<th>Mn (ppb)</th>
<th>Pb (ppb)</th>
<th>Zn (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.16</td>
<td>184</td>
<td>BDL</td>
<td>140</td>
<td>BDL</td>
<td>2300</td>
<td>BDL</td>
<td>15000</td>
<td>10000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site #35</th>
<th>pH</th>
<th>Total Acidity (mg/l)</th>
<th>As (ppb)</th>
<th>Cd (ppb)</th>
<th>Cu (ppb)</th>
<th>Fe (ppb)</th>
<th>Mn (ppb)</th>
<th>Pb (ppb)</th>
<th>Zn (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.01</td>
<td>178</td>
<td>BDL</td>
<td>42</td>
<td>160</td>
<td>740</td>
<td>BDL</td>
<td>11000</td>
<td>6300</td>
</tr>
</tbody>
</table>

Reclamation Measures
The recommended reclamation measure for this site is to remove the waste rock. As an alternative, the waste rock can be armored with riprap, wooden or concrete cribbing, or other commercial abutment product. If the pile is left in place, a deflector should be placed on the road culvert to direct flow downstream rather than into the pile.

Remington and Mix Mines (Sites #36 and #86)

Location
These waste piles are located in the streambed of Virginia Canon at the three-way intersection approximately 1.5 miles above Clear Creek (Figures 3 and 28). The Remington mine waste pile was sampled as site # 36. Site #36 is located at LAT. N39° 45' 26.7", LONG. W105° 31' 42.3". The estimated volume of mine waste is 200 cubic yards. The Mix mine waste pile was sampled as site # 86. Site #86 is located at LAT. N39° 45' 27.5", LONG. W105° 31' 46.0". The estimated volume of mine waste is 200 cubic yards.

Historic Structures
There are no historic structures or artifacts at either site.

Water Quality Impacts
Remnants of the original waste rock piles are all that remain at the two sites. The Remington waste rock is located on the east side of the stream. The Mix mine waste is located upstream from the Remington on the west side of the stream. Both piles are in contact with the stream channel. The piles are actively eroding in this area because the stream channel becomes significantly narrower. In general, both waste rock piles have higher than average metal concentrations. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #36</th>
<th>pH s.u.</th>
<th>Total Acidity (mg/l)</th>
<th>As (ppb)</th>
<th>Cd (ppb)</th>
<th>Cu (ppb)</th>
<th>Fe (ppb)</th>
<th>Mn (ppb)</th>
<th>Pb (ppb)</th>
<th>Zn (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.59</td>
<td>112</td>
<td>BDL</td>
<td>300</td>
<td>260</td>
<td>190</td>
<td>BDL</td>
<td>39000</td>
<td>37000</td>
</tr>
</tbody>
</table>
Reclamation Feasibility Report – Virginia Canyon

Site #86

<table>
<thead>
<tr>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.54</td>
<td>1265</td>
<td>1400</td>
<td>210</td>
<td>4200</td>
<td>270000</td>
<td>680</td>
<td>2000</td>
<td>33000</td>
</tr>
</tbody>
</table>

Reclamation Measures
The recommended reclamation measure for this site is to remove the waste rock. Access to remove the mine wastes is along the stream channel. Some stream sediments will have to be removed along with the mine waste. It is likely that the overall volume of sediment and mine waste will double.

Figure 28. Remington Mine (Site #36)
Jenny Lind Mine (Site #37)

Location
This waste pile is located in the streambed of Virginia Canon approximately 1.4 miles above Clear Creek (Figures 3 and 29). The Jenny Lind mine waste pile was sampled as site # 37. Site #37 is located at LAT. N39° 45' 23.3", LONG. W105° 31' 38.1". The estimated volume of mine waste is 200 cubic yards.

Historic Structures
There are no historic structures or artifacts at this site.

