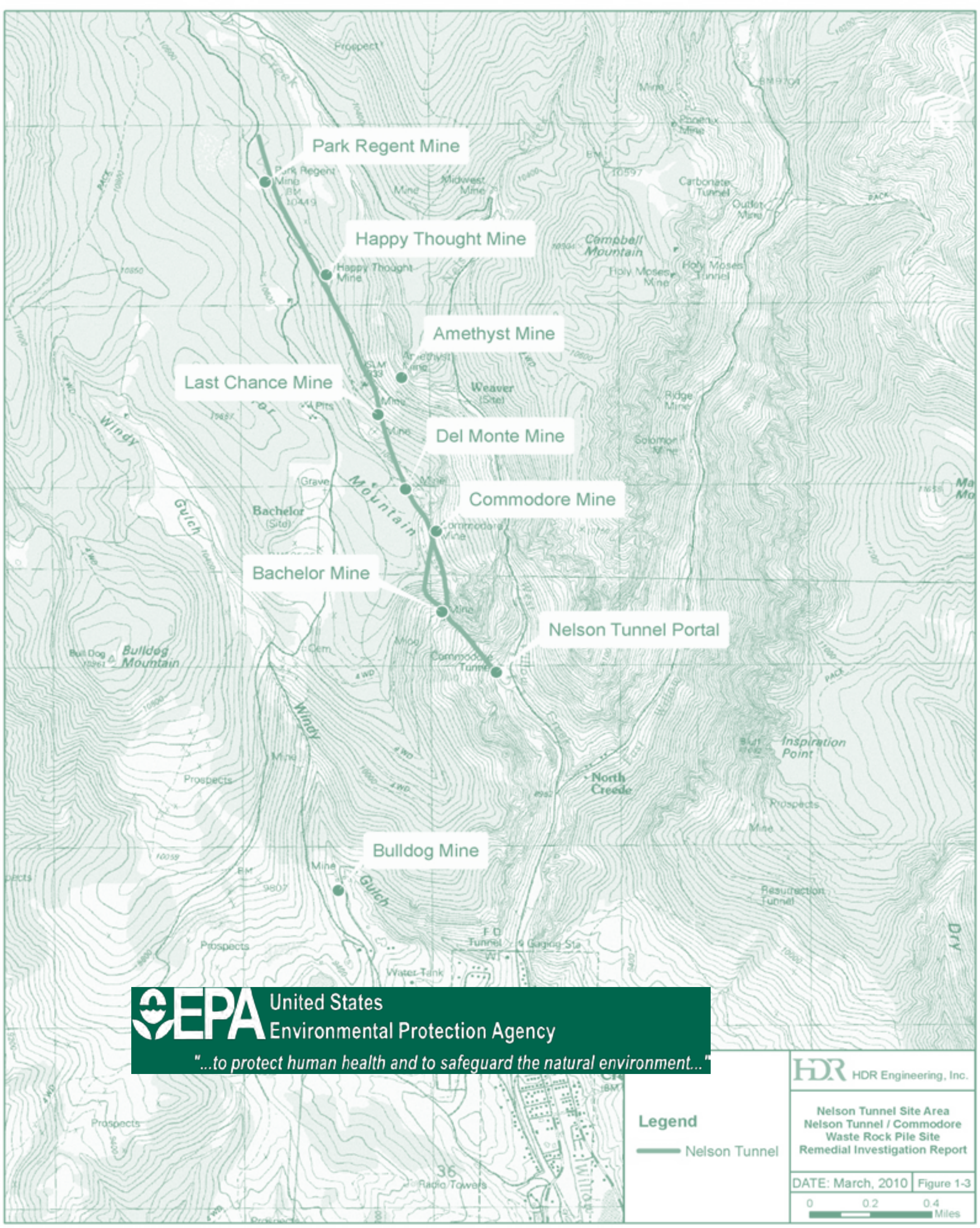
Remedial Investigation

Creede, Colorado

National Priorities List Site
USEPA Region 8

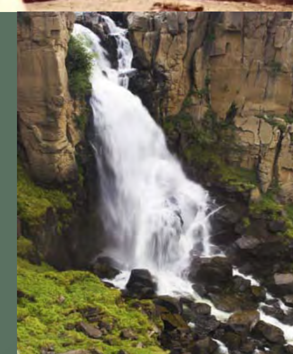
Nelson Tunnel/Commodore Waste Rock Pile

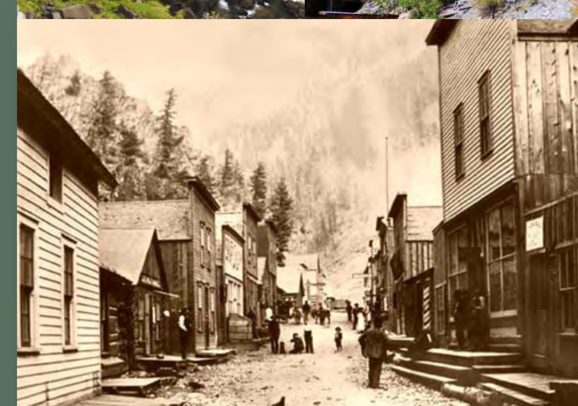
November 2011



EPA United States Environmental Protection Agency

"...to protect human health and to safeguard the natural environment..."





Remedial Investigation

Nelson Tunnel/Commodore Waste Rock Pile
National Priorities List Site
Creede, CO

November 2011

Prepared for
US Environmental Protection Agency
Region 8

by
HDR Engineering, Inc.
and
TechLaw, Inc.

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List of Acronyms

ABS	Activity-Based Sampling
ARAR's	Applicable or Relevant and Appropriate Requirements
asl	above sea level
ATSDR	Agency for Toxic Substances and Dietary Registry
ATV	All Terrain Vehicle
BCF	Bioaccumulation Factor
BKSF	Biokinetic Slope Factor
BERA	Baseline Ecological Risk Assessment
BRL	Below Reporting Limit
CDC	Center for Disease Control
CDRMS	Colorado Department of Reclamation Mining and Safety
CDPHE	Colorado Department of Public Health and Environment
cfs	cubic feet per second
COC	Contaminants of Concern
COPC	Contaminants of Potential Concern
COPEC	Contaminants of Potential Environmental Concern
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
DI	Deionized water
DIC	Dissolved Inorganic Carbon
EDD	Estimated Daily Dose
EPA	Environmental Protection Agency
EPC	Exposure Point Concentration
EPT	Ephemeroptera, Plecoptera, Trichopera
EU	Exposure Unit
GPM	Gallons Per Minute
GSD	Geometric Standard Deviation
HHRA	Human Health Risk Assessment
HI	Hazard Index
HRS	Hazard Ranking System
HQ	Hazard Quotient
ICP-MS	Inductively Coupled Plasma – Mass Spectrometry
INSTAAR	Institute of Arctic and Alpine Research
IUR	Inhalation Unit Risk (Factor)
lbs/day	pounds per day
LOE	Line of Evidence
MFG	MFG, inc.; now part of Tetra Tech
mg/Kg	milligram per Kilogram
MSL	Mean Sea Level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

NPL	National Priorities List
OSWER	Office of Solid Waste and Emergency Response
PEC	Probable Effects Concentration
PEF	Particulate Emission Factor
RAGs	Risk Assessment Guidance
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RFC	Reference Concentration
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SAP	Sample Analysis Plan
SAR	Sampling Activities Report
SCEM	Site Conceptual Exposure Model
SF	Slope Factor
Site	Nelson Tunnel/ Commodore Waste Rock National Priority List Site
SLERA	Screening-Level Ecological Risk Assessment
SMDP	Scientific Management Decision Point
TCLP	Toxicity Characteristic Leaching Procedure
TMDL	Total Maximum Daily Load
TRV	Toxicity Reference Value
TVS	Table Value Standard
UCL	Upper Confidence Limit
ug/dl	micrograms per deciliter
µg/L	micrograms per liter
ug/m^3	micrograms per cubic meter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WCRC	Willow Creek Reclamation Committee
WQS	Water Quality Standard
WRCC	Western Regional Climate Center

EXECUTIVE SUMMARY

This Remedial Investigation (RI) Report describes the nature and extent of mining-related contamination in surface water, mine pool water, and waste rock material in the Nelson Tunnel-Commodore Waste Rock pile National Priorities List (NPL) Site (the Site; Figures ES-1 and ES-2).

Approximately 300 gallons per minute of water contaminated with heavy metals flows from the Nelson Tunnel portal into West Willow Creek which ultimately discharges into the Rio Grande approximately four miles from the Site. Due to adverse impacts of Nelson Tunnel discharge to water quality in Willow Creek and the Rio Grande and the necessity for a prompt and properly funded remedy, the Site was placed on the NPL.

The Site features and surrounding areas addressed in the RI report include:

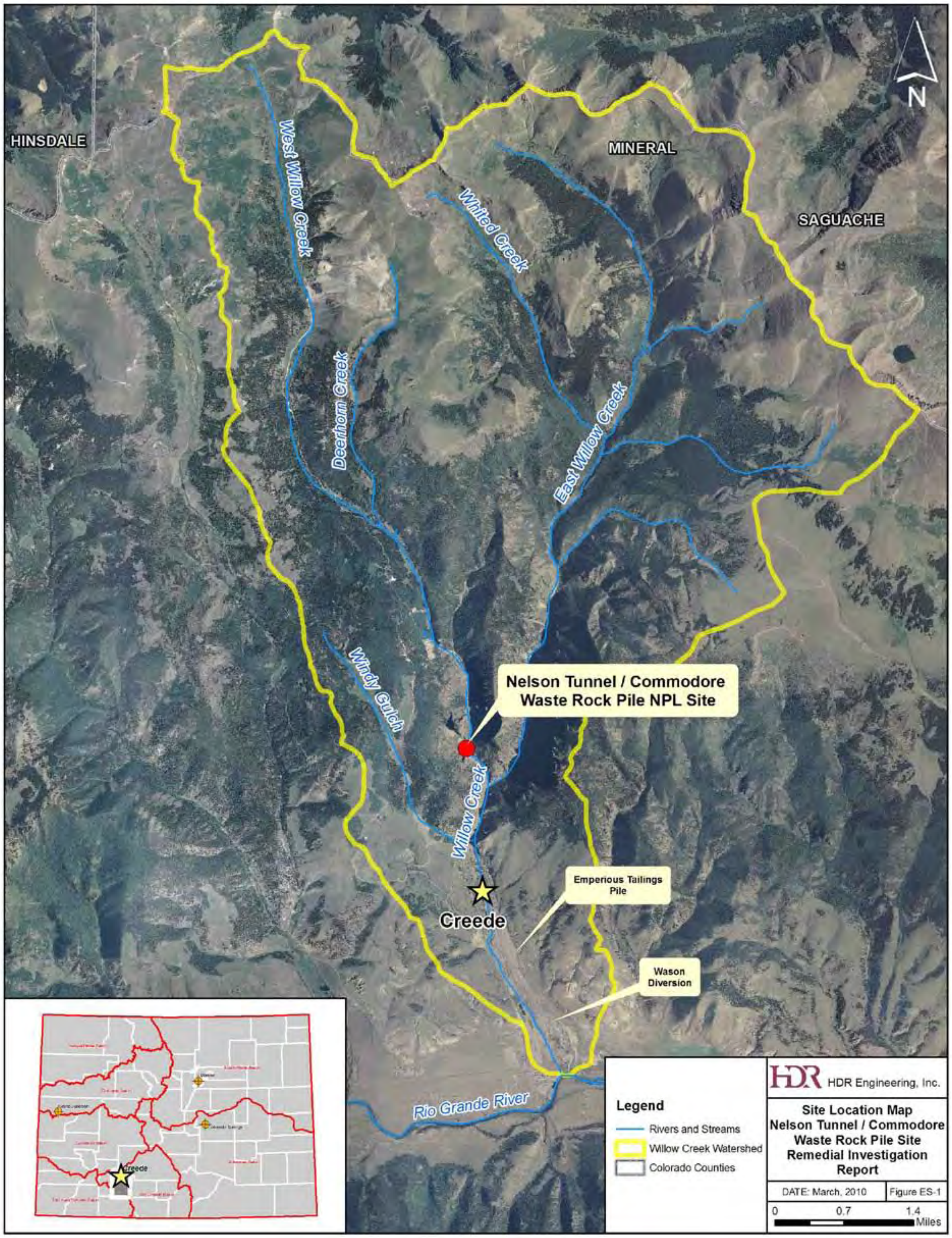
- Nelson Tunnel underground complex
- Nelson Tunnel discharge
- Surface water quality in the Willow Creek watershed
- Surface water quality in the Rio Grande
- Commodore Waste Rock pile
- County Road 503

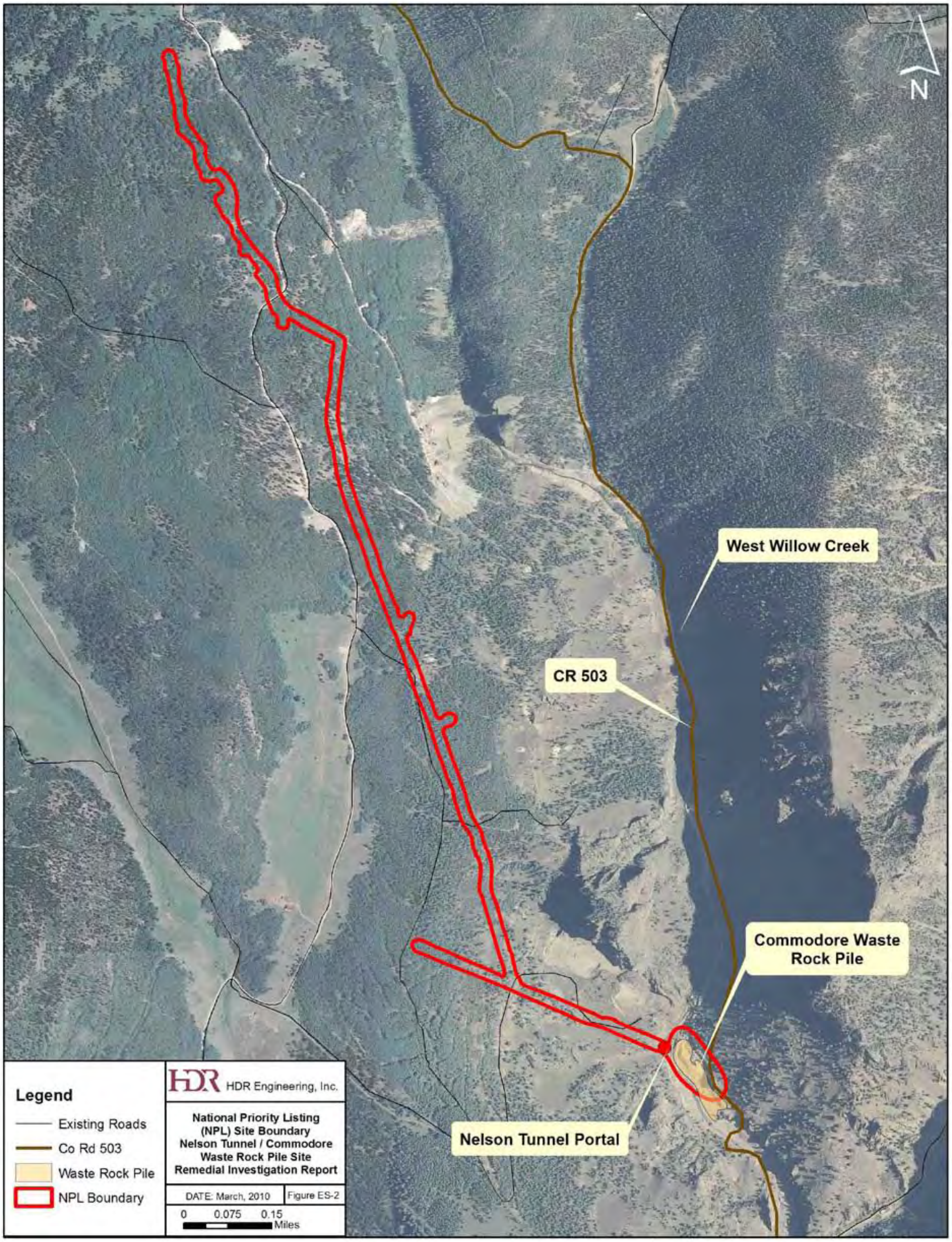
<u>Nelson Tunnel underground complex</u>

The Commodore Mine Complex (including the Nelson Tunnel) includes a number of separate mines. Most shafts developed 12 or more levels along a nearly 1,400 foot vertical section of the mineralized Amethyst Vein. Nearly three continuous miles of the Amethyst Vein were worked by various mines. Most shafts that sunk workings along the Amethyst Vein system were eventually all joined through the Nelson Tunnel and overlying Commodore 5 level tunnel.

In addition to groundwater entering the mine workings via faults and fractures in undifferentiated ash flow tuff bedrock, a limited amount of surface water is suspected or known to be entering mine shafts at various locations. This water enters lower mine workings ultimately discharging from the Nelson Tunnel, but only accounts for a very minor portion of the discharge observed at the Nelson Tunnel portal.

Water level data collected between 2002 and 2006 indicate a series of collapses in the Nelson Tunnel resulting in formation of three mine pools whose elevations fluctuate. This fluctuation may result from new collapses impounding additional water or from blowout of previous collapses.


HINSDALE
MINERAL
SAGUACHE
N
West Willow Creek
Whited Creek
Deerhorn Creek
East Willow Creek
Windy Gulch
Willow Creek
Nelson Tunnel / Commodore Waste Rock Pile NPL Site
Emperious Tailings Pile
Creede
Wason Diversion
Rio Grande River
Legend
Rivers and Streams
Willow Creek Watershed
Colorado Counties
HDR Engineering, Inc.
Site Location Map
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: March, 2010
Figure ES-1
0
0.7
1.4
Miles


N
West Willow Creek
CR 503
Commodore Waste
Rock Pile
Nelson Tunnel Portal
Legend
Existing Roads
Co Rd 503
Waste Rock Pile
NPL Boundary
HDR Engineering, Inc.
National Priority Listing
(NPL) Site Boundary
Nelson Tunnel / Commodore
Waste Rock Pile Site
Remedial Investigation Report
DATE: March, 2010
Figure ES-2
0 0.075 0.15
Miles

High water marks, noted by iron staining, indicate some mine pool elevations 8 to 10 feet higher than recent observations.

Water at the Nelson Tunnel portal and throughout the length of submerged mine workings has a low pH, relatively high concentrations of dissolved metals, and has minimal alkalinity. Cadmium and zinc concentrations fluctuate throughout the Nelson Tunnel, but generally vary in a similar way.

A tritium study indicated water ages over 60 years and carbon^{14} values suggest a median age on the scale of hundreds to thousands of years. This indicates the water takes a slow pathway through the subsurface and mine inflows cannot be controlled by reducing surface infiltration.

Nelson Tunnel discharge

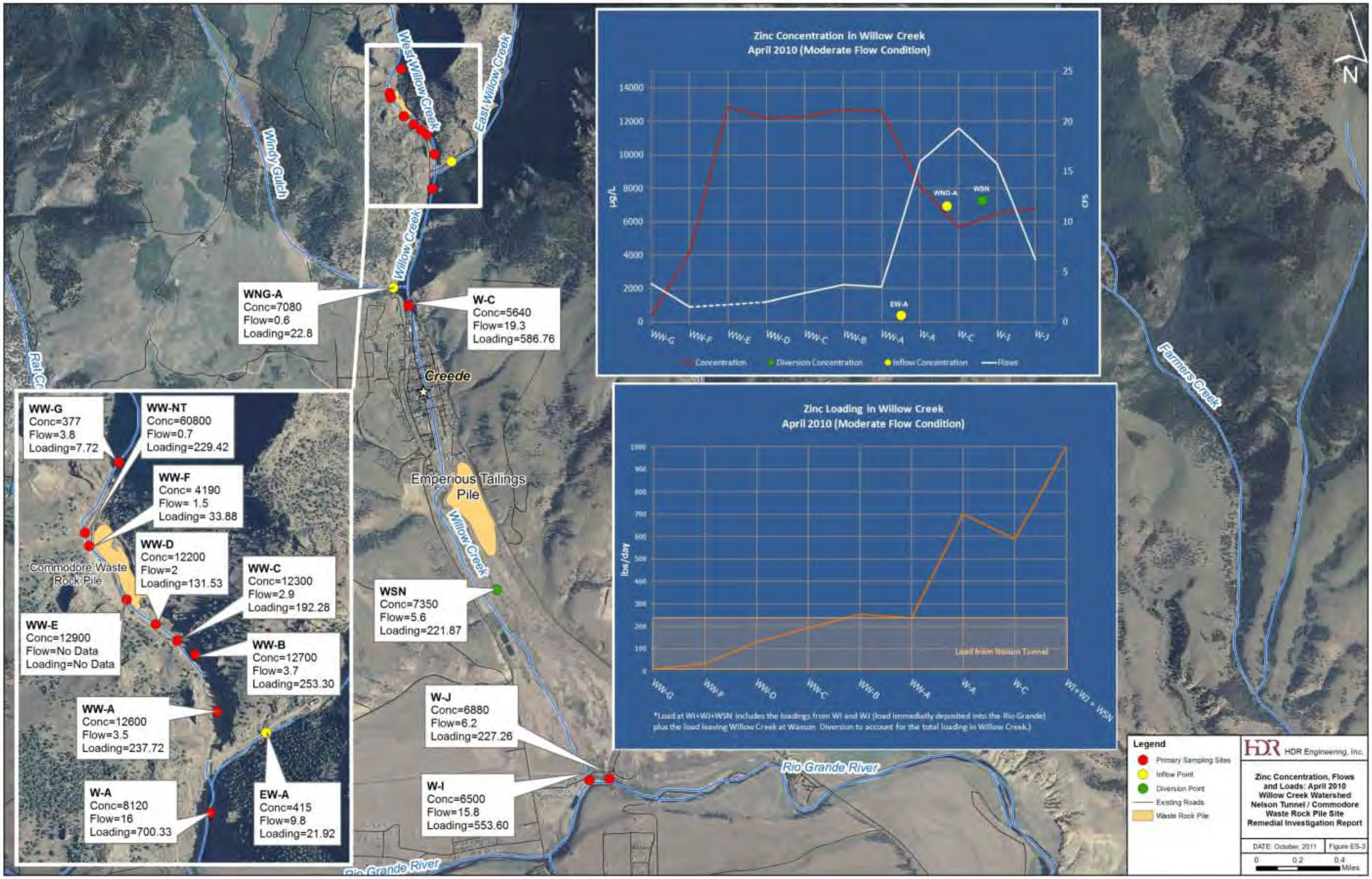
The Nelson Tunnel portal is the major known point source for metal load, particularly cadmium and zinc, to the Willow Creek watershed based on data from 1999-2011. However, it often does not account for the majority of cadmium and zinc load measured in lower reaches of the watershed. In periods of the year when low flows are observed (August – mid May), the Nelson Tunnel contributes approximately 11-48% and 22-78% of the highest cadmium and zinc load, respectively, measured in Willow Creek.

During high-runoff periods (mid-May to July), the Nelson Tunnel contributes between 19-39% and 30-55% of the highest cadmium and zinc load, respectively, measured in Willow Creek.

Surface water quality in Willow Creek watershed

Generally increasing metal loads are observed downstream of the Nelson Tunnel portal in West Willow and Willow Creeks. Other than the Nelson Tunnel discharge itself, large increases and losses in metal load were observed at the following locations as illustrated on Figure ES-3 for the case of zinc in April 2010:

- Gradually increasing load below station NT to just above the confluence with East Willow Creek. The source of this load may include mine wastes in the channel vicinity including Commodore Waste Rock and Nelson Tunnel discharge temporarily lost to alluvium below the portal before entering the channel.
- A sudden large increase in load near the confluence with East Willow Creek. This load increase, although present, was much smaller both prior to and after 2010. The source of this load is uncertain, however, it may have been a transient condition related to disturbance of the Commodore Waste Rock pile. This waste rock pile was re-contoured in 2009 and any continuing release of metals is expected to decline over time.



Zinc Concentration in Willow Creek
April 2010 (Moderate Flow Condition)
µg/L
CFS
WW-G
WW-F
WW-E
WW-D
WW-C
WW-B
WW-A
W-A
W-C
W-I
W-J
WNG-A
WSN
EW-A
Concentration
Diversion Concentration
Inflow Concentration
Flows
Zinc Loading in Willow Creek
April 2010 (Moderate Flow Condition)
lbs/day
Load from Nelson Tunnel
WI+WJ+WSN
*Load at WI+WJ+WSN includes the loadings from WI and WJ (load immediately deposited into the Rio Grande) plus the load leaving Willow Creek at Watson Diversion to account for the total loading in Willow Creek.)
West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Farmers Creek
Creede
Emperious Tailings Pile
Commodore Waste Rock Pile
Rio Grande River
WNG-A
Conc=7080
Flow=0.6
Loading=22.8
W-C
Conc=5640
Flow=19.3
Loading=586.76
WW-G
Conc=377
Flow=3.8
Loading=7.72
WW-NT
Conc=60800
Flow=0.7
Loading=229.42
WW-F
Conc= 4190
Flow= 1.5
Loading= 33.88
WW-D
Conc=12200
Flow=2
Loading=131.53
WW-C
Conc=12300
Flow=2.9
Loading=192.28
WW-E
Conc=12900
Flow=No Data
Loading=No Data
WW-B
Conc=12700
Flow=3.7
Loading=253.30
WW-A
Conc=12600
Flow=3.5
Loading=237.72
W-A
Conc=8120
Flow=16
Loading=700.33
EW-A
Conc=415
Flow=9.8
Loading=21.92
WSN
Conc=7350
Flow=5.6
Loading=221.87
W-J
Conc=6880
Flow=6.2
Loading=227.26
W-I
Conc=6500
Flow=15.8
Loading=553.60
N
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Zinc Concentration, Flows and Loads: April 2010
Willow Creek Watershed
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: October, 2011
Figure ES-3
0 0.2 0.4 Miles

- Increase in load below the Town of Creede as the main stem of Willow Creek traverses a broad floodplain. Potential sources for this additional load include undifferentiated mine wastes in the floodplain and consolidated Emperious tailing deposit.
- Loss of load as a result of flow diversions into Wason Ditch.

Surface water quality in the Rio Grande

The Rio Grande currently exceeds cadmium and zinc standards in Segment 4 and is regulated under temporary modifications of Table Value Standards (TVS). The temporary modification of underlying TVS for arsenic, cadmium, copper, lead, and zinc are set at existing quality until December 2012 when they will be reviewed by the Colorado Water Quality Control Commission.

Willow Creek contributes the majority of cadmium and zinc load to Segment 4 of the Rio Grande. Upstream of the confluence with Willow Creek, the Rio Grande achieves the TVS. Downstream of Willow Creek, the Rio Grande almost continuously exceeds cadmium and zinc TVS.

Based on available data, the Nelson Tunnel may contribute between 6-48% and 10-78% of the respective cadmium and zinc loads in Rio Grande Segment 4. The lowest percentages were based on April 2010 measurements.

Commodore Waste Rock pile

The Commodore Waste Rock pile comprises over 200,000 cubic yards that were recontoured under a time-critical removal action completed in 2009. The purpose was to remove mine waste from the West Willow Creek channel and establish stable pile geometry. The post removal action surface was sampled to support the risk assessment

Spatial variation in arsenic and lead concentrations across the waste pile is by about a factor of five with no obvious pattern apparent. The concentration of both chemicals in the 27 field samples is summarized in the table, below.

Commodore Waste Rock Sample Results (fine fraction <250 micron)

Chemical	Minimum mg/Kg	Maximum mg/Kg	Mean mg/Kg
Arsenic	261	1,350	672
Lead	8,050	52,100	25,416

County Road 503 (CR-503)

County Road 503 traverses a portion of the Site and is a part of an extensive tourist loop road. Metal levels in road base and mobilized into air by recreational activities were measured to support risk assessment. Air data of primary interest were collected during driving of all terrain vehicles (ATV). This type of sampling is referred to as Activity-Based Sampling (ABS). Portions of CR-503 were subjected to co-located ABS and road base sampling and other portions of the road were subject to road base sampling, alone.

The results of road base and air sample analyses are summarized in the tables below:

County Road 503 Road Base Sample Results (fine fraction <250 micron)

Chemical	Minimum mg/Kg	Maximum mg/Kg	Mean mg/Kg
Arsenic	6	166	53
Lead	28	2,380	435
Manganese	54	3,130	702

Activity-Based Air Sample Results

Chemical	Minimum ug/m^3	Maximum ug/m^3	Mean [a] ug/m^3
Arsenic	BRL	BRL	5.6
Cadmium	BRL	BRL	2.2
Lead	60.3	188	107.1
Manganese	44.7	139	83.6
Zinc	55.0	163	91.2

BRL – below reporting limit
[a] – mean calculated using ½ the reporting limit.

Human heath risks were assessed for the above-ground portions of the Site (Commodore Waste Rock pile and a small segment of CR-503; Figure ES-2) as well as for portions of CR-503 located north and south of the Site.

The Commodore Waste pile is currently fenced and public access is not allowed. However, it is possible for recreational visitors to travel on CR-503 (on and near the Site) and to trespass on the waste rock. Based on results of community interviews, two scenarios were selected to serve as representative activities of recreational Site visitors.

- *Adult and Child Rock Hunters*: The rock hunter is selected to represent a typical Site exposure. This population is assumed to include adults and older children (ages 6 to 12) who pass across the Site while rock hunting and hiking in the area.
- *Adult and Child ATV Riders*: ATV riders on CR-503 are selected to represent a high impact exposure because ATV riding by adults and older children (ages 6 to 12) is likely to result in higher than average exposures from inhalation of dust particles released into air by the riding activity.

Activities of ATV riders and rock hunter/hikers for this Site are similar in nature to activities evaluated for the Standard Mine in Crested Butte, Colorado. Exposure durations and frequencies for these populations at the Standard Mine are considered conservative estimates of exposures likely to occur within and near the Site.

The risk assessment reached the following conclusions:

Risks to Adult and Child Rock Hunters

Cancer risks and non-cancer effects to Rock Hunters are as follows:

- Non-cancer effects are below a level of concern (Hazard Quotient (HQ) <1) for all contaminants for reasonable maximum and central tendency exposure (RME and CTE, respectively) populations.
- Cancer risks do not exceed the EPA level of concern of 1E-04 for any contaminant, alone or in combination for either the RME or CTE exposure populations.
- The probability of a fetal blood lead concentration exceeding EPA's health based level of 10 ug/dL (P_{10}) is very low (estimated P_{10} is <1%)

Risks to Adult and Child ATV Riders

Cancer risks and non-cancer effects to ATV riders are as follows:

- Inhalation of manganese at the concentration detected from ABS air sampling indicates non-cancer effects for adults and children above a level of concern for both the CTE and RME populations.
- Inhalation of arsenic at the estimated air concentration based on road base concentrations in CR-503 indicates non-cancer effects for adults and children above a level of concern for the RME population.
- Cancer risks do not exceed the EPA level of concern of 1E-04 for any contaminant, alone or in combination for the adult or child CTE and RME populations.
- The probability of a fetal blood lead concentration exceeding EPA's health based level of 10 ug/dL is 11% (P_{10} = 11%). This exceeds EPAs goal of $P_{10} \leq 5\%$.

The likelihood of groundwater use in and near the residential and commercial areas of Creede was assessed as a part of this RI. The assessment was limited to a review of a 2003 private water well survey and contact with the Colorado State Engineer's office to determine if any new wells had been permitted since 2003.

Based on the 2003 survey and Colorado State Engineer's records, no permitted groundwater wells exist in the developed portion of Creede. In addition, Creede provides municipal water sourced from wells proximal to the Rio Grande.

Ecological risks were assessed for terrestrial and aquatic receptors in the Willow Creek watershed and for aquatic receptors in the Rio Grande. The weight of evidence indicates ecological risks above a level of concern for aquatic and some terrestrial receptors from exposure to water and aquatic plants in Willow Creek at and downstream of the Site. Risks in Willow Creek are driven by a variety of metals including cadmium and zinc. Chronic-based hazard quotients (RME) estimated for water column invertebrates ranged from 1 to 148.5.   Effect-based hazard quotients (RME) for birds and mammals ranged from <1 to 1,027. Risks to most terrestrial receptors are hypothetical given their food sources (e.g. fish) are not present in Willow Creek.

The weight of evidence indicates ecological risks above a level of concern for water column invertebrates, trout, and aquatic insectivorous birds in the Rio Grande downstream of Willow Creek. A benthic survey of the Rio Grande below the confluence with Willow Creek indicates relatively mild, mine-related impacts to invertebrates. Impacts to other aquatic receptors were based on methods other than population surveys (e.g. site-specific toxicity study for fish). Risks in the Rio Grande are driven by a variety of metals including cadmium and zinc. In the case of trout, ambient conditions in the Rio Grande are close to the threshold for acute toxicity and likely to be above the threshold for chronic toxicity. For water column invertebrates and some birds, chronic-based hazard quotients range from <1 to 6.7.

1.0 INTRODUCTION

1.1 PURPOSE OF THE REPORT AND REPORT ORGANIZATION

This Remedial Investigation (RI) Report describes the nature and extent of mining-related contamination in surface water, mine pool water, and waste rock material in the Nelson Tunnel-Commodore Waste Rock pile National Priorities List (NPL) Site (the Site). Water quality monitoring at the Site and surrounding area has been on-going since the late 1990's. In addition, response actions to reduce metal loading to the watershed have been implemented over the past decade. This RI Report uses analytical and other data gathered since the late 1990's to describe the nature and extent of contamination.

The RI Report is organized into the following major sections:

Section 1.0 – Introduction – This section describes the purpose of the RI and summarizes prior work and NPL Site history and setting.

Section 2.0 – Site Characteristics – This section provides a brief description of climate, surface water hydrology, geology and hydrogeology.

Section 3.0 – Nature and Extent of Contamination – This section describes the current type and extent of surface and mine pool water contamination as well as temporal trends in contaminant concentrations and metal loading. Concentrations of metals in Commodore Waste Rock samples, roadbase and air-born particulates are also presented.

Section 4.0 – Baseline Risk Assessment – This section discusses human and ecological risks in and near the Site.

Section 5.0 – Contaminant Fate and Transport – This section provides a qualitative discussion of contaminant migration routes and environmental persistence.

Section 6.0 – Conclusions – This section presents general conclusions.

Section 7.0 – References – This section provides full references for all citations in the report.

1.2 SITE LOCATION AND TOPOGRAPHY

The Site is located in the San Juan Mountains in south-central Colorado and lies one mile north of the town of Creede in Mineral County, Colorado (Figure 1-1). It includes the abandoned Nelson Tunnel, which drains directly into West Willow Creek, and Commodore Waste Rock pile surrounding the Nelson Tunnel portal (Figure 1-2). The Site lies approximately 9,175 feet (ft) above sea level (asl) in the bottom of a steep canyon with nearly vertical walls. Vertical relief within the Site is approximately 100 ft, but surrounding canyon walls reach roughly 10,600 ft asl. A topographic map illustrating Nelson Tunnel alignment and location of major area mines is provided as Figure 1-3.

Approximately 300 gallons per minute (gpm) of water contaminated with heavy metals flows from the collapsed Nelson Tunnel portal into West Willow Creek (Figure 1-4). West Willow Creek drains into Willow Creek, which flows into the Rio Grande approximately four miles from the Site (Figure 1-1). Although the Site itself is limited to the Nelson Tunnel and Commodore Waste Rock pile, the study area addressed in this RI Report includes the following:

- West Willow Creek from above the Nelson Tunnel to the confluence with East Willow Creek.
- The confluence of East and West Willow Creeks
- Willow Creek to its confluence with the Rio Grande
- Segment 4 of the Rio Grande
- Portions of County Road 503 both north and south of the Nelson Tunnel.

1.3 SITE HISTORY

Mining in Mineral County started in 1876 when the first claim was staked along the Alpha Corsair Vein (Figure 1-5). Soon after, the Amethyst Vein was discovered and staked as the Bachelor Claim in 1878. Mining in Mineral County did not draw investors and was not highly profitable until 1890, spurred by discovery of the Solomon-Holy Moses Vein. This find increased interest in the Creede mining district, and over 15 mines were developed in the Willow Creek Watershed (Figure 1-6). Silver was the primary mineral mined in Mineral County, however, significant amounts of gold, copper, lead and zinc were also extracted. The population of Creede peaked at 12,000 residents in 1892 during the height of mining. The current day population of Creede and Mineral County is approximately 450 and 1,000, respectively (EPA, 2005).

The Amethyst Vein was the most profitable of the major vein systems. In the early stages of mining, seven separate mines, primarily shafts, were mined along the Amethyst Vein (Figure 1-3), including:

- Bachelor
- Commodore
- Del Monte
- Last Chance
- Amethyst
- Happy Thought
- Park Regent

Ore was processed in multiple mills including Amethyst and Humphreys Mills, located at the junction of East and West Willow Creek. In order to remove ore more efficiently, the Nelson Tunnel was constructed in the 1890s. Eventually, the tunnel was extended to a total of 13,100 ft as the Nelson, Wooster, and Humphreys Tunnel and accessed all major mines along the

Amethyst Vein. The Nelson Tunnel system provided both haulage and drainage for mines in the Amethyst Vein. A second tunnel, the Commodore 5 level, was drilled approximately 45 feet above the Nelson Tunnel system to access the same mines (Graves, 2006). The resulting Commodore Waste Rock pile, surrounding the Nelson Tunnel portal is enriched in heavy metals. Mining in the Creede district produced (Nelson, 1989):

- 85,000,000 ounces of silver
- 155,000 ounces of gold
- 5,480 tons of copper
- 160,000 tons of lead
- 50,000 tons of zinc

Mining continued in the Nelson and Commodore 5 level tunnels until 1976 and in Mineral County until 1989. Currently, multiple collapses in the Nelson Tunnel system have rendered it inaccessible except through historic mining shafts. The Commodore 5 level tunnel remains accessible; however, its condition is slowly deteriorating. The Colorado Division of Reclamation Mining and Safety (CDRMS) rehabilitated portions of the Commodore 5 level and access points to the Nelson level to ensure safe working conditions. Rehabilitation work included stabilization, cleanup, and improvements to ventilation (CDMG, 2003).

1.4 REGULATORY HISTORY

Contamination of Willow Creek and its tributaries by mining related activities and waste has been documented for over 35 years. In 1999, the Willow Creek Reclamation Committee (WCRC) was formed by Creede stakeholders to investigate the nature and extent of contamination originating in the watershed. Since that time, discharge from the Nelson Tunnel portal has been found to be the largest single source of contamination in Willow Creek as well as Segment 4 of the Rio Grande (CDPHE, 2010).

Due to adverse impacts of Nelson Tunnel discharge to water quality in Willow Creek and the Rio Grande and the necessity for a prompt and properly funded remedy, the WCRC, State of Colorado, and EPA supported a recommendation for the Site to be place on the NPL.

The following is a brief chronological summary of major regulatory actions at the Site and surrounding study area.

1998	Segment 4 of the Rio Grande from Willow Creek to the Rio Grande/Alamosa County line placed on Colorado’s 303(d) list of impaired waters.
March 2008	NPL Proposal (Hazards Ranking System (HRS) Documentation Record).

2008-2009 Time Critical Removal Action for Commodore Water Rock pile to remove mine waste from a flowing channel and establish stable pile geometry.

September 3, 2008 Site placement on the NPL.

1.5 PREVIOUS INVESTIGATION REPORTS

Numerous reports have been published over the past 35 years describing Site conditions and characteristics. Over 18 reports are considered relevant to the Site and are listed below by primary subject as follows:

Mine Geology and Hydrogeology

- Results of Ground-Water Tracing Experiments in the Nelson-Wooster-Humphrey Tunnel, Cambrian Ground Water Co., 2001.
- Underground Report January 2004 to December 2004, Colorado Division of Minerals and Geology, Willow Creek Reclamation Committee, January 2005.
- Interim Underground Report December 2002 to December 2003, Colorado Division of Minerals and Geology, Willow Creek Reclamation Committee, 2003.
- Nelson Tunnel Pilot Dewatering Project, Colorado Division of Reclamation, Mining, and Safety, May 2008.
- Case Study of Groundwater Flow within the Commodore Mine Complex and Implications for Source Control. Presented at the 2006 National Association of Abandoned Mine Land Programs 28th Annual Conference, September 25-27, 2006, Billings, MT.
- Hydrologic System of the Nelson Tunnel/Commodore Mine, Creede, CO. Prepared by Anton Krupicka and Mark Williams, INSTAAR University of Colorado - Boulder. August 23, 2011.

Human and Biological Risks

- Health Consultation Nelson Tunnel-Commodore Waste Rock Pile Superfund Site, Creede, Mineral County, Colorado. Colorado Department of Public Health and Environment, Agency for Toxic Substances and Disease Registry. EPA Facility ID: CON000802630, March 13, 2009.
- HRS Documentation Record. Prepared by URS Operating Service for EPA, March 2008.
- Final Report on Characterization of Fish and Aquatic Macroinvertebrates in Willow Creek, U.S. Fish and Wildlife Service, Willow Creek Reclamation Committee, February 2004.
- Aquatic Resources Assessment of the Willow Creek Watershed. Internal Report prepared by USEPA Region 8. August, 2005.

- Baseline Ecological Risk Assessment for the Nelson Tunnel Superfund Site, Creede, Colorado. Prepared by TechLaw. October 2011.