Water Quality Impacts
Most of this waste rock pile has already been eroded away by the stream. There is a vertical scarp of waste rock along the stream channel. The waste rock analysis indicates that this material is not high in heavy metals relative to the other sites sampled. However, because of the erosion that has occurred at this site in the past and the likelihood of additional erosion, this pile should be considered a high priority. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #37</th>
<th>pH</th>
<th>Total Acidity</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.61</td>
<td>198</td>
<td>BDL</td>
<td>59</td>
<td>790</td>
<td>3200</td>
<td>180</td>
<td>6100</td>
<td>10000</td>
</tr>
</tbody>
</table>
Reclamation Measures
The preferred reclamation measure for this site is to remove the waste rock. Access to remove the mine wastes is along the stream channel. Some stream sediments will have to be removed along with the mine waste. It is likely that the overall volume of sediment and mine waste will double.

Bullion Tunnel (Site #40)

Location
The Bullion Tunnel is located on the west side of Boomerang Gulch immediately below the road and above the Rattler Tunnel (Figures 3 and 30). The Bullion Tunnel mine waste pile was sampled as site #40. Site #40 is located at LAT. N39° 45’ 28.3”, LONG. W105° 31’ 23.7”. The estimated volume of mine waste is 4,100 cubic yards.

Historic Structures
There are no historic structures or artifacts at this site.

Water Quality Impacts
This waste rock pile is eroded by drainage from the road above and erosion by Boomerang Gulch. Currently, most of the erosion occurs from road runoff, but an active head cut in Boomerang Gulch is subjecting the toe of the waste rock pile to slumping. A small vegetation kill zone exists below the pile. The vegetation has been killed principally by sedimentation.
With the exception of lead, the waste rock analysis indicates that this material is not high in heavy metals relative to the other sites sampled. However, because of the erosion that has occurred at this site in the past and the likelihood of additional erosion, this pile should be considered a high priority. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #40</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.27</td>
<td>104</td>
<td>BDL</td>
<td>130</td>
<td>330</td>
<td>140</td>
<td>2800</td>
<td>4500</td>
<td>20000</td>
<td></td>
</tr>
</tbody>
</table>

Reclamation Measures
The preferred reclamation measure for this site is to divert road runoff around the waste pile, and move the stream channel to the east. The stream channel should be regraded to eliminate the active head cut. The toe of the waste rock pile will have to be armored with riprap to prevent future erosion as the stream channel migrates toward the west.

**Unknown Site #46**

**Location**
The mine waste pile is located in Boomerang Gulch above the Rattler Tunnel, and immediately below the Inter Ocean Mine sites 45 and 144 (Figures 3 and 31). The site is on the Bullion Inter Ocean Vein. The mine waste pile was sampled as site #46. Site #46 is located at LAT. N39° 45' 30.1", LONG. W105° 31' 19.2". The estimated volume of mine waste is 2,000 cubic yards.
Historic Structures
There are no historic structures or artifacts at this site.

Water Quality Impacts
The toe of this waste rock pile is directly in a small tributary drainage of Boomerang Gulch. Most of the water in this drainage currently comes from water concentrated by the road above that flows across the road. The majority of the road drainage passes over waste sites #45 and #144.

The waste rock analysis indicates that this material is not high in heavy metals relative to the other sites sampled. However, because of the erosion that has occurred at this site in the past and the likelihood of additional erosion, this pile should be considered a high priority. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #46</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.44</td>
<td>45</td>
<td>BDL</td>
<td>39</td>
<td>170</td>
<td>850</td>
<td>BDL</td>
<td>860</td>
<td>6700</td>
</tr>
</tbody>
</table>

Reclamation Measures
The preferred reclamation measure for this site is to divert road runoff from waste piles #45 and #144, and remove the waste rock from the active stream channel. A small upland diversion should also be constructed to direct upland flow around the pile. The toe of the pile should be armored with riprap to prevent stream migration into the pile. There is no road into this site, although an old overgrown road ends approximately 150 feet above.

Unknown Site #54

Location
This small waste pile is located near the headwaters of Seaton Gulch between the roads at the hairpin curve near the junction with the road to Gilson Gulch (Figures 3 and 32). The mine waste pile was sampled as site # 54. Site #54 is located at LAT. N39° 45' 27.9", LONG. W105° 30' 49.6". The estimated volume of mine waste is 300 cubic yards.