Surface Water Quality and Hydrology

- Evaluation of Metal Loading to Streams near Creede, Colorado, August and September 2000. U.S. Geological Survey Scientific Investigations Report 2004-51, 2006.
- Preliminary Characterization of the Willow Creek Watershed: Existing Conditions and Recommended Actions. McCulley, Frick, and Gillman, Inc, April 5, 1999.
- Site Inspection Comprehensive Analytical Results Report East Willow Creek and West Willow Creek, Mineral County, Colorado, Colorado Department of Public Health and the Environment Hazardous Materials and Waste Management Division, April 9, 1997.
- Report on Surface and Mine Water Sampling in Willow Creek Watershed, Mineral County, CO 1999-2002, Willow Creek Reclamation Committee, March 2004.
- Report on Characterization of Waste Rock and Tailings Pile Above Creede, Colorado, Willow Creek Reclamation Committee, 2004.
- Sampling Activities Report, 2010 Sampling Events, Nelson Tunnel Mining Site, Creede, Colorado, Mineral County. Prepared by TechLaw, February 2011.
- Sampling Activities Report, 2011 Sampling Event, Nelson Tunnel Mining Site, Creede, Colorado, Mineral County. Prepared by TechLaw, October 2011.

Treatability Studies

- Nelson Tunnel Treatment Feasibility Study Addendum Report Bench Scale Testing of Chemical Precipitation Treatment Effectiveness. Willow Creek Restoration Committee, June 2006.
- Nelson Tunnel Water Management Feasibility Study for the Willow Creek Reclamation Committee Creede, Colorado. McLaughlin Rincón, January, 2006.

2.0 SITE CHARACTERISTICS

2.1 CLIMATE

Temperatures in Creede range from an average low of 6^o F in December to an average high of 78^o F in July. The annual average temperature is 40.8^o F. At the Site, temperatures are expected to be slightly cooler due to the increased elevation (WRCC, 2006).

Average annual precipitation at Creede is 13.5 inches; however precipitation can vary from 8.5 to 19.7 inches. Wettest months are August and September, and the driest months are December and January. Average annual snowfall is 47 inches (WRCC, 2006).

2.2 SURFACE WATER HYDROLOGY

2.2.1 Flows in Willow Creek

The Site lies on West Willow Creek in the Middle Section of the Willow Creek watershed. Only the small segment of West Willow Creek that receives drainage water from Nelson Tunnel and abuts the Commodore Waste Rock pile is included in the Site (Figure 1-2). The Willow Creek watershed has been divided into four distinct sections, Upper, Middle, Creede, and Lower Sections (Figure 2-1). The Upper Section starts at the ridge tops and contains the top-most sections of East and West Willow Creeks. Narrow canyons and a steep stream gradient characterize the Middle Section which contains the Creede Mining District and confluence of East and West Willow Creeks. Through the Creede Section, Willow Creek flows through the town of Creede, located at the canyon mouth. The Lower Section contains the gently sloping alluvial floodplain of Willow Creek before its confluence with the Rio Grande (EPA, 2005). The Emperious Tailing pile is located in the floodplain (Figure 1-1).

West Willow Creek above Nelson Tunnel receives snowmelt from numerous high peaks surrounding Creede. All major surface water features in the watershed are identified on Figure 1-1. Nelson Tunnel discharge and Deerhorn Creek are the largest tributaries to West Willow Creek. Willow Creek is formed by the confluence of West Willow and East Willow Creek, approximately half a mile below the Site. Windy Gulch joins Willow Creek and flows through Creede in a masonry flume, constructed in 1950 by the US Army Corps of Engineers for flood control (EPA, 2005). The masonry flume discharges into a braided floodplain below Creede. An irrigation diversion to Wason Ranch is located in the lower third of the floodplain (Figure 1-1). Only four flow measurements are available for the Wason diversion (made in 2009 and 2010). These range from 4 to 21 cubic feet per second (cfs). The Willow Creek watershed drains 39.8 square miles (MFG, 1999) before joining with the Rio Grande in two main channels below the Wason diversion.

Flows within the Willow Creek watershed are monitored at stations illustrated on Figure 2-2. Stream monitoring is primarily conducted on an annual or biannual basis by volunteers from the WCRC. However, monitoring during 2010 and 2011 was conducted by EPA. Flumes are not installed in the majority of monitoring locations, so flow is measured using area-velocity method, portable flume, or volumetric method (WCRC, 2004a).

The high flow season occurs in spring, primarily in May and June, dominated by snowmelt from high-mountain peaks. Low flows occur throughout the fall and winter months. Based on available flow data from 1995 – 2010, flows in Willow Creek at the confluence with the Rio Grande (the sum of measurements at monitoring stations W-I and W-J) ranged from 7 to 160 cfs. Flows in West Willow Creek just below the confluence with the Nelson Tunnel discharge (station WW-F; Figure 2-2) ranged from 1.5 to 70 cfs.

2.2.2 Flows in the Rio Grande

The Rio Grande originates in the San Juan Mountains west of Mineral County. Limited flow data is available at the confluence with Willow Creek. The United States Geological Survey (USGS) maintains the closest downstream gauging station, located below Wagon Wheel Gap approximately five miles downstream from Willow Creek (USGS Gauge # 08217500). Median monthly flows vary seasonally and range from 100 to 1,870 cfs. Lowest flows occur in January with a minimum of 130 cfs measured between 1952 and 2000 (CDPHE, 2010). High flow is correlated with snowmelt, reaching a peak in June of more than 3,380 cfs during the period 1952 to 2000. Multiple tributary streams outside the Willow Creek watershed enter the Rio Grande before Wagon Wheel Gap.

2.3 GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Site and surrounding Willow Creek Watershed has been previously characterized by CDRMS in several reports authored by Jeff Graves. The following discussion (entirety of Sections 2.3.1 and 2.3.2) is either directly quoted or paraphrased from his work. References to original authors are included as presented in Graves' reports.

2.3.1 Geology

2.3.1.1 Regional Geology and Mineralization

The Creede mining district occupies a geologically complex region of Tertiary aged volcanic activity. The majority of rocks exposed regionally throughout the San Juan Mountains can be closely tied to the formation and eruption of at least 17 separate volcanic calderas shown in Figure 2-3 (Steven and Eaton, 1975). Eruption and formation of the numerous calderas deposited thick sequences of ash flow tuffs across hundreds of square miles. Collapse and eventual resurgence of many calderas resulted in substantial fracturing and faulting that provided pathways for migration of ore forming solutions.

Magma associated with caldera development was generally responsible for heating of circulating meteoric waters which carried metal rich solutions towards the surface for eventual precipitation. Within the Creede district, ore deposition appears linked to post formational processes of the Creede caldera.

The Creede caldera, an eight mile wide collapse feature formed by eruption of the Snowshoe Mountain Tuff, was the final eruption within the central San Juan Mountains resulting in widespread ash flow sheeting. Following eruption of the Creede caldera, resurging magma within the caldera boundary led to a set of north trending distentional fractures just north of the caldera's margin as shown in Figure 2-4. This distentional fracturing formed what is now referred to as the Creede Graben, and is composed of four major fault systems shown in Figures 2-5 and 2-6:

- Alpha-Corsair
- Bulldog Mountain
- Amethyst
- Solomon-Holy Moses

Mineralization within the Creede District appears to have taken place close to the surface and along recently active distentional faults formed by intrusion of magma (Steven and Eaton, 1975).

2.3.1.2 Commodore Mine Complex

The Commodore Mine complex (the Mine) includes a number of separate mines, mostly shafts that sunk workings along the Amethyst Vein system and were eventually all joined through the Nelson Tunnel and Commodore 5 level. Figure 2-7 provides a plan-view of the Nelson and Commodore 5 levels, intersecting shafts, drifts (horizontal tunnels driven from the Nelson or Commodore 5) and mineralized faults. Most shafts developed 12 or more levels along a nearly 1,400 foot vertical section of the Amethyst Vein. Nearly 3 continuous miles of the Amethyst Vein were worked by various mines.

The lowest entry into the Mine complex is the Nelson Tunnel. Approximately 45 feet above the Nelson Tunnel is the Commodore 5 level. Additional exploration work was conducted below the Nelson Tunnel level at the Bachelor, Commodore and Berkshire Shafts (Figure 2-7). Exploratory drifts were driven along the Amethyst Vein around 350 feet below the Nelson Tunnel; however exploration indicated unprofitable sulphide ore (Graves, 2006).

The Mine worked the Amethyst Fault system, including mineralized veins varying from less than inches to more than 15 feet in width that strike N 20º W and dip southwest between 55º and 80º. The Amethyst Fault is the eastern complement to the Bulldog Fault with both bounding one of the inner keystone blocks of the Creede Graben (Figure 2-6).

The majority of the Amethyst Fault has displaced members of the Bachelor Mountain rhyolite, with the Willow Creek member forming the footwall and the Campbell Mountain member forming the hanging wall. Towards the southern and upper end of the Commodore Mine complex, the Creede formation is also displaced by the fault.

Two additional veins were also worked; the OH-Vein and the P-Vein (shown on Figure 2-5). The OH-Vein is a nearly vertical vein striking northwest and possibly extending to the Bulldog Mountain Fault. Numerous open cavities with extensive crystal growth are evident along both OH- and P-Veins. The upward migration of hydrothermal fluids appears to be responsible for deposition of ore along the veins. Ore fluids migrated upward and cooled, depositing sulfide minerals including sphalerite, galena, chalcopyrite and pyrite towards the surface. Over time an oxidized zone along the vein developed within approximately 300 feet of the surface as shown in Figure 2-8. Much of the silver ore was concentrated near the base of the oxidized zone as native silver and silver chlorides.

2.3.2 Hydrogeology

2.3.2.1 Mine Working Hydrology

Historical observations and discharge measurements of water flow within Mine workings provide a well documented account of hydrologic conditions in existence during mining. In the early 1890's water was encountered within 200 feet of the surface as shafts were sunk along the Amethyst Vein. Undifferentiated volcanic tuff bedrock is essentially impermeable except along fractures and faults. As shafts were driven deeper, the amount of water needing to be pumped and the costs associated with dewatering increased substantially. During development of the Nelson Tunnel, historic accounts indicate that large quantities of water were encountered near the base of the Last Chance and Amethyst Shafts. Exploratory work conducted from the Berkshire Shaft below the Nelson Tunnel from 1917-1920 encountered discharge from the drifts at nearly 1,300 gpm. Documents filed in water court by Mine owners indicated up to an 8,500 gpm discharge from the Nelson Tunnel working face near the Amethyst Shaft. A subsequent report by Hodges (1902) indicated discharge from the Nelson Tunnel portal at approximately 3,000 gpm.

During operation and pumping of the Bulldog Mine adjacent to the Commodore Mine complex, discharge from the Nelson Tunnel was less than 45 gpm. In the early 1990's, discharge from the Nelson portal averaged below 20 gpm, but steadily rose to around 300 gpm in 1999, after closure of the Bulldog Mine. A sudden increase in portal flow from 300 gpm to well over 400 gpm was observed between November of 1999 and December of 2000, when flow subsided to approximately 250 gpm.

A flume at the Nelson Tunnel portal was reconfigured in 2003 in an unsuccessful attempt to allow more accurate flow measurements. Periodic discharge measurements between 2002 and 2009 indicate stabilization of the flow, with fluctuations between 200 gpm and 300 gpm.

However the 2010 data indicate variable discharge for that year, ranging from 269 gpm to 380 gpm. Nelson Tunnel discharge measurements are presented graphically on Figure 2-9.

The reported relationship between pumping at the Bulldog Mine and diminished discharge at the Nelson Tunnel portal suggests an indirect hydraulic connection exists between the Bulldog and Amethyst Faults. Several faults and numerous extension fractures are inferred to connect these two north-south trending faults as shown in Figures 2-5.

In addition to groundwater entering the Mine workings via faults and fractures in the undifferentiated ash flow tuff bedrock, a limited amount of surface water is suspected or known to be entering Mine shafts at various locations. This water enters lower Mine workings ultimately discharging from the Nelson Tunnel, but only accounts for a very minor portion of the discharge observed at the Nelson Tunnel portal.

Monitoring points have been established to characterize hydrologic and water quality conditions within the Mine (Figure 2-10). Due to collapses and unsafe access, monitoring locations were limited to areas where the Nelson Tunnel is accessible from the Commodore 5 level.

Limited flow measurements conducted at Nelson Tunnel portal, Nelson Tunnel at Bachelor Shaft and Nelson Tunnel near No Name Winze (See Figures 1-2 and 2-7 for location of named features) indicate that on average between 80% and 90% of Nelson Tunnel portal discharge originates upstream of No Name Winze. This observation is supported by the lack of additional discreet inflows reported between the portal and No Name Winze.

Water level data collected between 2002 and 2006 indicate a series of collapses in the Nelson Tunnel resulting in formation of three Mine pools (Figures 2-11 and 2-12) including:

- The Nelson Tunnel Portal Pool extends from the portal to almost the Bachelor Shaft.
- The Lower Mine Pool extends from a collapse just upstream of the Bachelor Shaft to just past No Name Winze.
- The Upper Mine Pool appears to extend from the Hospital Decline through the Berkshire Shaft and OH-Amethyst junction to within 500 ft of No Name Winze. The OH-Amethyst junction identified on Fig. 2-11 as an “area of interest”. This discussed further in Section 3.7.

Additional collapses may be present within major Mine pools, but do not appear to affect water levels. The collapse sequence from the Nelson Tunnel portal to the Bachelor Shaft is unknown; however, discussions with former Mine employees indicate a complex pattern of poor rock conditions resulting in the possibility of numerous collapses along that portion of the Mine.

Mine pool water elevations and flows at both Nelson Tunnel portal and Bachelor Shaft fluctuate. Because only limited data was collected, discerning distinct correlations is difficult.

Some fluctuations in Mine pool elevation may result from new collapses impounding additional water or from blowout of previous collapses. High water marks, noted by iron staining, indicate some Mine pool elevations 8 to 10 feet higher than currently observed. High flows at the Nelson Tunnel portal in 2000 may have resulted from blowout of a large impoundment within the Mine. No obvious seasonality can be linked with flows or Mine pool elevations, nor are trends between Mine pool elevations and flow measurements correlative with each other.

2.3.2.2 Sources of Recharge and Age of Mine Pool Water

Dr. Mark Williams at the University of Colorado Institute of Arctic and Alpine Research (INSTAAR) was provided a grant by the Colorado Department of Public Health and the Environment (CDPHE) to investigate the age of Nelson Tunnel water. From 2007-2010 a series of water samples were collected from sites within the Nelson Tunnel and from surface waters, springs, domestic wells and precipitation collectors in the West Willow Creek watershed. These samples were analyzed for stable isotope content of $\delta^{18}O$ and deuterium and the radiogenic isotope tritium. A subset of five of these samples was analyzed for the $\delta^{14}C$ of dissolved inorganic carbon (DIC). The purpose of dating Mine pool water was to determine the source of water in the Nelson Tunnel. Water recharging the tunnel could be from two sources:

- Infiltrating from the surface through multiple Mine shafts
- Recharged by groundwater

A memorandum prepared by Dr. Williams for this RI report is presented in Appendix A and describes his findings that:

> *"evaluation of the stable water isotopes along the main stem of tunnel suggests a well-mixed reservoir, composed of either a mixture of rain and snow recharge, or snow recharge that has undergone fractionation."*

The tritium study indicated waters over 60 years old. In addition, Dr. Williams concluded:

> *The isotopic results show that the waters in the mine are largely not directly connected to surface waters or to the shallow groundwater (springs, seeps). Instead, this water in the tunnel appears to have a residence time on the order of hundreds to thousands of years and tracer results suggest that this water is entering the tunnel in the slow-moving, quasi-stagnant upper mine pool, likely resulting from the intersection of the tunnel with a system of watershed-wide faults.*
>
> *The water discharged from this upper mine pool is well-mixed and especially after the Bachelor Shaft enjoys a much quicker passage through the lower mine pool before it discharges at the Nelson Tunnel Portal. It appears there may be some small surface connection to the tunnel waters at both the Del Monte and Corkscrew Raises—or that*

these are the sites of more poorly-mixed eddies—but these possible connections' overall contribution to the quantity of water in the tunnel is fairly insignificant.

In addition to the isotopic analysis, in 2010 a slug injection tracer test using three inorganic salts was conducted along the length of the Nelson Tunnel. The purpose of this test was to characterize the flow regimes of the two major Mine pools in the tunnel and to help determine where water is entering the tunnel and whether it might be leaving the tunnel before it reaches the portal. This tracer test follows a similar test performed by Cambrian Groundwater in 2001 (Cambrian Ground Water Co., 2001).

Dr. Williams reached the following conclusions from the tracer test:

Results from this test suggest that the upper mine pool—located between the Decline Shaft and No Name Winze—is very slow moving. Flow velocities of roughly 10m/hr were calculated along the length of the upper mine pool, indicating a quasi-stagnant body of water with significant lateral exchange due to eddies, tunnel blockages, and dispersion and diffusion with less dominant down-tunnel advection.

In contrast to this, the lower mine pool—located between No Name Winze and the tunnel Portal—had flow velocities of approximately 25m/hr and a well-defined tracer breakthrough curve that indicated advection-dominant channelized flow with likely no additional inflows of water. Flow in the lower mine pool seems to be especially advection-dominant below the Bachelor Shaft with flow between No Name Winze and Bachelor Shaft being affected by some dispersion as characterized by a possible slow leakage of tracer in the tunnel hydrograph after the initial breakthrough tracer curve.

While this 2010 tracer test indicates inflows occurring in the upper mine pool, results from the 2001 tracer test (Cambrian Ground Water Co., 2001) with a slug injection in the Berkshire Shaft (located in the upper mine pool) showed a very strong tracer breakthrough curve, suggesting similar conditions between the Berkshire and the Portal as was observed in the fall 2010 tracer test for just the lower mine pool. If this is indeed the case now, 10 years later, it would show that the hypothesized upwelling tunnel inflows are likely occurring somewhere between the Decline Shaft and the Berkshire Shaft—reducing the tunnel distance for significant inflows to only 270 meters versus the current spatial resolution for inflows of 1050 meters, i.e. the length of the entire upper mine pool.

3.0 NATURE AND EXTENT OF CONTAMINATION

3.1 INTRODUCTION

The Site boundaries are restricted to the Nelson Tunnel and Commodore Waste Rock pile (Figure 1-2). However, conditions in the overall watershed are described out of necessity as surface water quality beyond the NPL Site boundary was a driver for NPL status.

Multiple investigations were conducted within the Willow Creek Watershed to classify water quality and aquatic health. These investigations have consistently identified the Nelson Tunnel and Commodore Waste Rock pile as the major contributors of metal loads to the watershed (EPA 2005, Kimball 2006, CDPHE 2010).

All available data was evaluated and selected sets were used to describe the nature and extent of contamination. This section is organized as follows:

- Summary of available data
- Identification of contaminants of concern (COCs)
- Description of Commodore Waste Rock pile
- Description of County Road 503 (CR-503) road base
- Air sample results
- Description of water quality in the Nelson Tunnel
- Description of water quality in the Willow Creek watershed
- Contribution of the Nelson Tunnel to metal loads in Willow Creek
- Effects of Commodore Waste Rock Removal Action on water quality
- Description of water quality in the Rio Grande
- Summary of the contribution of Nelson Tunnel to metals load in the Rio Grande

3.2 SUMMARY OF AVAILABLE DATA

Site analytical and other data was provided from multiple sources including the WCRC, EPA, and CDPHE. Table 3-1 summarizes analytical and other data and their sources.

Some of the data was collected between 10 and 15 years ago. Since that time, several Site characteristics have changed, including Nelson Tunnel discharge volume and configuration of the Commodore Waste Rock pile (under a Removal Action completed in 2009). Much data collection before Site listing was not conducted on a regular basis. Sampling location varied by year, and many locations identified in a 2003 Sampling and Analysis Plan (SAP; WCRC, 2003) were not regularly sampled.

For this reason, EPA conducted a comprehensive sampling program (including the use of sampling stations established by WCRC) in 2010 to characterize the following:

- Metals concentrations in surficial mine wastes in the Commodore Waste Rock pile (this waste rock feature was subjected to a recontouring removal action completed in 2009, prior to this sampling event).
- Metal concentrations in road base on CR-503 near the Site.
- Metal concentrations in air samples collected during the operation of all terrain vehicles (ATV) on CR-503.
- Surface water quality and flow rates in the Willow Creek watershed and in the Rio Grande, both up- and down-stream of the confluence with Willow Creek.

In addition, one round of surface water samples and other measurements were collected during April of 2011 at a limited number of monitoring stations.

All available data was screened to retain information that was the most comprehensive and representative of recent Site conditions. Also considered was the appropriateness of certain data for use in risk assessment or for describing the nature and extent of contamination.

With few exceptions, the 2010 data were used for both site characterization and for risk assessment. The April 2011 data were also used to describe site characteristics. In addition, some historic water quality and flow data were retained for the following reasons:

- To describe water quality conditions in the Mine workings (Nelson Tunnel). No data was collected from the subsurface during 2010 or 2011.
- To demonstrate temporal concentration trends near the Commodore Waste Rock pile to examine the effects of a recently completed removal action.
- To determine whether the 2010 and 2011 surface water quality data at certain critical locations are representative of typical conditions. These include the Nelson Tunnel portal, confluence of East and West Willow Creeks, and locations in the Rio Grande where compliance with Applicable, Relevant or Appropriate Requirements (ARARs) is assessed.

Because numeric criteria for surface water (See Section 3.3.3) are based on dissolved metal concentrations, all data used to describe the nature and extent of metals contamination in water samples is reported as dissolved.

3.2.1 Surface Water

Surface water chemistry and flow data is available dating back to 1995. These data are described on Table 3-1.

The majority of the data was collected on an annual basis in May and occasionally October at varying stations in the Willow Creek watershed. Despite most data collection occurring at the same time of year, flows vary greatly. Additionally, the majority of sampling events include a limited number of stations in the area of interest, from upstream of the Site to the Rio Grande.

Most recently, sampling was conducted in April, June and September of 2010 to address data gaps described, above. Limited additional sampling was conducted in April 2011.

These data were selected to represent water quality during high (June) and low flow (April pre-runoff and September post-runoff) periods in Willow Creek for the following reasons:

- Most recent and comprehensive data set collected.
- Data collected after recontouring of the Commodore Waste Rock pile (under a Removal Action completed in 2009) which is expected to reduce metals loads once continuing releases (if any) from the new pile configuration stabilize.
- Nelson Tunnel portal measurements reflect the current flume configuration, which was re-constructed in 2003 and reset in 2009.
- Measurements were taken after stabilization of Nelson Tunnel portal discharge rate in 2002.

The 2010 sample collection and flow measurement methodologies are discussed in a 2011 Sampling Activities Report (SAR; TechLaw, 2011a). These methodologies were also employed during the limited sampling in 2011 (SAR; TechLaw, 2011b).

As discussed at the beginning of Section 3.2, these data were supplemented with selected measurements made prior to 2010 when necessary to demonstrate temporal trends at specific sample stations.

3.2.2 Mine Pool Water

Mine pool water chemistry is available for the years 2000, 2002, 2003, 2007, and 2009 (See Figure 2-10 for monitoring locations). These data are described on Table 3-1.

Water sampled in 2009 was only analyzed for total metals. As discussed at the beginning of Section 3.2, dissolved metal results were selected to describe the nature and extent of contamination. Therefore, the 2009 data were excluded.

Only one sampling event occurred in years 2000, 2002, and 2003; however multiple sampling events (4) occurred within 2 days in 2007. To avoid biasing data, 2007 data was averaged and resulting values were used to represent a single water quality sampling event.

Unlike surface water data, no single monitoring event included all Nelson Tunnel sample stations. As a result, available measurements at each station were averaged (as necessary) under the following conditions:

- Only one water quality sample was collected at the Commodore, Del Monte Raise, Amethyst 3, and Park Regent stations.
- The Nelson Tunnel portal flow was measured during both underground and surface water monitoring events, so all measurements were averaged.
- Up to four measurements were averaged at remaining underground stations.

3.2.3 Commodore Waste Rock Pile

Multiple, independent investigations were conducted on Commodore Waste Rock prior to recontouring under a time critical removal action completed in 2009. These investigations are summarized in Table 3-1 and include limited wet chemistry, X-ray fluorescence and leach tests using both acidic and neutral pH solvents. Given that these data are representative of the former surface of the waste pile (prior to the removal action), the total metals content of samples analyzed prior to completion of the removal action are not used to described the current nature and extent of contamination of Commodore Waste Rock. However, leach test results are retained for discussion in the fate and transport section of this report.

Additional characterization of Commodore Waste Rock was conducted in 2010 after removal action completion. These recent data were reported in a SAR (TechLaw, 2011a) and are used to characterize the nature and extent of contaminants at the surface of the recontoured waste rock and to support an estimate of risks to human health and the environment from contaminants in waste rock. A total of 27 waste rock samples were collected and sieved to retain the <250 micron fraction for chemical analyses for 21 metals plus silica.

3.2.4 CR-503 Road Base Material

Portions of CR-503 traverse the Site and also extend outside the Site boundaries to the south and north (Figure 1-2). Samples of road base materials were collected in 2010 to support estimation of human heath risks posed by exposure to road base materials through ingestion or inhalation (See Section 4 for further discussion of the mobilization of road base into air). A total of 17 samples were collected and analyzed for 15 metals. These recent data were reported in the SAR (TechLaw, 2011a) and are used to characterize the nature and extent of contaminants in road base.

3.2.5 Activity-Based Air Samples

Air sampling for particulates was conducted in 2010 along CR-503 to provide data to support estimation of human health risks posed by inhalation of road base materials mobilized into the air by wind and vehicle travel. Air samples included stationary as well as those collected by samplers affixed to ATV operators traveling along portions of CR-503. A total of three stationary and three ATV riding samples were collected and analyzed for arsenic, cadmium, manganese, lead and zinc. These data were reported in the SAR (TechLaw, 2011a).

3.2.6 Miscellaneous Data

Isotope and tracer data was collected within the Nelson Tunnel and at the portal. Two independent tracer studies were conducted by Cambrian Groundwater Co. and Dr. Mark Williams from the University of Colorado (UC) at Boulder to quantify the travel time of water through the Mine workings and identify if water from the Nelson Tunnel was present in seeps near the portal. Isotope work was conducted by Dr. Mark Williams UC at Boulder to estimate the age and sources of the water found in tunnel workings. Results of these studies are described in Section 2.3.2.2.

3.3 CONTAMINANTS OF CONCERN

The media-specific contaminants of concern (COCs) for the Site were selected by assessing all analytical data collected during 2010 to determine whether one or more chemicals pose a risk above a level of concern to human health or environmental receptors or exceeds a regulatory threshold. In general, COCs in solid media were driven by risks to humans whereas COCs in water were driven by ecological risk or regulatory thresholds such as water quality standards. Details of this COC identification process is provided below as well as in Section 4 (Risk Assessment).

If a specific environmental medium contains no chemicals that pose risks above a level of concern, then one or more non-COC chemicals were selected to describe the nature and extent of contamination in that particular medium. Although the selected chemicals pose risks below a level of concern, they remain elevated above likely background conditions.

3.3.1 Commodore Waste Rock

The human health risk assessment (HHRA - Section 4) concludes that exposure to Commodore Waste Rock by the likely exposed populations (e.g. rock hunter and ATV rider) poses health risks that are below a level of concern. Therefore, there are no COCs associated with Commodore Waste Rock. However, for the purposes of describing the nature and extent of contamination, arsenic and lead were selected.

3.3.2 County Road 503 Road Base

The HHRA (Section 4) concludes that exposure to dust generated by vehicle traffic on CR-503 may result in adverse health effects largely due to manganese. Therefore, this chemical is used to describe the nature and extent of contamination in CR-503 road base. For consistency with other solid media (e.g. waste rock), arsenic and lead concentrations are also used to describe the nature and extent of contamination in road base.

3.3.3 Water

Available data on levels of mining-related contaminants in the Willow Creek watershed indicate that a number of metals are elevated, including arsenic, cadmium, copper, lead, manganese, and zinc (ATSDR, 2009). Regulatory criteria for Segment 4 of the Rio Grande, downstream of the Site indentify numeric standards for physical parameters, dissolved metals, and non-metallic inorganic contaminants. Metals concentrations are regulated based on hardness and can be calculated using metal-specific equations yielding Table Value Standard (TVS).

Table Value Standards are set by the CDPHE Water Quality Control Commission. Based on historic and recent data, cadmium and zinc almost always exceed the chronic TVS for the Rio Grande calculated as follows:

$$\text{Cadmium TVS} = (1.101672-[\ln(\text{hardness}) * 0.041838]) * e^{0.7998[\ln(\text{hardness})]-4.4451} \quad \text{(Equation 3-1)}$$

$$\text{Zinc TVS} = 0.986 * e^{(0.825[\ln(\text{hardness})]+0.9109} \quad \text{(Equation 3-2)}$$

Average hardness in the Rio Grande is approximately 36 milligrams per liter (mg/L; CDPHE, TMDL Assessment, 2010). The corresponding TVS for chronic cadmium and zinc exposure are 0.20 micrograms per liter (µg/L) and 52 µg/L, respectively (CDPHE, 2009). No other regulated chemicals are noted to exceed TVS values in Segment 4 of the Rio Grande (CDPHE, 2010).

The HHRA (Section 4) identified no additional chemicals posing risks above a level of concern based on incidental ingestion of surface water. The Baseline Ecological Risk Assessment (Chapter 4) identified several chemicals in water other than cadmium and zinc that may pose risks above a level of concern. Among these are lead, manganese, copper, beryllium and others.

However, risks to ecological receptors are most frequently driven by cadmium and zinc. Therefore, the chemicals used to describe the nature and extent of contamination in site water are cadmium and zinc.

3.4 COMODORE WASTE ROCK

The Commodore Waste Rock pile is comprised of mine wastes from the Commodore and Nelson Tunnel workings, deposited between 1890 and 1960. The pile contains approximately 200,000 cubic yards of barren and mineralized rock containing metals such as lead, cadmium, copper, and zinc (EPA, 2008a). The minerals found in the waste rock include metallic sulfides which are dominated by pyrite.

A time critical removal action memorandum was issued in 2008 calling for stabilization of waste rock material at the Site. In accordance with the removal action, the pile has been reworked to reduce erosion and uncontrolled releases into Willow Creek during flooding or high runoff periods (EPA, 2008a).

The footprint of the post removal action waste pile along with the concentration of arsenic and lead in surface samples collected in 2010 is illustrated on Figures 3-1 and 3-2, respectively. As discussed in section 3.2.3, waste rock samples were dried and sieved with the fraction passing a 250 micron sieve analyzed for total metals by ICP-MS.

A review of the figures reveals no obvious pattern in the spatial variation of arsenic and lead concentrations (variability is by about a factor of five). The concentration of both chemicals in the 27 field samples is summarized in the table, below.

Summary of Arsenic and Lead Concentrations
Commodore Waste Rock (fine fraction <250 micron)

Chemical	Minimum mg/Kg	Maximum mg/Kg	Mean mg/Kg
Arsenic	261	1,350	672
Lead	8,050	52,100	25,416

The post-removal action pile is shown in a photograph presented as Figure 3-3.

3.5 COUNTY ROAD 503 ROAD BASE

A total of 17 road base samples were collected over a four mile length of CR-503 beginning at the intersection with CR-502 and extending to the north (See Figure 3-4 for sample locations and results). Each sample was comprised of five subsamples collected from the 0-2 inch depth interval at equal distances along a transect line placed perpendicular to the road. The composite samples were dried and sieved with the fine fraction (<250 micron) subjected to chemical analyses by ICP-MS.

Analytical results for arsenic, lead and manganese are summarized in the table below.

Summary of Arsenic, Lead and Manganese Concentrations
County Road 503 (fine fraction <250 micron)

Chemical	Minimum mg/Kg	Maximum mg/Kg	Mean mg/Kg
Arsenic	6	166	53
Lead	28	2,380	435
Manganese	54	3,130	702

A review of Figure 3-4 reveals that the concentration of the contaminant of primary concern (manganese; see Section 3.3.2) is in the 400-800 mg/Kg range with a few exceptions:

- Concentrations are below 400 mg/Kg near the intersection of CR-503 with CR-502 above the Nelson Tunnel portal (Samples CR-503-8 through CR-503-11).
- Isolated concentrations above 1,000 mg/Kg occurred at the Nelson Tunnel portal (Sample CR-503-2) and near the end of the four-mile reach of CR-503 subjected to sampling (Sample CR-503-14).

3.6 AIR SAMPLING

Two types of air sampling were performed to support assessment of human health risks to hypothetical rock hunters on the Commodore Waste Rock and to individuals who travel on CR-503. These include both stationary air samples and samples collected by equipment mounted on ATVs driving along CR503.

<u>Stationary Air Samples</u>

Stationary sampling equipment consisted of BGI PQ200 and AirCoin2 air samplers placed at three locations along CR-503 shown on Figure 3-4. Samples were collected on 0.45 micron filters. Specific collection times varied due to the amount of battery life in the portable air samplers. After collection, the samples were placed in sealable bags and then in a cooler until delivered to Reservoirs Environmental Inc. for analysis (TechLaw, 2011a). Analytical results are summarized in the table, below. A detailed data summary is provided in the SAR (TechLaw, 2011a).

Stationary Air Sample Results

Chemical	Minimum ug/m^3	Maximum ug/m^3	Mean [a] ug/m^3
Arsenic	BRL	BRL	2.1
Cadmium	BRL	BRL	0.85
Lead	BRL	11.0	5.06
Manganese	BRL	BRL	2.1
Zinc	BRL	7.2	3.8

BRL – below reporting limit

[a] – mean calculated using ½ the reporting limit.

<u>Activity-Based Samples</u>

Activity based sampling (ABS) involved a lead and following ATV driving along segments of CR-503 with air sampling equipment affixed to the driver of the following ATV. This ABS sampling was intended to measure the concentration of chemicals in the breathing zone of an ATV rider following another vehicle. A total of three “runs” were made primarily between the north end of Creede to a location approximately 1.75 miles north of Creede along CR-503 as shown on Figure 3-4.

The ATV drivers operated the ATV's under typical recreational speeds. During the collection of one of the samples, it was noted that two earth graders were leveling the road which caused noticeable fine particulates to be exposed on the road surface. In addition to the road graders, 10 vehicles passed by the ATV's while collecting air samples.

Analytical results for these three samples are summarized in the table, below. A detailed data summary is provided in the SAR (TechLaw, 2011a).

Activity-Based Air Sample Results

Chemical	Minimum ug/m^3	Maximum ug/m^3	Mean [a] ug/m^3
Arsenic	BRL	BRL	5.6
Cadmium	BRL	BRL	2.2
Lead	60.3	188	107.1
Manganese	44.7	139	83.6
Zinc	55.0	163	91.2

BRL – below reporting limit
[a] – mean calculated using ½ the reporting limit.

3.7 WATER QUALITY IN THE NELSON TUNNEL

Water at the Nelson Tunnel portal and throughout the length of submerged Mine workings has a low pH, relatively high concentration of dissolved metals, and has minimal alkalinity. Average portal flow is 256 gpm, and has remained fairly constant over the past 10 years (Figure 2-9). However, the 2010 data indicate variable discharge ranging from 269 gpm to 380 gpm. Table 3-2 presents average water quality data for Nelson Tunnel portal discharge from 2001 to 2010.

Cadmium and zinc concentrations fluctuate throughout the Nelson Tunnel but generally vary in a similar way (Figures 3-5 and 3-6). Concentration data for cadmium and zinc from the back of the Mine workings to the portal is described below:

- Zinc concentrations measured in the three sampling locations furthest from the portal (Park Regent Shaft, Decline, and Berkshire Shaft) are similar at approximately 45,000 µg/L. Water at this location has a relatively low cadmium concentration with the lowest at the Park Regent Shaft in the rear of the tunnel. Unlike the samples collected at the Decline and Berkshire, the Park Regent samples represent surface infiltration inflows and not Mine pool water.
- Between the Berkshire Shaft and No Name Winze, cadmium and zinc concentrations increase despite relatively clean surface inflows from the Amethyst 3 Shaft. Although not measured, the clean inflows occur at a low flow rate relative to flow in the Mine pool. Therefore, any dilution effect is expected to be minor.
- A steep decline in zinc and cadmium concentrations was observed between No Name Winze and the Commodore Shaft. There are no obvious sources of clean water inflow in this region of the tunnel. Below the Commodore Shaft, a steady increase in

cadmium concentration was observed all the way to the portal. In the case of zinc, the concentration of zinc decreases between No Name Winze and the lower Mine pool. The Peak drift, which has low concentration of cadmium and zinc (CDMG, 2003), intersects the lower Mine pool below the Commodore Shaft. The Peak Draft is thought to flow at less than 5 gpm. The last two stations, the Bachelor Shaft and Nelson Tunnel portal show a distinct increase in zinc concentration compared with the next station upstream, with no known source.

3.8 WATER QUALITY IN THE WILLOW CREEK WATERSHED

3.8.1 Stream Classifications

Willow Creek watershed has a multitude of steam classifications that are dependant on Rio Grande watershed stream segment as shown in Figure 3-7 and summarized in Table 3-3. The segments of the Willow Creek watershed are described as follows:

- Segment 5 contains the uppermost section of East and West Willow Creek and has the same classification as the Rio Grande:
    - Aquatic Life Cold 1
    - Recreation E
    - Water Supply
    - Agriculture
- Segment 6 is a small segment of West Willow Creek above the Site and has fewer regulated inorganic contaminants and less stringently regulated metals:
    - Aquatic Life Cold 1
    - Recreation E
- Segment 7 includes the lower Willow Creek watershed and has no numeric standards for inorganic contaminants or metals:
    - Agriculture
    - Recreation E

The Site lies in Segment 7 and the Nelson Tunnel drainage is currently in compliance with segment specific standards.

3.8.2 Approach Used to Describe Spatial Contaminant Trends

The accuracy of flow measurements in Willow Creek or its tributaries is uncertain because few flumes are installed in the watershed and depth in larger stream segments is calculated using an area-velocity method. Additionally, a portion of stream flow may be temporarily lost to adjacent and underlying alluvium, and resurface lower in the watershed, contributing to inaccurate flow measurements. Therefore, metal load estimates (flow times concentration) within a watershed may be significantly affected by errors in flow measurements. Metal loading calculations are also depended upon an assumption of complete mixing within the stream and that a single grab sample represents the entire flow volume.

Spatial variation in zinc and cadmium concentrations in surface water is considered to be a meaningful measure of the occurrence of contaminant sources within a watershed as it is independent of flow. Therefore, the nature and extent of contamination is based on both concentration and loading profiles.

Because inflows (surface or subsurface) to streams can simultaneously increase load and decrease concentration (due to dilution effects), an observed increase in concentration between monitoring stations is a strong indicator of a significant source of metals load. When an increase in concentration between monitoring stations is observed due to inflows, the source of the inflow certainly contains contaminant concentrations higher than the receiving water.

Alternatively, increases in contaminant concentration between stations may be unrelated to water inflows and be the result of a leachable contaminant source in contact with water in or near the channel.

Seasonal variability (during 2010) is also discussed by comparing COC concentrations, loading and flow profiles for the following months:

- April 2010 - Moderate flow conditions
- June 2010 - High flow conditions
- September 2010 - Low flow conditions

In addition, April 2011 data collected from the upper portion of the watershed is also used to describe conditions in that area. The Baseline Ecological Risk Assessment (TechLaw, 2011c; summarized in Section 4.3) identifies April as associated with sensitive life stages for aquatic life as compared with the time of other sampling events (e.g. September). Therefore, the discussion of surface water quality focuses on conditions in the Willow Creek watershed during that month.

In order to simplify the presentation, discussion of conditions in the watershed is divided into three reaches including:

- West Willow Creek above the confluence with East Willow Creek - Stations WW-G to WW-A (Figure 2-2).
- Confluence of West and East Willow Creeks - Stations WW-A to W-A
- Willow Creek - Stations W-A to WW-I and J

3.8.3 West Willow Creek (Stations WW-G to WW-A)

As discussed in Section 3.2.1, surface water monitoring data from April, June and September 2010 were used to represent moderate, high and low flow conditions, respectively.

Figures 3-8 through 3-13 illustrate the spatial variability in flow, concentration and loading for zinc and cadmium. Nelson Tunnel portal drainage (Station WW-NT) enters West Willow Creek between Stations WW-G and WW-F. As expected, a large increase in cadmium and zinc concentration and load is observed between these stations during April.

However, the increasing concentration trend extends to station WW-E (no flow data is available for this station in April and so metal loading cannot be calculated). This suggests that some of the flow from the Nelson Tunnel portal escapes into alluvium between the Nelson Tunnel weir and banks of West Willow Creek. Much of this lost flow appears to reenter West Willow Creek before Station WW-E accounting for the concentration peak at that location in April 2010.

Beyond Station WW-E, a gradual increase in flow, coupled with constant zinc and cadmium concentrations results in increasing load downstream of WW-E until all Nelson Tunnel zinc load is accounted for at Station WW-B (Station WW-D, in the case of cadmium). The gradual increase in flow is due to discharge of metal impacted waters from materials adjacent too or underlying the stream channel. These waters may have been lost to the near subsurface between stations WW-G and WW-F, only to re-emerge in the lower reaches of West Willow Creek.