Historic Structures
There are no historic structures or artifacts at this site.

Water Quality Impacts
This waste rock pile is eroded by drainage from the road. The waste rock is low in leachable metals relative to the other sites tested in Virginia Canyon. There is also some vegetation on the waste rock where a shallow soil cover has been deposited. However, drainage from the road has been observed to flow across the pile and erode the near vertical portion of the pile adjacent to the road cut at the lower crossing. Most of this erosion has been observed to occur in the past few years due to changes in the road drainage pattern. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #54</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.81</td>
<td>21</td>
<td>BDL</td>
<td>BDL</td>
<td>32</td>
<td>BDL</td>
<td>BDL</td>
<td>1500</td>
<td>520</td>
</tr>
</tbody>
</table>
Reclamation Measures
Because of good access, reclamation of this site should be simple and low-cost. The waste pile can be removed, or reclaimed in-place. At a minimum, the road drainage should be improved to direct water around the pile.

Since there is already some sparse vegetation on the pile, no neutralizing agents should be required for in-place reclamation. The cover material can be derived from a local source or from future road maintenance. If the pile is reclaimed in-place, the waste rock at the edge of the road cut should be pulled back to a minimum grade of 3h:1v. In addition, the road drainage should be improved around this site.

Pine Shade Mine (Site #55)

Location
The Pine Shade Mine is located at the headwaters of Seaton Gulch immediately north of the Gilson Gulch turnoff (Figures 3 and 33). The Pine Shade mine waste pile was sampled as site # 55. Site #55 is located at LAT. N39° 45' 35.0", LONG. W105° 30' 49.3". The estimated volume of mine waste in the main pile is 12,500 cubic yards. Site 55A is located immediately south of the main pile at LAT. N39° 45' 31.1", LONG. W105° 30' 47.2".
Figure 33. Pine Shade Mine in Middle (Site #55). Ricard Mine on Right and Tropic Mine Above.

Historic Structures
Scattered metal and wooden debris is all that remains at site #55. The remains of a burnt building remain at site #55A.

Water Quality Impacts
During normal precipitation events, this waste pile is a minor source of metals to Virginia Canyon. The vegetated slopes above the mine contribute very little runoff. The access road to the Seaton mine does concentrate runoff, which erodes the area between piles #55 and #55A. However, during heavy precipitation events, water builds up on the bench of Pile #55, resulting in leaching of metals from the pile. In addition, pile #55A slumped onto Virginia Canyon road in 1995.

The waste rock at this site had higher than average leachable metals. The waste rock had the highest Arsenic level and high cadmium and zinc levels in the total metals analysis. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #55</th>
<th>pH</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.13</td>
<td>96</td>
<td>BDL</td>
<td>120</td>
<td>760</td>
<td>130</td>
<td>1300</td>
<td>10000</td>
<td>18000</td>
</tr>
</tbody>
</table>
Reclamation Measures
The preferred reclamation measure for this site is to construct a series of diversions. An upland diversion should be constructed, encompassing piles #55, #55A, and #77. A diversion should also be constructed to divert drainage from the upper portion of the access road away from piles #55 and #55A. Regrading should be done to prevent ponding of water on pile #55.

Seaton Mine (Site #66)

Location
This mine site is located in upper Seaton Gulch immediately above Virginia Canyon (Figures 3 and 34). The mine site is accessed along a road from the Pine Shade mine. The mine waste pile was sampled as site #66. Site #66 is located at LAT. N39° 45' 34.0", LONG. W105° 31' 01.0". The estimated volume of mine waste is 2,400 cubic yards. The main waste pile is above the road, but during construction of the Virginia Canyon road, some of the mine waste was used as fill. This waste rock is shown as site #189 on Figure 4. Site #189 is located at LAT. N39° 45' 31.3", LONG. W105° 31' 02.0". The estimated volume of mine waste is 3,000 cubic yards.
Figure 34. Seaton Mine (Site #66), Above Upper Road and Site #189 Between Roads

Historic Structures
There are no historic structures or artifacts at this site.