The metal content of these waters may originate from Nelson Tunnel discharge lost to the alluvium below the portal as well as leaching from unconsolidated mine waste that dominates the area above the confluence of East and West Willow Creeks, encompassing Stations WW-F, WW-E, WW-D, WW-B, and WW-A. Sources of additional metal load in this reach (beyond that contributed by the Nelson Tunnel) is suggested by a cadmium load at Station WW-B that is more than twice that of the Nelson Tunnel discharge. Although the source of additional metal load in these waters is undetermined, possible sources may include:

- Infiltrating precipitation that leaches metals from mine wastes in this reach (including the Commodore Waste Rock). The water then migrates as shallow groundwater towards and discharges to the creek channel.
- Dissolution of metals from mine waste in or immediately adjacent to the channel.

During June and September, 2010, and April 2011, concentration, flow and loading profiles are similar to conditions observed in April, 2010 with the following exceptions:

- In June 2010, the Nelson Tunnel metal load is fully accounted for at Station WW-E, closer to the Nelson Tunnel portal (WW-NT) than during April.
- In September 2010, the Nelson Tunnel metal load is fully accounted for at Station WW-A, farther from the Nelson Tunnel portal (WW-NT) than during April or June.
- In April of 2011 (see Figures 3-14 and 3-15), the Nelson Tunnel metal load is fully accounted for at station WW-D (Nelson Tunnel metal load was not measured in April of 2011 and so the maximum load measured in 2010 was used).

Specific conductance was measured along the right and left stream banks as well as in the center of the channel during the April 2011 sample event. The purpose of these measurements was to identify the extent of mixing zones in West Willow and Willow Creeks. Results of these measurements are presented on Figure 3-16 and indicate that Nelson Tunnel discharge is well mixed in West Willow Creek at Station WW-E.

The data were also examined for evidence of relatively high conductivity water entering West Willow Creek from either bank between Station WW-E and WW-A. No obvious pattern was observed that would indicate high salinity inflows. However, the ability of the conductivity survey to detect diffuse (non-point source) discharge of groundwater to the Creek is uncertain and was not an objective of the survey.

3.8.4 Confluence of West and East Willow Creeks - Stations WW-A to W-A

Measurements at three monitoring stations describe conditions at the confluence between West and East Willow Creeks (Figures 3-8 through 3-13). During April 2010, a large excess zinc and cadmium load was observed below the confluence of East and West Willow Creeks as shown below for the case of zinc:

> W-A Zinc Load (700 lbs/day) - [WW-A Zinc Load (238 lbs/day) + EW-A Zinc Load (22 lbs/day)] = **440lbs/day**

This additional zinc load constitutes 192% of the load contributed by the Nelson Tunnel portal discharge measured at the Station WW-NT flume. This entire metal load entered surface water at a location between 2,000 and 2,800 feet downstream of the Nelson Tunnel portal.

A similar situation existed during June and September of 2010 where excess zinc load as a percentage of Nelson Tunnel portal load are 124% and 45%, respectively. Similar results are found when cadmium loading is examined.

However, a review of April 2011 measurements and all relevant historical measurements suggest that this excess metal load was unique to 2010. The 2010 and 2011 data are discussed first followed by a discussion of older data.

Reconciliation of flow measurements across the three stations indicates an inflow of between 0.06 cfs and 12.2 cfs in 2010 and 2011. The following table summarizes these observations and extrapolates the concentration of zinc and cadmium in the inflows necessary to reconcile the metal loads across the three monitoring stations of interest.

Summary of Mass Balance at Confluence of East and West Willow Creeks

Date	Gain in Flow cfs	Gain in Flow as a Percent of Station W-A Flow	Gain in Zn/Cd Load lbs/day	Gain in Zn/Cd Load as a Percentage of Nelson Tunnel Load	Estimated Concentration of Zn/Cd in Inflows mg/L	Estimated Concentration of Zn/Cd in Inflows as a Percentage of Nelson Tunnel Concentrations
April 2010	2.7	17	441/1.85	192/370	31/0.13	51/98
June 2010	12.2	14.8	201/0.89	124/153	3/0.014	6/8
Sept. 2010	0.5	4	102/0.44	45/73	38/0.17	77/130
April 2011	0.06	<1	24/0.087	10[1]/17	31/0.27	51[1]/205

1 - April 2010 Nelson Tunnel data used in calculations. Data unavailable for April 2011.

As discussed in Section 3.8.2, some error in flow measurements is not unexpected for a variety of reasons. Nevertheless, the consistently large increase in observed metal load across the three stations of interest in 2010 coupled with estimated inflows between 4% and 14.8% of flow at Station W-A suggests that a relatively large additional metals load entered surface water in this reach in 2010. Much smaller inflows and additional metal loads were observed in April of 2011.

In some cases, the estimated zinc and cadmium concentrations of these inflows approach or exceed those of the Nelson Tunnel discharge as summarized in the table, above. Therefore, the source for the additional increment of metals load is presumed to be relatively potent and is similar only to subsurface flows in the Mine.

In the table presented above, the relatively low estimated inflows and additional incremental load reflected in the 2011 data may be within a reasonable range of measurement error. Therefore, this data set it is considered less indicative of a real source of contaminated inflows than the 2010 data.

The Commodore waste rock and miscellaneous mine waste deposits along West Willow Creek also constitute a potential source for metal loading to the Creek. However, the observed appearance of the additional metal load is restricted to a short reach of the creek located more than 2,000 feet from both the Nelson Tunnel and majority of Commodore Waste Rock.

Therefore, three scenarios seem plausible:

- Seepage from underground Mine workings and/or shallow subsurface flows in contact with mine waste is forced to the surface (and into the creek channel) in a limited area between Stations WW-A and W-A.
- Precipitation (rain/snow melt) in contact with the recently disturbed Commodore Waste Rock pile (disturbed under a removal action completed in 2009) yielding an exceptionally high (and potentially transient) metal load that is forced to the surface (and into the creek channel), largely below station WW-A.
- A distinct point source such as an unknown buried adit or fault complex discharging to the creek in this location. The Amethyst Fault is mapped near this location (See Figure 2-5).

Under scenario's 1 and 2, it would be necessary for a high concentration gradient to exist between surface and near surface waters for a long length of channel (along most of West Willow Creek below the Nelson Tunnel portal) before near surface water discharged to the channel. This scenario seems unlikely given the evidence of exchange of near surface and surface waters between Stations WW-G and WW-A (note variable flows along this reach; Figures 3-8 through 3-13).

Historical data were examined to determine whether the conditions observed in 2010 had occurred in previous years. Unfortunately, flow and concentration data for the three stations of interest (WW-A, EW-A and W-A) are available only for the years 2000 and 2002-2004. A mass balance for those years is summarized in Table 3-4.

A review of the table shows that although unaccounted for additional zinc and cadmium load was noted for most sample events, the increase in load was modest (on the order of a few percent of the load at W-A) compared with that observed during 2010. This, along with the April 2011 data supports the theory that conditions observed in 2010 were due to recent disturbance of the Commodore Waste Rock pile. However, some uncertainty remains, particularly regarding the transport mechanism from the inferred source (Commodore Waste Pile) to the confluence of West and East Willow Creeks.

Specific conductivity measurements made in 2011 (Figure 3-16) suggest incomplete mixing of East and West Willow Creek waters at Station W-A. Therefore, it is possible that metal concentration data are not representative of the entire flow volume at that station. However, conductivity data show complete mixing at station WA-OPP and in April 2011 the zinc concentrations at station W-A and WA-OPP were 3,170 ug/L and 3,320 ug/L, respectively. This suggests that samples collected at W-A closely approximate complete mixing in the stream and are representative of the entire flow volume.

Additional historical data sets (excluding Station EW-A) were examined for evidence of a large metal load entering the creek below station WW-A. The largest increase in zinc and cadmium load was observed during high flow conditions in May of 2007 as illustrated on Figure 3-17. However, the lack of data from Station W-A and EW-A precludes localizing the source for the additional load. It is reasonable to conclude that the majority of the additional load did not originate from East Willow Creek as this drainage is known to be a relatively modest source for metal load.

Future water quality monitoring will provide insight into significance of the 2010 data at this location.

3.8.5 Willow Creek - Stations W-A to WW-I and J

Downstream of Station W-A, Willow Creek exits the narrow canyon that confines it, passes through the town of Creede via a concrete-lined channel and then traverses a broad floodplain before discharging into the Rio Grande.

A single tributary (Windy Gulch – Station WNG-A) enters the creek just north of Creede and creek flow is periodically diverted into the Wason Ditch at station WSN.

Other than a station located on the tributary and diversion, three stations were used in 2010 to monitor conditions in this segment of Willow Creek. These include W-C located just before the creek enters the concrete-lined channel and W-I and W-J which monitor condition in two distributary channels that discharge to the Rio Grande (Figures 3-8 through 3-13).

During April 2010, a small flow and zinc load entered the creek from Windy Gulch. This increment of load was less than 5% of the total load conveyed by the creek at this location. A decline in zinc concentration was measured between stations W-A and W-C resulting in about a 15% decrease in zinc load (despite an increase in flow).

Farther downstream, a diversion of 5.6 cfs from Willow Creek into Wason Ditch was occurring at the time of the April 2010 sampling. This diversion contained 29% of the flow and 38% of the zinc load measured at the nearest upstream station (W-C).

Beyond the Wason diversion, flows discharge into the Rio Grande. At stations W-I and W-J, cumulative zinc load in April (including the diversion at Wason Ditch) is 67% higher than measured at W-C and 338% higher that the Nelson Tunnel portal discharge. Additional load observed between W-C and the Rio Grande is due to a slight increase in concentration coupled with an increase in flow.

Nearly identical zinc load increases were measured during June 2010. However, during September 2010, no increase in zinc load was observed between W-C and the Rio Grande. In addition, the cumulative zinc load reporting to the Rio Grande (including the diversion at Wason Ditch) was identical to that measured at the Nelson Tunnel portal.

The additional zinc load observed in this reach of Willow Creek during April and June may originate from:

- Mobilization of dissolved metals from the consolidated Emperious Tailings shown on Figures 3-8 through 3-13.
- Undifferentiated mine wastes in the floodplain below station W-C may be releasing dissolved metals.
- Contaminated subsurface flows originating above station W-C that ultimately discharge to the channel.

There is some evidence to suggest that the Emperious Tailings are contributing metal load to alluvial groundwater (WCRC, 2004b) that ultimately discharges (in whole or in part) to Willow Creek. Station W-J monitors the eastern of the two distributary channels, and it is the eastern channel that is most likely to be recharged by groundwater influenced by the Emperious Tailing.

During 2010, the concentration of zinc and cadmium was higher at Station W-J than at W-I. The difference was most pronounced in June when the zinc concentration was 958 ug/L and 2,230 ug/L at W-I and W-J, respectively.

3.9 CONTRIBUTION OF NELSON TUNNEL TO METAL LOADS IN WILLOW CREEK

The Nelson Tunnel is the major known point source for metal load, particularly cadmium and zinc, to the Willow Creek watershed based on data from 1999-2010. The contribution of metals load from the Nelson Tunnel to Willow Creek for 2010 is described in Sections 3.8.3 through 3.8.5. All available data (from 1999-2010) is considered here to provide the historic range of Nelson Tunnel load contribution to the watershed. The contribution of the Nelson Tunnel to metal load in Willow Creek was calculated by the ratio of Nelson Tunnel load to the highest load recorded in Willow Creek for the same sampling event (station below WW-NT with the highest measured cadmium or zinc load).

In periods of the year when low flows are observed (August – mid May), the Nelson Tunnel contributes approximately 11-48% and 22-78% of the highest load of cadmium and zinc, respectively, measured in Willow Creek. Lowest percentages were observed during April 2010, the only year when measurements were made in April.

During high-runoff periods (mid-May – July), the Nelson Tunnel contributes between 19-39% and 30-55% of cadmium and zinc, respectively.

The relationship between runoff and the contribution of Nelson Tunnel discharge to overall metals loads in the watershed is illustrated on Figure 3-18. In this figure the flow at station W-A during May or June is plotted against the ratio of Nelson Tunnel zinc load to the maximum load measured in the watershed at that time. Station W-A was selected as an indicator of the relative magnitude of annual flows, however, any station low in the watershed could be substituted. Although the flow measurements are presented for May/June, they include several years where the May measurement represented a low flow condition (likely pre-runoff).

A review of the figure reveals an inverse relationship between flow in Willow Creek and the fraction of zinc load originating from the Nelson Tunnel. This is not unexpected as remaining sources for zinc load in the watershed will leach zinc into surface water generally as a function of snowmelt and other precipitation.

3.10 EFFECT OF COMMODORE WASTE ROCK REMOVAL ACTION ON WILLOW CREEK WATER QUALITY

As discussed previously, the Commodore Waste Rock pile was recontoured to create a stable geometry and to remove mine waste from the West Willow Creek channel. It is expected that this removal action, completed in 2009 would, among other things, reduce metal loading to the creek. However, it may be several years before the recently disturbed mine waste reaches an equilibrium condition with respect to releases of dissolved metals.

Although unlikely that this equilibrium condition had been reached as of the last high runoff sampling event (June 2010), available surface water quality data were examined to determine if a trend was apparent.

Temporal trends in zinc concentration and loads were examined using all spring (May-June) data collected at Station W-A (Figure 3-19) to discern any meaningful decline in the past year. A review of the figure reveals that, as expected, there is insufficient post removal action data to resolve a meaningful trend.

3.11 WATER QUALITY IN THE RIO GRANDE

Segment 4 of the Rio Grande, extending just above the confluence with Willow Creek to the Rio Grande/Alamosa County line, is currently listed on Colorado’s 303 (d) list of impaired waters (Figure 3-7).

As shown in Table 3-3, the State has classified Segment 4 of the Rio Grande as:

- Agriculture
- Aquatic Life Cold
- Recreation E
- Water Supply

The Rio Grande currently exceeds cadmium and zinc standards in Segment 4 and is regulated under temporary modifications. Temporary modification of TVS for arsenic, cadmium, copper, lead, and zinc are set at existing quality until December 2012 when they will be reviewed by the Colorado Water Quality Control Commission.

Willow Creek contributes the majority of cadmium and zinc load to Segment 4 of the Rio Grande. Upstream of the confluence with Willow Creek, the Rio Grande achieves standards underlying temporary modifications for the same water use classifications. Downstream of Willow Creek, the Rio Grande almost continuously exceeds cadmium and zinc TVS with the exception of cadmium in June as shown on Figures 3-20 and 3-21 (CDPHE, 2010).

3.12 CONTRIBUTION OF NELSON TUNNEL TO METAL LOADS IN THE RIO GRANDE

Minimal data is available on Rio Grande metal load and flow near the junction with Willow Creek. Few sampling events measured Rio Grande and Willow Creek watershed load and flow on or about the same day. Because of the lack of correlating measurements, the precise fraction of metal load in the Rio Grande originating from Willow Creek is unknown. Additionally, the load contribution from the Nelson Tunnel portal to the Rio Grande cannot be accurately calculated using available data. However, it can be assumed to not exceed the contribution to load in Willow Creek and the contribution of Willow Creek to the Rio Grande for both cadmium and zinc.

Metal load in Willow Creek originating from the Nelson Tunnel has been previously described in Section 3.8. Given the lack of concentration and flow data for the Rio Grande collected for the RI, estimates of metal load in the Rio Grande originating from Willow Creek were taken from the Total Maximum Daily Load (TMDL) Assessment for the Rio Grande (CDPHE, 2010) provided in Appendix B. Pages 24 and 25 of the TMDL assessment describe the Willow Creek cadmium and zinc load at Creede as a percent of the load in Segment 4 of the Rio Grande for each month of the year.

The TMDL Assessment reports that the cadmium and zinc load in Willow Creek constituted 58 - 168% and 46 - 252%, respectively, of the load in the Rio Grande. These percentages are highest during high flow periods (CDPHE, 2010).

The conclusion in the TMDL assessment that Willow Creek contributes more than 100% of the metal load in the Rio Grande at certain times is likely due to the following:

- The metal load in Willow Creek is measured at a USGS gauging station (C0RGR07) described as "at Creede" and is some distance upstream of the confluence with the Rio Grande. Therefore, metal load estimates at this location may not be representative of actual metal load discharging to the Rio Grande.
- Metal load sinks below the USGS gauging station may include diversions at Wason Ditch, temporary storage of creek water in adjacent alluvium and geochemical changes resulting in precipitation/sorption (fixation) of dissolved metals before discharge to the Rio Grande.

Nelson Tunnel metal load as a percent of Rio Grande metal load was calculated by combining the following percentages:

- Nelson Tunnel metal load as a percent of Willow Creek load
- Willow Creek metal load as a percent of Rio Grande load

The range of possible Nelson Tunnel metal loads as a percent of load in the Rio Grande was calculated as follows and converted to a percentage:

$$\frac{NT}{RG} = \left(\frac{NT}{WC}\right) \times \left(\frac{WC}{RG}\right) \qquad \text{(Equation 3-3)}$$

Where:

NT – Nelson Tunnel metal load
RG – Rio Grande metal load
WC – Willow Creek metal load

Minimum and maximum possible contributions were calculated using the above equation. Because Willow Creek cannot contribute more than 100% of load to the Rio Grande (such as is reported in the TMDL Assessment for high flow periods), calculations were performed using a maximum contribution of 100%. The combination of these percentages indicates that the Nelson Tunnel may contribute between 6-48% and 10-78% of respective cadmium and zinc loads in Rio Grande Segment 4. Lowest percentages were based on April 2010 measurements.

4.0 BASELINE RISK ASSESSMENT

4.1 INTRODUCTION

A Baseline Human Health Risk Assessment (HHRA) was conducted to determine whether Site contaminants pose a current or potential future risk to human health in the absence of any remedial action. A Baseline Ecological Risk Assessment (TechLaw, 2011c) was performed to assess ecological risks. Assessment of risks to human health and the environment were subject to the following limitations:

- Evaluation of human health risks is limited to recreational exposure to mine wastes associated with the Commodore Waste Rock pile, contaminants in CR-503 on and near the Site and any surface water within the limits of the Commodore Waste Rock pile.
- Evaluation of ecological risks included terrestrial receptor exposure to Commodore Waste Rock and aquatic receptors in Willow Creek and the Rio Grande.

4.2 RISKS TO HUMANS

The purpose of the HHRA is to quantify human health risks associated with potential exposures to Site-related contaminants under current and reasonably foreseeable future land use conditions, in the absence of any remedial actions. Results of the assessment are intended to help risk managers determine if there is a need for action at the Site.

The HHRA was performed using EPA guidance for risk assessment, as described in the Risk Assessment Guidance for Superfund document (EPA, 1989).

4.2.1 Site Characterization

4.2.1.1 Introduction

The Site is limited to the abandoned Nelson Tunnel, which drains directly into West Willow Creek, and Commodore Waste Rock pile surrounding the Nelson Tunnel portal (see Figure 1-2). As discussed in Section 3.0, both the Commodore Waste Rock pile and Nelson Tunnel discharge have been impacted by heavy metal contamination as a result of mining activities and environmental processes.

The Nelson Tunnel system provided both haulage and drainage for mines developed in the Willow Creek Watershed and the portal has been found to be the largest single source of contamination in Willow Creek. The Commodore Waste Rock pile is comprised of mine wastes from the Commodore and Nelson Tunnel workings, deposited between 1890 and 1960. The pile is comprised of barren and mineralized rock containing metals such as lead, cadmium, copper, and zinc. Minerals found in waste rock include metallic sulfides dominated by pyrite.

4.2.1.2 Data Summary

Table 4-1 summarizes all data considered in the HHRA. On-Site exposure is limited to contact with mine wastes associated with the Commodore Waste Rock pile, soil and dust from CR-503, and surface water within the Site limits. Sampling of relevant media was conducted in June 2010 to characterize metal concentrations in Commodore Waste Rock and to evaluate the extent of metals contamination in the Willow Creek watershed. Soil and surface water samples were collected. No sediment was present within the Site boundaries at the time of sampling thus sediments are not considered in this HHRA.

Waste rock soil sampling locations are shown in Figure 3-1 and surface water sampling locations are shown in Figure 2-2. Constituents detected in each medium are summarized in Tables 4-2 and 4-3. Included in the tables is a summary of the total number of samples collected, frequency of detection, range of detection/quantitation limits, and range of detected concentrations for each constituent detected.

In October 2010, soil sampling of CR-503 was conducted to evaluate the extent of metals contamination in road base between the town of Creede and the CR-504 junction (see Figure 3-4). As noted previously, portions of CR-503 traverse the Site. Samples of road base materials were collected to support estimation of human heath risks posed by inhalation of road base materials mobilized into air by wind and vehicle traffic. Table 4-4 summarizes the occurrence of constituents detected in the October 2010 sampling of CR-503.