Water Quality Impacts
Waste Pile #66 is eroded by run-on water from the slope above. Waste rock from site #189 is principally eroded by road drainage. In addition, the waste rock at site #189 is located in an ephemeral drainage. There is probably some leaching of the waste rock at site #189 during wet periods. Berms have been placed along the edge of the road to control erosion, but these berms have been observed to occasionally breach during thunderstorms.

The waste rock at site #66 had high leachable cadmium and zinc, and had the highest concentrations of cadmium and zinc of all the waste piles sampled in the total metals analysis. Waste rock is eroded from site #66 onto the road. Deep gullies have been cut in the waste rock at site #189. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #66</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.69</td>
<td>657</td>
<td>BDL</td>
<td>360</td>
<td>2400</td>
<td>33000</td>
<td>1500</td>
<td>13000</td>
<td>55000</td>
</tr>
</tbody>
</table>
Reclamation Measures
The preferred reclamation measure for waste pile #66 is to construct a diversion ditch to intercept upland flow and pass it around the site. Removal is a secondary option. The waste rock could be pushed down to the road for removal.

The preferred reclamation measure for waste pile #189 is to remove all or a portion of the waste rock. At least the top foot of the waste rock should be removed, then the remaining waste should be covered with soil. Removal of this waste rock will be difficult because the material is at the angle of repose. A slusher/dragline is probably the best method to remove the waste. The slusher or dragline can pull the waste onto the road below. At a minimum, the existing berms on the road should be improved to prevent breaching during thunderstorms.

Upper Clarissa Adit and Shaft (Site #80)

Location
This site consists of two waste piles located on the eastern side of the mainstem of Virginia Canyon approximately 2.5 miles above Clear Creek (Figures 3 and 35). There are no access roads to this site. The mine waste piles were sampled as site # 80. The waste piles were sampled as a composite because they both had similar mineralogy and were visually similar. The upper waste pile shown as site #80A on figure 3 is located at LAT. N39° 46' 03.7", LONG. W105° 32' 12.7". The estimated volume of mine waste at site #80A is 3,000 cubic yards. The lower waste pile shown as site #80B on figure 3 is located at LAT. N39° 46' 05.4", LONG. W105° 32' 10.8". The estimated volume of mine waste at site #80B is 8,200 cubic yards.

Historic Structures
There are no historic structures or artifacts at site #80B. The remains of a shaft house and loadout remain at site #80A.
Water Quality Impacts
The waste rock piles at this site both exhibit severe erosion. In addition, the vegetation below the waste rock has been killed for almost 600 feet below the piles. All vegetation has been killed for approximately 200 feet below the piles, and the herbaceous vegetation has been killed almost to the road below. Erosion appears to be principally from water flowing onto the waste rock from above. The waste rock from these mines is extremely acid forming and has very high concentrations of leachable arsenic and iron with high concentrations of leachable copper and lead. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #80</th>
<th>pH s.u.</th>
<th>Total Acidity mg/l</th>
<th>As ppb</th>
<th>Cd ppb</th>
<th>Cu ppb</th>
<th>Fe ppb</th>
<th>Mn ppb</th>
<th>Pb ppb</th>
<th>Zn ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.18</td>
<td>3380</td>
<td>1900</td>
<td>67</td>
<td>4900</td>
<td>670000</td>
<td>1800</td>
<td>6200</td>
<td>12000</td>
<td></td>
</tr>
</tbody>
</table>

There is probably little direct erosion of the mine waste into stream. The stream is located about 700 feet from the upper pile and 500 feet from the lower pile. There may be some movement of metals through leaching into the shallow ground water table during spring snowmelt.