In addition to soil and surface water sampling, activity based air sampling (ABS) involving ATV riding and placement of stationary air samplers along CR-503 was conducted in June 2010. Results of air sampling are summarized in Table 4-5. The purpose of this sampling was to provide data on particulate levels generated during mechanical and wind disturbances along CR-503, a small portion of which is located within the Site. Three samples were collected over one-hour time periods while ATV riding along CR-503. The primary portion of CR-503 traversed during the sampling is shown in Figure 3-4.

Descriptions of the routes covered for each specific sample collected are as follows:

- <u>Sample 93853</u> - Starting near soil sampling location CR-503-3, riding south to approximately 1,000 feet past soil sampling location CR-503-1 and then turning around and heading north to the Amethyst Mine turnaround area (near soil sampling location CR-503-7) with the remainder of the hour spent driving between soil sampling location CR-503-3 and approximately 500 feet south of soil sampling location CR-503-1.
- <u>Sample 92721</u> - Starting near soil sampling location CR-503-1, riding north to CR-503-14 and then turning around and riding the remainder of the hour between soil sampling location CR-503-1 and the Commodore Waste Rock pile parking area.

- Sample 92257 - Starting north of Creede, riding to the Amethyst Mine turnaround area and then riding the remainder of the hour between soil sampling locations CR-503-1 and the Commodore Waste Rock pile parking area.

During collection of sample 92721, it was noted by the sampling team that two earth graders were leveling the road, causing noticeable fine particulates to be exposed on the road surface. In addition, 10 vehicles passed by the ATVs while collecting this air sample (TechLaw, 2011a).

Three stationary air samplers were set up along CR-503 leading to the Commodore Waste Rock pile to represent conditions absent of human/mechanical disturbances. Specific sampling locations are shown in Figure 3-4.

4.2.2 Exposure Assessment

The exposure assessment objective is to estimate the type and magnitude of possible exposures to Chemical of Potential Concern (COPCs) that have been detected at, or migrating from, a given site. Consideration of appropriate Site-specific exposure scenarios provides the basis for analyzing risks.

Figure 4-1 presents a Site Conceptual Exposure Model (SCEM) with recognized potential source areas, release mechanisms, exposure routes, and likely receptors for Site contamination based on data currently available. A description of each of these aspects of the SCEM is presented in the following subsections.

4.2.2.1 Potential Source Areas

Primary sources of contamination include contaminants in CR-503 (on and near the Site), Nelson Tunnel discharge into West Willow Creek and the adjacent Commodore Waste Rock pile. Note that West Willow Creek is identified in 4-1 as the potential source area rather than the Nelson Tunnel portal as exposure at the collapsed portal is unlikely due to unstable slopes.

4.2.2.2 Release Mechanisms and Potentially Impacted Media

Various release mechanisms from contaminant source areas that are likely to occur at the Site and the potentially impacted media are outlined in Figure 4-1. Contaminant transport pathways that have been identified are surface water runoff and acid rock drainage, infiltration/percolation, and wind and human disturbances. Potentially impacted media from these release mechanisms are described as follows.

<u>Surface Water</u>
Approximately 300 gpm of water contaminated with heavy metals flows from the Nelson Tunnel portal into West Willow Creek. Leaching from the Commodore Waste Rock pile may contribute to contamination of the Creek. Sulfide minerals in waste rock react with infiltrating precipitation and oxygen to form sulfuric acid, which increases the ability of infiltrating rain, snowmelt and

surface water to leach metals from waste rock. This "Acid Rock Drainage" can cause any leachate that discharges from the waste rock pile to have a low pH and an elevated metals concentration, which is then transported in the environment via free flowing or otherwise migrating water.

Sediment

Sediments are not considered in this assessment as no sediment was present within the Site boundaries at the time of the 2010 sampling. As part of a time critical removal action involving stabilization of waste rock material at the Site, the waste rock pile was reworked in 2008 and 2009 to reduce erosion and a new channel was constructed to slow the flow of West Willow Creek, especially during flooding and high runoff periods. An armored channel was constructed after placing a liner and rip rap in the channel. Portions of the rip rap were grouted to keep water from seeping through. A photograph of a portion of the constructed channel is provided as Figure 3-3.

Groundwater

The scope of this RI excludes study of groundwater in host rock or alluvium within the NPL Site boundaries. However, the leaching of metals from waste rock by infiltrating precipitation is addressed via the surface water pathways under consideration. In addition, water flowing in the Nelson Tunnel and discharging from the portal have been characterized. Flows in the Nelson Tunnel originate primarily from groundwater in the surrounding host rock.

The likelihood of groundwater use in and near the residential and commercial areas of Creede was assessed as a part of this RI. The assessment was limited to a review of a private water well survey (Kirkham, 2003) and contact with the Colorado State Engineer's office to determine if any new wells had been permitted since 2003.

Based on the work done by Kirkham and Colorado State Engineer's records (Naugle, personal communication, 2011), no permitted groundwater wells exist in the developed portion of Creede.

In addition, Creede provides municipal water sourced from wells proximal to the Rio Grande.

Waste Rock / Soil

Direct contact of waste rock and soil in the Commodore Waste Rock pile and road base from CR-503 is possible.

Dust

Contaminated dust can be generated from mobilized particulates. Wind is a potentially effective release/transport mechanism for contaminants present in small particles within the waste rock pile due to the limited vegetation. Human disturbance from activities such as ATV riding on CR-503 could also release particulates into the air.

4.2.2.3 Potential Receptors

The Commodore Waste Rock pile is currently fenced and access is not allowed to the public. However, access to CR-503 within the Site boundary is not restricted and it is possible for recreational visitors in the surrounding area to trespass on the waste rock. Community interviews indicate rock hunting is the primary recreational activity undertaken in the Site vicinity and occurs just below the Commodore Mine (EPA, 2008b). Other activities mentioned in the survey included hikers (people walking dogs); mountain bikes, ATVs, and other motorists using the Bachelor Loop Road (CR-503); people snow shoeing and cross country skiing; and some wading. Survey respondents indicated that fishing activities in the area occur upstream of the Site.

Based on available information and responses from community interviews, there is no indication that young children (less than 6 years of age) access the Site. Therefore, it is assumed that people who visit the Site are mainly adults and older children/adolescents (ages 6 -12 years old). For the purposes of this assessment, two scenarios have been selected to serve as representative activities of recreational Site visitors.

Adult and Child Rock Hunters - The rock hunter is selected to represent a typical Site exposure. This population is assumed to include adults and older children (ages 6 to 12) who pass across the Site while rock hunting and hiking in the area.

Adult and Child ATV Riders - ATV riders on CR-503 are selected to represent a high impact exposure because ATV riding by adults and older children (ages 6 to 12) is likely to result in higher than average exposures from inhalation of dust particles released into air by the riding activity. County Road 503 runs adjacent to the Site with a small segment of the road located within the Site boundary (Figure 1-2).

4.2.2.4 Routes of Exposure

There are several potential pathways that could result in human exposure to Site contaminants. This analysis is conservative since the Commodore Waste Rock pile is currently fenced and access is not allowed to the public thus, actual exposures may be more limited than assumed herein.

Incidental Ingestion of Waste Rock / Soil

Recreational visitor populations considered in this assessment could have direct contact with Commodore Waste Rock. It is possible these Site users will incidentally ingest fine fractions from degradation of waste rock and underlying soil that adheres to their hands during outdoor activities and thus this pathway could be a significant route of human exposure.

Inhalation of Airborne Soil Particles

Contaminated soil can become suspended in air by wind or mechanical disturbances such as ATV riding and Site users could inhale those particles. Therefore, this pathway will be evaluated for both recreational visitor populations.

Ingestion of Surface Water

The rock hunter population considered in this assessment could have direct contact with surface water if they wade in or otherwise engage in activities along West Willow Creek. It is not expected that such users would use the water for drinking but incidental ingestion might occur and will be evaluated for the rock hunter population.

Dermal Contact with Waste Rock

Although recreational users could have dermal exposure to Commodore Waste Rock and CR-503, this pathway is considered minor in comparison to the amount of exposure that could occur through the oral and inhalation routes. Metals have a relatively low tendency to cross the skin even when contact does occur. Further, the EPA's IEUBK Model and Adult Lead Model do not include dermal absorption as it is not considered a significant pathway for inorganic lead. Therefore, dermal contact with Site waste rock and CR-503 soil will not be evaluated quantitatively but will be identified as a potential source of uncertainty.

Dermal Contact with Surface Water

Recreational visitors could have dermal contact with surface water while along or in West Willow Creek. Similar to dermal contact with soils, uptake of metals across the skin from contact with water is considered a minor exposure pathway due to the relatively low tendency of metals to cross the skin. As such, dermal contact with Site surface water will not be evaluated quantitatively but will be identified as a potential source of uncertainty.

4.2.2.5 Selection of Chemicals of Potential Concern

Chemicals of potential concern are chemicals which exist in the environment at concentration levels that might be of potential health concern to humans and which are or might be derived, at least in part, from Site-related sources. A chemical may be excluded from the risk assessment as a COPC if it meets one of the following two requirements:

- The maximum detected concentration of that chemical in a given medium is less than its applicable screening value.
- The chemical is recognized by EPA as an essential human nutrient, is present at low concentrations, and is toxic only at very high doses.

EPA (1989) recognizes magnesium, calcium, potassium, and sodium as essential nutrients that may be evaluated and justified for exclusion from the quantitative risk assessment based on consideration of concentration and toxicity.

Soil COPCs from Commodore Waste Rock and from CR-503 (which could be traveled on by ATV riders traversing near and/or directly through the Site) were selected based on comparison of the maximum detected concentration for each chemical to Site-specific Risk-Based Concentrations (RBCs). If the maximum detected concentration does not exceed the RBC, it may be concluded that the chemical does not pose a significant risk to humans, including maximally exposed individuals. Risk-based concentrations were calculated for both the ATV Rider and Rock Hunter populations based on exposure assumptions summarized in Table 4-6. Detailed calculations are included in Appendix C.

Selected waste rock soil COPCs are summarized in Table 4-7 and CR-503 road base soil COPCs are summarized in Table 4-8. Thallium was the only chemical for which an RBC could not be calculated because toxicity data are not available. Thallium is not considered a Site-related concern and was therefore not retained as a COPC.

Surface water COPCs were selected based on comparison of the maximum detected concentration for each chemical to EPA Regional Screening Values for Tap Water (EPA, 2010a). Surface water COPCs are summarized in Table 4-9.

Air sampling data for the HHRA is limited to three samples collected while ATV riding along CR-503 and three stationary samples placed on CR-503 leading to the waste rock pile. Sampling was conducted during ATV riding to simulate conditions relevant to the ATV exposure scenario and stationary samples were collected to represent conditions absent of mechanical disturbances. Samples collected were only analyzed for arsenic, cadmium, lead, manganese, and zinc.

4.2.3 Quantification of Exposure

Exposure is quantified by determining exposure point concentrations (EPCs) and conservative receptor-specific exposure parameters and then calculating intakes. These steps are described in the following subsections.

4.2.3.1 Exposure Point Concentrations

The EPC is a conservative estimate of the average chemical concentration in each environmental medium and is used in the calculation of estimated intake. Exposure point concentrations for COPCs in each media were determined for all receptors (see Table 4-10).

<u>Rock Hunter</u>
The rock hunter receptor consists of adults and older children who pass across the Site while rock hunting and hiking in the area. Routes of exposure are:

- Incidental ingestion of waste rock and underlying soil.
- Inhalation of contaminated windborne particulates.
- Incidental ingestion of surface water from wading or otherwise engaging in activities along West Willow Creek.

Since the true arithmetic mean concentration cannot be calculated with certainty from a limited number of measurements, the EPA recommends that the upper 95th percentile confidence limit (UCL) of the arithmetic mean at each exposure point be used when calculating exposure and risk at that location.

EPA's ProUCL software, Version 4.00.05 (EPA, 2010b) was used to estimate UCL95 values for soil COPCs from waste rock sampling. ProUCL calculates UCLs for a range of distributions of data and recommends the most appropriate UCL based on the best fit to a distribution. The recommended value from ProUCL was used as the UCL95. Detailed results from ProUCL are included in Appendix D.

Stationary air sampling conducted along CR-503 was used for evaluating rock hunter inhalation. Only lead and zinc were detected in stationary air samples. A UCL95 should only be estimated if there are at least 10 samples. With only three stationary air samples, the maximum detected values for lead and zinc are used as EPCs.

For arsenic, cadmium, and manganese the analytical detection limits from the air sampling are too great to eliminate any of these as COPCs in air. Rock hunter air EPCs for the COPCs not detected (arsenic, cadmium, manganese) and for chromium (which is a COPC that was not included in the air analysis) were estimated based on the concentration in waste rock soil for these COPCs multiplied by a particulate emission factor[1] (PEF). The EPA default PEF for wind erosion was used.

For surface water (with only two samples), the maximum detected value is used as the EPC.

ATV Rider

For adults and older children ATV riding along CR-503, exposure consists of ingestion of soil from CR-503 and inhalation of particulates from road base materials mobilized into the air by wind and vehicle traffic. There is no identifiable trend or pattern in the detection of COPCs in CR-503 samples. As shown in Table 4-4, the location of maximum detection varies for the different metals analyzed across nearly the entire length of road. This indicates that the composition of metals in the road base is fairly consistent across the road segment included in the sampling. Thherefore, the UCL95 for soil COPCs from the full length of CR-503 sampled are used as the soil ingestion EPCs for ATV receptors.

Results of air sampling conducted while ATV riding are used for evaluating inhalation. With only three ATV air samples, the maximum detected values are used as EPCs. Similar to stationary samples, arsenic and cadmium were not detected in the air sampling but the analytical detection limits are too great to eliminate these as COPCs in air. Air EPCs for the COPCs not

[1] The PEF is the soil to air emission factor and provides a means for estimating the contaminant levels in air due to re-suspended soil particles. Concentration in air (mg/m^3) = Concentration in soil (mg/kg) / PEF (m^3/kg)

detected and for chromium (which was not included in the air analysis) were estimated based on the concentration in soil from CR-503 for these COPCs multiplied by a PEF. The PEF was estimated based on air data from the ATV riding coupled with soil data from the segment of CR-503 traveled during the air sampling (see Appendix E).

4.2.3.2 Exposure Parameters

Exposure parameters are the variables that make up the exposure equation(s). They can be receptor or chemical-specific, or general and not vary by receptor or chemical. There are high end or upper-bound exposure parameters referred to as reasonable maximum exposure (RME) parameters (EPA, 1989), and there are average or central tendency exposure (CTE) parameters. The RME parameters represent the highest level, but not worst case, for which receptors would reasonably be expected to be exposed. The CTE parameters represent exposure for the average receptor.

The SCEM (see Figure 4-1) identifies adult and child ATV riders and adult and child rock hunters/hikers as the potentially exposed populations to Site contamination. As indicated in the SCEM, completed exposure pathways for these populations warranting quantitative evaluation are ingestion of surface water, ingestion of surface soil, and inhalation of particulates. Tables 4-11 thru 4-14 summarize the CTE and RME exposure parameters for the adult and child populations of concern.

Although community interviews indicate ATV riding and rock hunting/hiking are the primary recreational activities in the Site vicinity, interviews do not detail frequency and duration of such Site visits. Therefore, many selected exposure parameters have been extrapolated from exposure assumptions applied in the Baseline Risk Assessment conducted for the Standard Mine Site in Gunnison County, Colorado (SRC, 2008).

Activities of ATV riders and rock hunter/hikers for this Site are similar in nature to activities evaluated for the Standard Mine in Crested Butte, Colorado (SRC, 2008). Exposure durations and frequencies for these populations at the Standard Mine are considered conservative estimates of exposures likely to occur within the Site. Responses to interviews conducted for the Standard Mine indicate that the majority of people visit that site less than 20 times per year. It is reasonable to conclude that visits to the Site will not occur any more frequently than this, particularly since Site accessibility is limited by fencing. As outlined in the Standard Mine risk assessment, an exposure frequency of 20 times per year corresponds to four, two-day weekend trips and two, six-day visits per year. For CTE receptors, the population-weighted average duration of six days/year was selected for the Standard Mine based on the interview responses. This is considered a reasonable estimate of average Site visits.

4.2.3.3 Quantification of Ingestion Exposure

The Human Intake Factor (HIF) is used to represent the average amount of an environmental medium ingested by an exposed person in a day. The equation for calculating the HIF is as follows:

$$\text{Human Intake Factor} = \frac{IR*EF*ED}{BW*AT}$$

Where:

IR = Ingestion rate (mg soil/day) or (L water/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

BW = Body weight (kg)

AT = Averaging time[2] (days)

Units for the HIF are kg/kg-day for soil ingestion, and L/kg-day for surface water ingestion. The resultant HIFs used in the HHRA calculations are included in Tables 4-11 and 4-12 for the adult and child ATV Riders, respectively, and Tables 4-13 and 4-14 for the adult and child Rock Hunter receptors, respectively.

Ingestion exposure estimates are derived in terms of a chronic daily intake using the following general equation:

$$DI = C * HIF * RBA$$

Where:

DI = Daily intake (mg per kg of body weight per day)

C = concentration in environmental medium (mg/kg for soil; mg/L for surface water)

HIF = Human Intake Factor (kg/kg-day for soil; L/kg-day for surface water)

RBA = Relative bioavailability (bioavailability is assumed to be 100% for all metals except arsenic, which was assumed to be 50%).

4.2.3.4 Quantification of Inhalation Exposure

The EPA Superfund Program has updated its inhalation risk methodology (*Risk Assessment Guidance for Superfund (RAGS), Part F*, EPA, 2009a) to be consistent with EPA's *Inhalation*

[2] Length of time over which the average dose is calculated. For noncarcinogens, the averaging time is equal to the exposure duration. For carcinogens, the averaging time is 70 years.

Dosimetry Methodology[3], which represents EPA's current approach for inhalation dosimetry and derivation of inhalation toxicity criteria.

RAGS Part F currently recommends that when estimating risk via inhalation, risk assessors use the concentration of the chemical in air as the exposure metric (e.g., mg/m^3), rather than inhalation intake of a contaminant in air based on IR [intake rate] and BW [body weight] (e.g., mg/kg-day as described in EPA 1989). Therefore, the intake equation described in Section 4.2.3.3 for quantification of ingestion exposure is not consistent with the principles of EPA's *Inhalation Dosimetry Methodology* and cannot be used to quantify inhalation exposures. Instead, for chronic exposures, the inhalation exposure concentration is calculated based on the concentration of the contaminant in air multiplied by the time-weighting factor of the exposure.

EC = C * TWF

TWF = [(ET * EF * ED) / (AT * CF)]

Where:

EC = Exposure concentration (time-weighted based on exposure scenario) ($\mu g/m^3$).

C = Concentration in air ($\mu g/m^3$)

TWF = Time-weighting factor (unitless)

ET = Exposure time (hours/day)

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

AT = Averaging time[4] (days)

CF = Conversion factor (24 hours/day)

The resultant TWFs used in the HHRA calculations are included in Tables 4-11 and 4-12 for the adult and child ATV Riders, respectively, and Tables 4-13 and 4-14 for the adult and child Rock Hunter receptors, respectively.

4.2.4 Toxicity Assessment

The toxicity assessment identifies toxicity values which describe the relationship between daily intake and potential for a health effect. Toxicological effects fall into two categories: 1) effects that could potentially cause cancer (carcinogens), and 2) effects that could cause other types of

[3] http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=71993

[4] Length of time over which the average dose is calculated. For noncarcinogens, the averaging time is equal to the exposure duration. For carcinogens, the averaging time is 70 years.

adverse health effects (noncarcinogens). Table 4-15 summarizes the toxicity values used for evaluation of human health risks from COPCs at this Site. Values were taken from the EPA Regional Screening Table (EPA, 2010a), which follows the hierarchy of human health toxicity values recommended in OSWER Directive 9285.7-53, issued by EPA's Office of Solid Waste and Emergency Response on December 5, 2003.

The toxicity values pertinent to the risk assessment are oral reference dose ("RfD"), inhalation reference concentration ("RfC"), oral slope factor ("SF"), and inhalation unit risk factor ("IUR").

4.2.5 Risk Characterization

4.2.5.1 Estimation of Risk

The final step of a risk assessment is risk characterization. This involves combining exposure quantities and toxicity benchmarks to calculate excess lifetime cancer risks and non-cancer hazards for each pathway and receptor. Health risks associated with lead were also calculated. Results of quantitative cancer risk analysis and noncancer hazard analysis are presented in Tables 4-16 and 17 for the adult and child Rock Hunter receptors and in Table 4-18 and 4-19 for the adult and child ATV riders. Lead risks are summarized in Table 4-20 for the ATV Rider and Rock Hunter receptors.