Reclamation Measures
Because of poor access, the available reclamation options are limited. Removal of the mine waste or in-situ cementation would require construction of a road into the site, which would result in a large scar. Because of poor access, the recommended reclamation method is to construct diversions around the site, and neutralize the waste rock with lime and limestone. The diversion ditches can be constructed by hand, or by a small excavator that can negotiate through the trees with minimal damage.
To neutralize the waste rock, it is recommended that the waste piles be sprinkled with a mixture of lime and water. Sodium hydroxide could be used instead of lime. The piles can be sprinkled over a period of several weeks to allow the high pH water to percolate into the piles. Following completion of sprinkling, a slurry of ground limestone should be applied to the waste pile and the vegetation kill zone, then the entire area should be seeded and fertilized.

**Unknown Site #82**

**Location**
This site is located in the streambed of Virginia Canyon approximately 2.1 miles above Clear Creek (Figures 3 and 36). The mine waste pile was sampled as site # 82. The waste pile is located at LAT. N39° 45’ 49.6”, LONG. W105° 32’ 03.1”. The estimated volume of mine waste is 600 cubic yards.

**Figure 36. Unknown Site #82**

**Historic Structures**
There are no historic structures or artifacts at this site.

**Water Quality Impacts**
Virginia Canyon has heavily eroded the waste rock pile at this site. The top of the pile is covered with debris and is partially vegetated. During May of 2000, a spring was observed flowing from the base of the pile. The source of the water was apparently stream flow that had infiltrated into the alluvium, then surfaced at the toe of the waste pile. This indicates that there may be some leaching
of the waste rock. In May of 2000, virtually all the flow measured at water quality station VC-4 came from this spring. The waste rock analysis shows that this material has high concentrations of leachable arsenic, copper and iron. Results from the 2:1 leachate analysis are given below:

<table>
<thead>
<tr>
<th>Site #82</th>
<th>pH</th>
<th>Total Acidity</th>
<th>As</th>
<th>Cd</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>s.u.</td>
<td>mg/l</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
<td>ppb</td>
</tr>
<tr>
<td>2.55</td>
<td>1300</td>
<td>890</td>
<td>76</td>
<td>8600</td>
<td>230000</td>
<td>BDL</td>
<td>7200</td>
<td>16000</td>
<td></td>
</tr>
</tbody>
</table>

Reclamation Measures
The preferred reclamation option for this site is to remove the waste pile. This site is immediately adjacent to the mainstem road. This site is not readily visible from the road, so is not a significant contributing historic feature.

**Unknown Site #130 and Eclipse Mine (Site #131)**

**Location**
This site consists of two small waste piles located on the south-facing slope above the Foxhall (Figures 4 and 37). The waste piles are located in an ephemeral drainage below a recently constructed retaining wall. The eastern waste pile shown as site #130 on figure 4 is located at LAT. N39° 45' 29.0", LONG. W105° 31' 02.4". The western waste pile shown as site #131 on figure 4 is located at LAT. N39° 45' 28.9", LONG. W105° 31' 02.0". Both waste piles contain an estimated 250 cubic yards. These piles were not sampled.
Figure 37. Unknown Mine site 130 (left) and Eclipse Mine, Site #131 (right)
Historic Structures
There are no historic structures or artifacts at this site.

Water Quality Impacts
Both waste piles have been severely eroded by the ephemeral drainage. Road drainage braids below the retaining wall and has eroded most of the waste downstream. Site # 131 has a large vegetation kill zone below the pile.

Reclamation Measures
The waste rock adjacent to the drainages should be removed and consolidated on-site. Access to these sites is poor, so the waste may have to be moved using manual labor. There is sufficient topsoil in the area to cover and revegetate the piles if a road is built to the site.

Other Sites of Interest

Robinson Gulch
Three waste piles in Robinson Gulch ranked high on the basis of their chemical characteristics and past erosion. These include sites #69, #72, and #73. All three waste rock piles had high concentrations of leachable heavy metals. In fact, site #72 ranked third, #73 ranked fourth and #69 ranked twenty-third out of the 79 sites sampled. However, because the water quality sampling showed very little contribution of metals from Robinson Gulch, the overall ranking went down. These sites should receive consideration for reclamation once the higher priority sites are completed.