<u>Quantification of Non-Cancer Effects</u>

For determining whether noncancer health effects may be a concern, the hazard quotient ("HQ") was calculated. The HQ is the noncancer average daily exposure intake (mg/kg-day) divided by the RfD (mg/kg-day):

For ingestion exposures, the potential for non-cancer effects is evaluated by comparing the estimated daily intake of the contaminant over a specific time period with the reference dose (RfD) for that chemical derived for a similar exposure period, as follows (EPA, 1989):

Ingestion Pathway
Hazard Quotient (HQ) = C * HIF/ RfD

Where:

HQ = Hazard Quotient (unitless)

C = Concentration (mg/kg $_{(soil)}$ or mg/L $_{(water)}$)

HIF = Human Intake Factor (kg/kg-d $_{(soil\ ingest)}$ or L/kg-d $_{(water\ ingest)}$)

RfD = Reference Dose (mg/kg-d) $_{(oral)}$

For inhalation exposures, the potential for non-cancer effects is evaluated by comparing the time-weighted exposure concentration (EC) over a specific time period to the appropriate inhalation reference concentration (RfC) for that chemical, as follows (EPA, 2009a):

Inhalation Pathway
Hazard Quotient (HQ) = EC / (RfC * CF)

Where:

HQ = Hazard Quotient (unitless)

EC = Exposure concentration (time-weighted based on exposure scenario) ($\mu g/m^3$)

RfC = Reference concentration (mg/m^3)

CF = Conversion factor (1000 μg/mg)

The total chronic hazard attributable to exposure to all COPCs through a single exposure pathway is known as a hazard index ("HI"). The HI is calculated as the sum of the hazard quotients for each COPC and assumes that health effects of various COPCs are additive. A receptor's cumulative hazard is the sum of hazards from each individual exposure pathway (cumulative hazard index from all scenario-specific exposure pathways is equal to the sum of the hazard index for each specific exposure pathway).

The cumulative HI is then compared with the EPA acceptable noncancer hazard level of 1 (EPA, 1989). If the HI is less than or equal to 1, then concentrations of COPCs are not likely to cause adverse health effects. A cumulative HI can exceed the target hazard level due to either (a) one or more COPCs with an HQ exceeding the target hazard level, or the summation of several COPC-specific HQs that are each less than the target hazard level.

Quantification of Cancer Effects

In the case of exposure to potential carcinogens, estimates of cancer risk are expressed as the lifetime probability of additional cancer risk associated with the given dose. Excess lifetime cancer risks (ELCR) were calculated for potentially carcinogenic COPCs using cancer slope factors and unit risk values obtained from EPA-approved sources. Cancer risk estimates were compared to an ELCR range of 10^{-6} (one in a million) to 10^{-4} (one in ten-thousand) as stipulated in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Cancer risks were summed for all constituents to obtain an estimate of cumulative cancer risk.

The excess risk of cancer from ingestion exposure was calculated as follows:

Ingestion Pathway
Cancer Risk = C * HIF * SF

Where:

C = Concentration (mg/kg $_{(soil)}$; or mg/L $_{(water)}$)

HIF = Human Intake Factor (kg/kg-d $_{(soil\ ingest)}$; or L/kg-d $_{(water\ ingest)}$)

SF = Cancer Slope Factor (mg/kg-d)$^{-1}$ $_{(oral)}$

The excess risk of cancer from inhalation exposure was calculated as follows:

Inhalation Pathway
Cancer Risk = EC * IUR

Where:

EC = Exposure concentration (time-weighted based on exposure scenario) (μg/m^3).

IUR = Inhalation unit risk (μg/m^3)$^{-1}$

Quantification of Lead Effects

Because even low concentrations of lead have been linked to subtle neurological effects in children, lead is regulated on blood lead concentration. The human population of chief concern is generally young children and pregnant women. The populations exposed at this Site include older children (ages 6-12) and adult rock hunters and older children (ages 6-12) and adult ATV riders. The fetus of a pregnant woman is the most sensitive receptor for lead effects for this assessment. It is assumed that exposure levels that are protective for a pregnant woman would also be protective for an older child (ages 6-12).

Risks associated with potential exposures to lead from incidental ingestion of Site soils, inhalation of airborne dusts, and incidental ingestion of surface water were evaluated using the EPA Adult Lead Model (EPA, 2003 and EPA, 2009b). The model provides estimates of blood lead levels that may result from exposures to lead in environmental media. Estimated blood lead levels are compared to a threshold blood lead level of 10 micrograms per deciliter (ug/dl), which is a multi-Agency goal that has been designated by the US Centers for Disease Control (CDC) and the ATSDR as a level of concern to protect sensitive populations, including neonates, infants, and children. USEPA indicates that 95% of the exposed population should have a blood lead level that does not exceed 10 ug/dl.

PbB(fetus) target = 10.0 ug/dL

As outlined in the EPA Adult Lead Model, available data suggest that the ratio of the blood lead level in a fetus to that of the mother is approximately 0.9. Thus, the blood lead level in a pregnant female that would correspond to a blood lead level of 10 ug/dL in the fetus is 11.1 ug/dL:

PbB(mother) = PbB(fetus) / Ratio = 10 ug/dL / 0.9 = 11.1 ug/dL

The model predicts the blood lead level in a person with a site-related lead exposure by summing the baseline blood lead level (PbB0) (that which would occur in the absence of any Site-related exposure) with the increment of blood lead that is expected as a result of increased exposure due to contact with lead in Site media. This is estimated by multiplying the average daily absorbed dose of lead from Site exposure by a biokenitic slope factor (BKSF). The equation used to estimate exposure to lead in Site media is:

PbB = PbB0 + BKSF * [(Csoil*IRsoil*AFsoil*EF + Cair*BR*ET *EF + Csw*IRsw*EF)/365]

Where:

PbB = Geometric mean blood lead concentration (ug/dL) in women of child-bearing age exposed at the Site

PbB0 = Background blood lead concentration (ug/dL) in women of child-bearing age absent Site exposure

BKSF = Biokinetic slope factor (ug/dL blood lead increase per ug/day lead absorbed)

Csoil/air/sw = Lead concentration in soil (ug/g), air (ug/m3), and surface water (ug/L)

IRsoil/air/sw = Intake rate of soil (g/day), air (m^3/day), and surface water (L/day)

AF = Absorption fraction

EF = Exposure frequency (days/year)

Once the geometric mean blood lead value in adult women is calculated, the full distribution of likely blood lead values in the population of exposed people is estimated assuming the distribution is lognormal with a specific individual geometric standard deviation (GSDi). The probability that a random member of the population will have a blood lead value exceeding 11.1 ug/dL (corresponding to a value of 10 ug/dL in the fetus) is then calculated using the equation for a lognormal distribution:

PbB(95th) = PbB (GM)*GSD^1.645

A summary of the lead model inputs is provided in Table 4-21.

4.2.5.2 Risks to Adult Rock Hunters

Non-carcinogenic and carcinogenic risks to adult Rock Hunters are summarized in Table 4-16 and lead risks are summarized in Table 4-20. Conclusions are as follows:

- Non-carcinogenic risks are below a level of concern for all contaminants for the CTE and RME populations.
- Carcinogenic risks do not exceed the EPA level of concern of 1E-04 for any contaminant, alone or in combination for either the CTE or RME population.
- The probability of a fetal blood lead concentration exceeding EPA's health based level of 10 ug/dL is very low (estimated P_{10} is <1%)

4.2.5.3 Risks to Child Rock Hunters

Non-carcinogenic and carcinogenic risks to child Rock Hunters are summarized in Table 4-17. Conclusions are as follows:

- Non-carcinogenic risks are below a level of concern for all contaminants for the CTE and RME populations.
- Carcinogenic risks do not exceed the EPA level of concern of 1E-04 for any contaminant, alone or in combination for either the CTE or RME population.

4.2.5.4 Risks to Adult ATV Riders

Non-carcinogenic and carcinogenic risks to adult ATV riders are summarized in Table 4-18 and lead risks are summarized in Table 4-20. Conclusions are as follows:

- Inhalation of manganese at the concentration detected from on-Site air sampling indicates non-carcinogenic risks above a level of concern for both the CTE and RME populations.
- Inhalation of arsenic at the estimated air concentration based on soil concentrations in CR-503 indicates non-carcinogenic risks above a level of concern for the RME population.
- Carcinogenic risks do not exceed the EPA level of concern of 1E-04 for any contaminant, alone or in combination for the CTE or RME population.
- The probability of a fetal blood lead concentration exceeding EPA's health based level of 10 ug/dL is 11% (P_{10} = 11%). This exceeds EPAs goal of $P_{10} \leq 5\%$.

4.2.5.5 Risks to Child ATV Riders

Non-carcinogenic and carcinogenic risks to child ATV riders are summarized in Table 4-19. Conclusions are as follows:

- Inhalation of manganese at the concentration detected from on-Site air sampling indicates non-carcinogenic risks above a level of concern for both the CTE and RME populations.
- Inhalation of arsenic at the estimated air concentration based on soil concentrations in CR-503 indicates non-carcinogenic risks above a level of concern for the RME population.
- Carcinogenic risks do not exceed the EPA level of concern of 1E-04 for any chemical, alone or in combination for the CTE or RME population.

4.2.6 Uncertainty Analysis

Quantitative evaluation of risks to humans from environmental contamination is frequently limited by uncertainty regarding a number of key data items. Possible factors that may contribute to uncertainty in the risk estimates include:

- Uncertainty in the adequacy of site characterization data
- Uncertainty in selection of COPCs
- Uncertainty in the toxicity criteria
- Uncertainty in the exposure assessment

These uncertainties are usually addressed by making assumptions or estimates based on whatever limited data are available. Because of these assumptions and estimates, the results of risk calculations are themselves uncertain, and it is important for risk managers and the public to keep this in mind when interpreting the results of a risk assessment. The following sections review the main sources of uncertainty in the risk calculations performed for this HHRA.

4.2.6.1 Uncertainty in Site Characterization Data

The method in which site data are collected can lead to an overestimation or an underestimation of site risks. Collection of samples from historically impacted areas can bias results and lead to a higher proportion of contaminated samples than would be obtained due to random sampling throughout the area. Thus, exposure and risk estimates are likely biased high.

The number of site samples in any given media also lends to uncertainty. Although numerous samples of waste rock and road base were collected, only limited air sampling was conducted, making characterization of this media more uncertain. In addition to a limited number of samples, not all site COPCs were included in the air sampling and for some COPCs included, detection limits from the analysis were too great to rule out the presence of these COPCs in air.

For the rock hunter receptor, two of three stationary air samplers for evaluating inhalation of contaminated particulates from waste rock pile were located outside the Site boundary. Therefore, these samples may not be fully indicative of on-Site conditions. For the ATV receptor, air sampling was conducted along only a portion of CR-503. The sampling included combined road segments within and outside of the Site boundary, making it difficult to differentiate between on- and off-Site impacts. There was no air sampling conducted which covered only off-Site portions of CR-503 thus it is also difficult to assess if detected concentrations from ATV sampling are from airborne particulates mobilized solely from road base or if there are other contributory sources (e.g., windborne particulates from the waste rock pile).

4.2.6.2 Uncertainty in Selection of COPCs

There is some uncertainty in the selection of COPCs. However, based on historic use of the Site, the available evidence indicates that the most probable COPCs were adequately identified and characterized.

All Site data were evaluated for potential toxicity relative to conservative screening levels thus uncertainty in COPC selection is unlikely to bias the risk characterization results, but including more analytes than necessary increases cumulative risk estimates.

4.2.6.3 Uncertainty in the Toxicity Criteria

In general, uncertainty in toxicity factors is one of the largest sources of uncertainty in risk estimates at a site. Because of the conservative methods USEPA uses in dealing with uncertainties, it is much more likely that the uncertainty will result in an overestimation rather than an underestimation of risk. The toxicity criteria used in the risk assessment were obtained from the EPA Regional Screening Table (EPA, 2010a), which includes sources from the most current toxicity research available, including IRIS and Provisional Peer Reviewed Toxicity Values. The toxicity criteria contain inherent uncertainties. While many have a strong basis in human epidemiological research (i.e., lead), others are not as well studied and the criteria are dependent primarily on animal studies. Toxicity of metals can also vary with the form (e.g., arsenite, arsenate), and where the more toxic form is likely to occur, the more stringent criterion was applied.

Another source of uncertainty with toxicity is in bioavailability. Bioavailability of most metals in soil was not considered or estimated (bioavailability was assumed to be 100% for all metals except arsenic, which was assumed to be 50%). It is expected that bioavailability of metals in Site-related media will be lower than bioavailability of metals in diets fed to laboratory animals (i.e., metals in diet are more toxic than metals adsorbed to soil particles). Therefore, toxicity data are more stringent than necessary. This may lead to a substantial overestimation of risk for some metals.

4.2.6.4 Uncertainty in the Exposure Assessment

Assumptions in the exposure assessment also contribute to the likelihood of biasing risk estimates high, particularly where professional judgment was necessary due to lack of Site-specific information. The exposure assessment proposed receptors, defined exposure areas, and estimated intakes. Many of the required exposure parameters are not known with certainty and were based on professional judgment and knowledge from other similar sites. This may lead to an overestimation of actual exposure and risk. For example, actual exposure frequencies and durations are likely more limited than assumed since the Site is restricted, making access difficult. Additionally, assumed ingestion and inhalation rates are very uncertain as data regarding intake rates for the populations considered in the HHRA are not available. Assumptions used in calculations are based on professional judgment, using data for residential exposures as a frame of reference. Thus, actual intakes may be either higher or lower than assumed.

4.2.6.5 Uncertainty in Exposure Point Concentrations

Conservative estimates were used to represent the EPCs. The UCL95 was used as the EPC for soil COPCs and maximum detected concentration was used for surface water and air COPCs. Soils data are of sufficient quantity that the UCL95 of the mean is only moderately larger than the sample mean for most COPCs so this source of uncertainty is relatively minor.

Estimated air EPCs for all receptors have a high degree of uncertainty. Only limited air sampling was conducted and much of it was conducted outside of the Site boundary. Additionally, not all COPCs were included in the analysis. The air EPCs for COPCs with high reporting limits and those not included in the air sampling were estimated by applying a site-specific PEF. The site-specific PEF was calculated from limited air data coupled with road data from the area covered by air sampling. This calculation assumes that road base is the sole source of detected contaminants in air. Potential contribution of airborne particulates from waste rock or any other potential sources in the vicinity of the road is not considered in the calculation. If there are other contributory sources for detected air concentrations besides metal contaminants from the road, then the calculated PEF is overestimated. This would result in overestimation of the air EPCs calculated using this PEF.

4.2.6.6 Uncertainty in Lead Model Predictions

The effect on blood lead from lead ingestion and inhalation is uncertain. The rate and extent of blood lead absorption is a highly complex physiological process, and can only be approximated by a mathematical model. Thus, the blood lead values predicted by the adult lead model should be understood to be uncertain.

In addition to uncertainties with the model, there is uncertainty in the target blood lead level for the fetus. Recent studies have demonstrated adverse neurodevelopment effects, such as lowered

IQ, at blood lead levels below the current CDC intervention level of 10 μg/dL (Canfield et al., 2003; Lanphear et al., 2000).

4.3 RISKS TO ECOLOGICAL RECEPTORS

4.3.1 Introduction

A Baseline Ecological Risk Assessment (BERA) was performed on the aquatic habitats potentially affected by the Site. This BERA was prepared by TechLaw, Inc. (2011c) after a Draft Screening-Level Ecological Risk Assessment (SLERA; HDR, 2010) identified the potential for ecological risks above a level of concern. The following is a summary of the BERA.

The major habitats affected by the Site consist of West Willow Creek, Willow Creek, and the Rio Grande. Samples used in the BERA were collected in 2010 on up to three separate occasions (depending on sample type) in April, June, and/or September to represent three distinct seasonal flow regimes in Willow Creek and the Rio Grande. The analytical data collected during these sampling events were not combined in order to quantify the exposures associated with each sample location and season.

The ecological risk management goal for this BERA is as follows:

"Ensure that acceptable risk levels are achieved for aquatic and aquatic-dependent receptors within the Site boundary and the receiving waters of the Rio Grande by protecting those receptors from the deleterious effects of exposures to Site-related contaminants."

4.3.2 Risk Analysis

The Conceptual Site Model (CSM) developed for the SLERA was re-evaluated to identify exposure pathways and receptors in the on- and off-Site aquatic habitats. The receptor groups of concern were benthic invertebrates, water column invertebrates, fish, aquatic insectivorous birds, piscivorous birds, omnivorous birds, and herbivorous mammals. Exposure routes included direct exposures in sediment and surface water by aquatic receptors (invertebrates and fish), and ingestion of contaminated surface water and food items (such as aquatic insects, plants, and fish) by wildlife receptors feeding in Willow Creek and the Rio Grande.

An assessment endpoint was selected for each receptor group of concern. It was not possible to directly quantify the risk to these assessment endpoints in all cases. Instead, different measurement endpoints were used, as follows.

- Compare Contaminant of Potential Environmental Concern (COPEC) levels in sediment and surface water samples to published sediment or surface water benchmarks.
- Expose juvenile rainbow trout for 96 hours in the laboratory to serial dilutions of Willow Creek surface water or undiluted Rio Grande surface water.

- Quantify the structure and function of the benthic invertebrate community in the Rio Grande based on a field survey.
- Use food chain modeling to calculate an Estimated Daily Dose (EDD) to the four wildlife receptor groups based on ingesting contaminated surface water and food items from Willow Creek and the Rio Grande; compare these EDDs to published wildlife Toxicity Reference Values (TRVs).

Specific Exposure Units (EUs) were defined for each assessment endpoint. The analytical data were then summarized per EU for use in exposure calculations. The EUs were based on the following Willow Creek sample locations (See Figure 2-2).

- WW-M: located above the Nelson Tunnel discharge confluence to Willow Creek (and above station WW-G shown on Figure 2-2); considered 'background' to the Tunnel influences.
- WW-NT: located at the Nelson Tunnel discharge before its confluence with West Willow Creek.
- WW-F: located in West Willow Creek just below the confluence with the Nelson Tunnel discharge.
- WW-E: located in West Willow Creek below WW-F.
- W-I: located at the end of the western braided channel of Willow Creek just before discharging into the Rio Grande.
- W-J: located at the end of the eastern braided channel of Willow Creek just before discharging into the Rio Grande.

Each sample location in the Rio Grande consisted of a transect running from bank to bank perpendicular to the river from which up to four, equally-spaced grab samples were collected (e.g., sample location RG-2 is comprised of samples RG-2-1, RG-2-2, RG-2-3, and RG-2-4). These sample locations are as follows:

- RG-2: located immediately above the confluence with Willow Creek (Figure 2-2); represents background conditions for the Rio Grande.
- RG-4: located at the Wason Ranch Bridge (Figure 2-2), 1.29 miles below the confluence with Willow Creek.
- RG-8: located at the Hwy 149 bridge (La Garita Bridge), 6.55 miles below the confluence with Willow Creek.
- RG-9: located at the 4UR Bridge, 7.78 miles below the confluence with Willow Creek.

Each EU had an associated “reference” location which was unaffected by the Mine but resembled the impacted EUs in all other respects. The reference EUs served to track the risks from local background conditions.

A COPEC-specific EPC was calculated at each EU in terms of a RME represented by the maximum concentration (or the one available concentration, if only a single sample was collected from a sample location per season, as was the case in Willow Creek) and the CTE represented by the arithmetic mean (if more than one sample was collected from a sample location per season, as was the case in the Rio Grande). All the data sets were too small to calculate 95^{th} percentile upper confidence limits of the means.

Where appropriate, the potential for ecological risk was determined using HQs. An HQ was calculated for each COPEC by dividing an exposure or dose by a corresponding toxicity value. Statistics were also used to determine the presence of risk in the rainbow trout toxicity tests and the benthic invertebrate community assessment.

The BERA presents HQs by:

- EU (i.e., the individual sample locations on Willow Creek and the Rio Grande)
- Season (April, June, and/or September 2010),
- Receptor (i.e., benthic invertebrate, aquatic invertebrate, fish, and four wildlife receptors),
- EPC (mean and/or maximum, depending on sample location), and toxicity measure (i.e., acute and chronic surface water benchmarks, no effect- and effect-based sediment benchmarks, and no effect- and effect-based bird or mammal TRVs).

Only the RME scenarios are presented below to allow for valid COPEC-specific risk comparisons across the two waterways for the same receptor group. Hence, the risk conclusions should be viewed as “worst-case” situations. The BERA also provided CTE scenarios, when available.

4.3.3 General Conclusions

4.3.3.1 Benthic Invertebrate Community

The potential for ecological risk to the benthic invertebrate community exposed to mine-related contamination was only assessed in the Rio Grande using two measurement endpoints:

- Compare COPEC levels in bulk sediment samples to sediment benchmarks.
- Measure the structure and function of the benthic invertebrate community based on a field survey.

The first measurement endpoint identified Cd, Pb, and Zn as major risk drivers in sediments from the Rio Grande, based on comparing metal concentrations to effect-based sediment benchmarks (known as Probable Effect Concentrations [PECs]). The risk associated with Cd and Zn both increased with distance from the confluence with Willow Creek, with the highest PEC HQs observed at RG-9, the most down-gradient location, while the risk for Pb remained relatively constant. The risk to the benthic invertebrate community in Willow Creek could not be quantified because sediment samples were not collected from this waterway.