Buttermilk Gulch
Two mine waste piles in the Buttermilk Gulch watershed (Sites #56 and #58) ranked high on the basis of their chemical characteristics and past erosion. Site #56 ranked twenty-fourth out of 79. Site #58 commonly erodes several tons of waste onto the Gilson Gulch road following summer thunderstorms.

CONCLUSIONS

Based upon the information collected during this investigation, the following conclusions can be made:

1. The majority of the heavy metals from mining related sources is derived from a few sites. Conversely, most of the mine waste piles in Virginia Canyon are minor sources of metals.

2. Road drainage patterns contribute to erosion of mine waste piles. Changing the road drainage is a high priority.

3. Sediments in Virginia Canyon contain significant quantities of metals. Ultimately, the sediments must be removed to have a positive effect on water quality.

4. Robinson Gulch and Buttermilk Gulch are minor sources of heavy metals.

5. The mainstem of Virginia Canyon above Robinson Gulch, Boomerang Gulch, and Seaton Gulch are the principal sources of heavy metals.

6. Hydrologic controls can be very effective in controlling erosion and leaching of heavy metals from waste rock piles.
The highest priority for reclamation should be diversion of water away from the waste rock piles. Diversions will be the most cost effective methods to reduce heavy metals contributions to Virginia Canyon. Removal of some of the waste rock piles will require construction of a repository in order to be cost effective.

Road drainage patterns should be studied to determine where culverts and drainage control berms should be placed to minimize erosion of the mine waste piles. The crystal stope should be capped to prevent road drainage from entering the mine workings, which could possible eliminate this perennial or near perennial source of heavy metals. The shaft at site #13 should also be capped to prevent water from entering the mine workings, which may contribute to mine drainage from adit DM-2.

Erosion of material from the gravel roads has been observed to contribute greatly to the sediment load during thunderstorms in Virginia Canyon. It is recommended that sediment traps be constructed and maintained near culvert crossings in the major drainages.
References


5. EPA Method 1312: Synthetic Precipitation Leaching Procedure.


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MAY 2000 WATER QUALITY DATA
May 2000 Water Quality Data
May 2000 Water Quality Data
May 2000 Water Quality Data
May 2000 Water Quality Data
May 2000 Water Quality Data
May 2000 Loading Data
May 2000 Loading Data
May 2000 Loading Data
May 2000 Loading Data
May 2000 Loading Data
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August 2000 Stormflow Data
August 2000 Stormflow Data
August 2000 Stormflow Data
August 2000 Stormflow Data
August 2000 Stormflow Data
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August 2000 Loading Data
August 2000 Loading Data
August 2000 Loading Data
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SPRING 1999 WATER QUALITY DATA
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AUGUST 1999 LOW-FLOW DATA
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AUGUST 1999 POST-THUNDERSTORM WATER QUALITY DATA
AUGUST 1999 POST-THUNDERSTORM DATA
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VIRGINIA CANYON WASTE ROCK DATA
VIRGINIA CANYON WASTE ROCK DATA
VIRGINIA CANYON WASTE ROCK DATA
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MEASUREMENTS AND OBSERVATIONS
AT WASTE ROCK SAMPLING SITES
MEASUREMENTS AND OBSERVATIONS AT WASTE ROCK SAMPLING SITES
MEASUREMENTS AND OBSERVATIONS AT WASTE ROCK SAMPLING SITES
MEASUREMENTS AND OBSERVATIONS AT WASTE ROCK SAMPLING SITES
MEASUREMENTS AND OBSERVATIONS AT WASTE ROCK SAMPLING SITES
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OBSERVATIONS AT NON-SAMPLED SITES
OBSERVATIONS AT NON-SAMPLED SITES
OBSERVATIONS AT NON-SAMPLED SITES
APPENDIX 9

STREAM SEDIMENT ANALYSES
STREAM SEDIMENT ANALYSIS
STREAM SEDIMENT ANALYSIS