The data from the benthic survey performed in the Rio Grande in September 2010 did not identify severe mine-related effects to the community at RG-4 and RG-8. Any impacts appeared to be relatively mild and included a potential shift towards scrapers at both RG-4 and RG-8 (presumably due to increased silting), a decreased number of mayfly taxa (but not mayfly numbers) at RG-4, and a decrease in the percent of intolerant taxa at RG-8. However, the major indicators of community health (e.g., EPT taxa richness and Shannon's Index) did not suggest that benthic invertebrates in the Rio Grande below the confluence with Willow Creek were systematically affected. The uncertainty associated with this conclusion was moderate however, because the benthic community data sets used in the statistical analyses were small (i.e., three replicates per sample location; three sample locations on the Rio Grande). The health of the benthic invertebrate community in Willow Creek was unknown because a benthic survey was not performed in this waterway.

The sediment chemistry Line of Evidence (LOE) showed a high potential for ecological risk to the benthic community in the Rio Grande below the confluence with Willow Creek. However, the benthic community survey LOE suggested that any mine-related risks were probably relatively minor. The survey should be given more weight in the risk decision-making process because it represented location-specific responses measured in benthic invertebrates exposed *in-situ* for long periods of time to mine-derived discharge. This conclusion was considered reliable because it was based on two independent LOEs, including a community survey.

4.3.3.2 Water Column Invertebrate Community

The potential for ecological risk to the water column invertebrates exposed to mine-related discharge was assessed for Willow Creek and the Rio Grande using one measurement endpoint, i.e., comparing the dissolved metal levels in surface water samples to acute and chronic benchmarks. Only the HQs derived from the (more conservative) chronic surface water benchmarks are summarized below, even though the BERA also provides the acute HQs.

This measurement endpoint identified Cd, Pb, and Zn as the main risk drivers in Willow Creek and the Rio Grande. Manganese (Mn) was only a risk driver in Willow Creek. Risks from Beryllium (Be), Iron (Fe), Selenium (Se), Strontium (Sr), and Vanadium (V) were specific to sample location WW-NT. Copper was identified as a stressor at sample locations WW-NT, WW-E, and W-J in Willow Creek, and at sample location RG-8 in the Rio Grande. The reliability of this conclusion was low because it was based on a single, semi-qualitative LOE. The potential risk associated with the four major contaminants is discussed below.

Cadmium

The chronic-based HQs (maximum exposure scenario) for Cd exceeded 1.0 at all the sample locations in Willow Creek and the Rio Grande, except for the background locations (Figure 4-2). These HQs ranged from 21.3 to 148.5 for Willow Creek and from 1.2 to 6.5 for the Rio Grande across the seasons. This LOE indicated severe impact from Cd to the water column community in Willow Creek, with less severe but still substantial impacts possible in the Rio Grande.

Lead

The Pb chronic-based HQs (maximum exposure scenario) exceeded 1.0 at all the sample locations in Willow Creek and the Rio Grande, except for the background locations and Rio Grande in September 2010 (Figure 4-3). These HQs ranged from 5.6 to 139.2 for Willow Creek and from <1 to 2.6 for the Rio Grande across the seasons. This LOE indicated severe impacts of Pb to the water column community at Willow Creek. The impact in the Rio Grande was relatively small in April and June and non-existent in September.

Zinc

The Zn chronic-based HQs (maximum exposure scenario) exceeded 1.0 at all the sample locations in Willow Creek and the Rio Grande, except for the background locations (Figure 4-4). These HQs ranged from 20.6 to 123.2 for Willow Creek and from 1.5 to 6.7 for the Rio Grande across the seasons. This LOE indicated severe impacts of Zn to the water column community at Willow Creek, with less severe but still substantial impacts possible in the Rio Grande.

Copper

The chronic-based HQs for Cu (maximum exposure scenario) slightly exceeded 1.0 at sample locations WW-NT, WW-E, W-J, and RG-8. The risk from Cu both in Willow Creek and the Rio Grande is minimal in April and June, and non-existent in the fall (Figure 4-5).

4.3.3.3 Fish

The potential for ecological risk to the fish community exposed to mine-related discharge was assessed in Willow Creek and the Rio Grande using two measurement endpoints:

- Compare dissolved metal levels in surface water samples to acute and chronic benchmarks.
- Assess 96-hr acute surface water toxicity using juvenile rainbow trout exposed to surface water from Willow Creek (diluted) and the Rio Grande (undiluted).

The first measurement endpoint identified Cd, Pb, and Zn as the main risk drivers in Willow Creek and the Rio Grande. Manganese was only identified as a risk driver in Willow Creek. Risks from Be, Fe, Se, Sr, and V were specific to sample location WW-NT. Copper was identified as a stressor at sample locations WW-NT, WW-E, and W-J in Willow Creek, and at sample location RG-8 in the Rio Grande. The reliability of this conclusion was low because it was based on a single, semi-qualitative LOE. The potential for risk to fish associated with the major contaminants was not repeated here since they were identical to those presented in the previous subsection for the surface water invertebrate community (same exposure route via surface water).

The second measurement endpoint showed that Willow Creek surface water was highly toxic to juvenile rainbow trout. Acute toxicity was only removed after the Willow Creek surface water was diluted down to 3.13% with uncontaminated water. Significant acute toxicity was observed at Rio Grande sample location RG-8 (75% survival in undiluted water), but not at RG-4 (95% survival in undiluted water), even though the latter was closer to the confluence with Willow Creek.

The available information was interpreted as follows:

- Weakly-diluted Willow Creek surface water was acutely toxic to juvenile rainbow trout.
- The flow of the Rio Grande below the confluence consisted of about 4% Willow Creek water at the time of sampling in September 2010.
- Acute toxicity in Willow Creek surface water was removed only when this surface water was diluted down to 3.13% of its original volume using uncontaminated water. This dilution was roughly similar to the one observed in the Rio Grande below the confluence in September.
- The average Cd and Zn levels measured in the non-toxic 3.13% serial dilution test water (diluted by RG-2 water) equaled 0.37 µg/L and 83.7 µg/L, respectively. The hardness-adjusted acute Water Quality Standard (WQS) for Cd and Zn equaled 0.67 µg/L and 57.3 µg/L, respectively. It was notable that Zn exceeded its WQS without causing significant acute toxicity in the 3.13% dilution.
- The test results for the two Rio Grande surface water samples were contradictory: RG-4 was non-toxic but RG-8 was toxic, even though RG-8 was located several miles downstream from RG-4. Regardless, the fact that significant acute toxicity was measured in RG-8 raises concern with the surface water quality in the Rio Grande downstream of the confluence with Willow Creek.

The challenge with interpreting this information was that the volume of Willow Creek flow into the Rio Grande resulted in a natural dilution of about 4% which, by chance, fell at the threshold between the presence and absence of acute toxicity observed in the serial dilution test. The observed mortality pattern suggested that acute toxicity in rainbow trout would likely be observed in both the RG-4 and RG-8 samples had the natural dilution been around 6%. On the other hand, it also appears that acute toxicity would be absent from both samples had the natural dilution been around 2%.

Based on the available body of evidence, it would be premature to conclude that the surface water of the Rio Grande below the confluence with Willow Creek was not toxic to fish. The fact that the hardness-adjusted, chronic WQS for Cd was between three and four times lower than the Cd concentrations measured in the 3.13% Willow Creek dilution used in the acute toxicity test, and in both RG-4 and RG-8, strongly suggested that the Rio Grande below the confluence may be unable to support a healthy, sustainable fish community due to the presence of Cd. In addition, the concentration of Cd and Zn were higher in the Rio Grande during April than they were during September when water samples were collected for the toxicity tests. This insight further strengthens the conclusion that sensitive life stages of the fish community in the Rio Grande below the confluence with Willow Creek are likely impaired due to heavy metals.

4.3.3.4 Aquatic Insectiverous Birds (American dipper)

Risk to birds feeding on aquatic insects over Willow Creek and the Rio Grande was assessed based on one measurement endpoint, i.e., use generic Bioconcentration Factors (BCFs) to estimate COPEC levels in insects and apply a conservative food chain model to calculate daily doses to the American dipper for comparison to no effect- and effect-based bird TRVs.

This measurement endpoint identified Zn as the major risk driver to insectivorous birds ingesting surface water and winged aquatic insects from Willow Creek and the Rio Grande. Cadmium and Pb were only identified as risk drivers in Willow Creek, while Cu was only a risk driver at sample location WW-NT. The reliability of these findings was low because it was based on a single, semi-qualitative LOE.

The potential risk associated with the major contaminants is discussed below. Note that winged insects were not expected to emerge in substantial numbers from highly-contaminated Willow Creek. Hence, the risk to aquatic insectivorous birds feeding in Willow Creek under current conditions should be considered entirely hypothetical. Also, in this summary, the risk was only discussed in terms of the effect-based HQs for the sake of brevity, even though the BERA also provided the no effect-based HQs.

<u>Zinc</u>
The effect-based HQs (maximum exposure scenario) for Zn exceeded 1.0 at all sample locations in Willow Creek and the Rio Grande, except for the background locations (Figure 4-6). These HQs ranged from 19 to 1,027 for Willow Creek and from 1.1 to 3.1 for the Rio Grande across the seasons. This LOE indicated a high risk potential from Zn to birds feeding on aquatic insects in Willow Creek, with only a small risk potential for the same birds feeding in the Rio Grande. The impacts to Willow Creek downstream from WW-NT are also relatively less severe in the spring than in the fall.

<u>Cadmium</u>
The effect-based HQs (maximum exposure scenario) for Cd exceeded 1.0 at all the sample locations in Willow Creek, but at none of the sample locations in the Rio Grande (Figure 4-7). These HQs ranged from 1.9 to 79 for Willow Creek across the seasons. This LOE indicated a higher potential for risk from Cd in the fall compared to the spring. Cadmium did not represent a risk to aquatic insectivorous birds feeding over the Rio Grande.

<u>Lead</u>
The effect-based HQs (maximum exposure scenario) for Pb exceeded 1.0 at each sample location in Willow Creek (Figure 4-8). These HQs ranged from 3.0 to 153 for Willow Creek across the seasons. This LOE indicated that Pb had a high potential to affect aquatic insectivorous birds feeding in Willow Creek. Lead did not represent a risk to aquatic insectivorous birds feeding over the Rio Grande.

4.3.3.5 Omniverous Birds (Mallard)

Risk to omnivorous birds feeding in Willow Creek and the Rio Grande was assessed based on a single measurement endpoint, i.e., use generic BCFs to estimate the COPEC levels in benthic invertebrates (spring and fall) and aquatic plants (fall only) and apply a conservative food chain model to calculate daily doses to mallards for comparison to no effect- and effect-based avian TRVs.

This measurement endpoint identified Cd, Pb, and Zn as the major risk drivers to omnivorous birds ingesting surface water, and feeding on benthic invertebrates and aquatic plants from Willow Creek. Copper was only identified as a risk driver at sample location WW-NT. The reliability of the risk conclusion was considered low because it was based on a single, semi-qualitative LOE.

The potential risk associated with the four major contaminants is discussed below. Note that benthic invertebrates were not expected to be present in substantial numbers in Willow Creek. Hence, the risk to aquatic omnivorous birds feeding on benthic invertebrates in Willow Creek under current conditions should be considered entirely hypothetical. Also, in this summary, the risk was only discussed in terms of the effect-based HQs for the sake of brevity, even though the BERA also provides the no effect-based HQs.

<u>Cadmium</u>
The effect-based HQs (maximum exposure scenario) for Cd exceeded 1.0 at each sample location in Willow Creek, except for sample locations WW-F and WW-I in the spring (Figure 4-9). These HQs ranged from <1 to 31 for Willow Creek across the seasons, but fell below 1.0 in the Rio Grande. This LOE indicated a high potential for risk from Cd to omnivorous birds feeding in Willow Creek (particularly in the fall), but not in the Rio Grande.

Lead

The effect-based HQs (maximum exposure scenario) for Pb exceeded 1.0 at each sample location in Willow Creek, except for sample location W-I in the fall (Figure 4-10). These HQs ranged from <1 to 58 for Willow Creek across the seasons, but fell below 1.0 in the Rio Grande. This LOE indicated a high potential for risk from Pb to omnivorous birds feeding in Willow Creek, but no risk in the Rio Grande.

Zinc

The Zn effect-based HQs (maximum exposure scenario) exceeded 1.0 at each of the sample locations in Willow Creek (Figure 4-11). These HQs ranged from 7.3 to 386 for Willow Creek across the seasons. This LOE indicated that Zn had a high potential to severely impact omnivorous birds feeding in Willow Creek. The impacts of Zn in Willow Creek downstream from WW-NT were relatively less severe in the spring than the fall. No risk from Zn was observed for omnivorous birds feeding in the Rio Grande.

Copper

The effect-based HQs (maximum exposure scenario) for Cu exceeded 1.0 at sample location WW-NT only in the spring (Figure 4-12). This LOE showed a potential for risk from Cu to omnivorous birds feeding in Willow Creek only at location WW-NT in the spring, with no impact to the rest of Willow Creek or the Rio Grande.

4.3.3.6 Piscivorous Birds (belter kingfisher)

Risk to piscivorous birds feeding in Willow Creek and the Rio Grande was assessed based on a single measurement endpoint, i.e., use generic BCFs to estimate the COPEC levels in fish and apply a conservative food chain model to calculate daily doses to belted kingfisher for comparison to no effect- and effect-based avian TRVs.

This measurement endpoint identified Cd and Zn as the major risk drivers to piscivorous birds exposed to surface water and fish in Willow Creek. No risk to this receptor group was identified in the Rio Grande. The reliability of this conclusion was low because it was based on a single, semi-qualitative LOE.

The potential risk associated with the two major contaminants is discussed below. Note that fish were not expected to be present in substantial numbers in Willow Creek. Hence, the risk to piscivorous birds feeding in Willow Creek should be considered entirely hypothetical. Also, in this summary, the risk was only discussed in terms of the effect-based HQs for the sake of brevity, even though the BERA also provided the no effect-based HQs.

Cadmium

All the effect-based HQs (maximum exposure scenario) for Cd exceeded 1.0 in Willow Creek in the fall, whereas risk in the spring was identified at only one sample location (WW-NT) (Figure 4-13). These HQs ranged from <1 to 13 for Willow Creek across the seasons. This LOE showed that Cd had a high potential to affect piscivorous birds feeding at sample location WW-NT in the spring and fall, with a lower impact for the rest of Willow Creek in the fall only. No risk from Cd to this receptor group was identified in the Rio Grande.

Zinc

The effect-based HQs (maximum exposure scenario) for Zn exceeded 1.0 at all the sample locations in Willow Creek, with HQs ranging from 5.4 to 290 across the seasons (Figure 4-14). The impacts to Willow Creek downstream from WW-NT were relatively less severe in the spring than in the fall. None of the HQs for Zn exceeded 1.0 in the Rio Grande. This LOE showed a high potential for risk to piscivorous birds exposed to Zn in Willow Creek.

4.3.3.7 Herbivorous Mammals (muskrat)

Risk to herbivorous mammals feeding in Willow Creek and the Rio Grande was assessed based on a single measurement endpoint, i.e., use generic BCFs to estimate the COPEC levels in aquatic plants and apply a conservative food chain model to calculate daily doses to muskrat for comparison to no effect- and effect-based mammal TRVs.

This measurement endpoint identified Cd, Zn, and Pb as the major risk drivers to herbivorous mammals exposed to surface water and aquatic plants in Willow Creek. Lead was only identified as a risk driver at sample locations WW-NT, WW-E, and WW-J. No risk drivers were identified for the Rio Grande. The reliability of this conclusion was low because it was based on a single, semi-qualitative LOE.

The potential risk associated with the major contaminants is discussed below. In this summary, the risk was only discussed in terms of the effect-based HQs for the sake of brevity, even though the BERA also provides the no effect-based HQs.

Cadmium

The effect-based HQs (maximum exposure scenario) for Cd exceeded 1.0 for sample location WW-NT in the fall and spring, but only for WW-F and WW-E in the fall (Figure 4-15). These HQs ranged from <1 to 7.0 for Willow Creek across the seasons. No HQs for Cd exceeded 1.0 in the Rio Grande. This LOE showed some risk from Cd to herbivorous mammals feeding at sample location WW-NT in the spring and fall, with much lower risk at sample locations WW-F and WW-E in the fall only. No risk from Cd to this receptor group was identified in the Rio Grande.

Zinc

The effect-based HQs (maximum exposure scenario) for Zn exceeded 1.0 at all sample locations in Willow Creek (Figure 4-16), ranging from 2.2 to 120 across the seasons. No HQs for Zn exceeded 1.0 in the Rio Grande. This LOE indicated a high potential for risk from Zn to herbivorous mammals feeding in Willow Creek. The risk downstream from WW-NT was less severe in the spring than in the fall.

Lead

The effect-based HQs (maximum exposure scenario) for Pb exceeded 1.0 at sample locations WW-NT, WW-F and WW-E in the fall, and WW-NT and W-J in the spring in Willow Creek (Figure 4-17). These HQs ranged from <1 to 5.3 for Willow Creek across the seasons, indicating a low potential for risk from Pb to herbivorous mammals feeding at several locations on Willow Creek in spring and fall. No risk from Pb was observed for herbivorous mammals in the Rio Grande.

In conclusion, completing the BERA represented a stage in the process where a Scientific Management Decision Point was achieved. The various LOEs showed that Nelson Tunnel discharge contributed ecological risk to Willow Creek and the Rio Grande. Cadmium, Pb, and Zn were the major risk drivers, with several other metals contributing lower levels of risk to the targeted receptor groups.

The rainbow trout toxicity test showed that diluting Willow Creek surface water down to 3.13% in the laboratory achieved the BERA endpoint of "trout survival" under acute exposure conditions. However, this ratio was unlikely to provide a defensible long-term "dilution" remedial goal for the Rio Grande for the following reasons:

- Significant acute toxicity in rainbow trout was measured at one location in the Rio Grande (RG-8) with a flow estimated to consist of about 4% Willow Creek water at the time of the test in September 2010.
- Comparing the Cd levels measured in the 3.13% Willow Creek dilution sample to a hardness-adjusted chronic surface water benchmark for Cd showed that chronic toxicity to trout was most likely present at that dilution, but could not have been detected by the test due to the short-term (96-hour) exposure duration.

Also, the water quality in April was worse than in September when the surface water samples were collected for toxicity testing and chemical analyses. Hence, the toxicity test conducted in September can only be considered a rough approximation of the April flow conditions, with much uncertainty.

The benthic macroinvertebrate community measures showed the potential for risk based on the sediment chemistry LOE, but only a small potential for risk based on the benthic community survey LOE. It would be a challenge to develop realistic sediment remedial goals for benthic invertebrates based on the available information because other factors may have affected the benthic community structure and function. These include differences in habitat quality across sample locations or the response by the invertebrates to exposure to metal-enriched surface water or silting.

5.0 CONTAMINANT FATE AND TRANSPORT

5.1 CONTAMINANT SOURCES AND CHARACTERISTICS

5.1.1 Generation of Acid Mine Drainage

The Mine contains deposits of sulfide minerals including sphalerite, galena, chalcopyrite, and pyrite. Additional, unprofitable sulfide ore is located below the Nelson Tunnel. These sulfide formations contain metals including lead, iron, zinc, and cadmium (Graves, 2006). Oxidation mechanisms (discussed below) result in release of metals into aqueous solution which is then transported in the environment via free flowing or otherwise migrating water.

The oxidation of sulfide minerals can produce metal ions, low pH water (high hydrogen ion concentrations), and high sulfate concentrations. Oxidation occurs when sulfide minerals are exposed to oxygen and water. This phenomena has been well documented for pyrite and the mobilization of iron (Equations 5-1 to 5-4).

$$2FeS_2\ (s) + 7O_2\ (aq) + 2H_2O \rightarrow 2\ Fe^{+2} + 4SO_4^{-2} + 4H^+ \qquad \text{(Equation 5-1)}$$

Pyrite is oxidized and creates ferrous iron (Fe^{+2}), sulfate, and hydrogen ions. Further oxidation of ferrous iron results in ferric iron (Fe^{+3}) (Equation 2).

$$2\ Fe^{+2} + ½\ O_2 + 2H^+ \rightarrow 2\ Fe^{+3} + H_2O \qquad \text{(Equation 5-2)}$$

Ferric iron can react with pyrite to create ferrous iron and acidity (Equation 3) or precipitate as iron (III) hydroxide (Equation 4), also known as yellow boy (Costello, 2003). Precipitated iron (III) hydroxide is a common sign of water contamination due to mining activities.

$$14Fe\ Fe^{+3} + FeS_2\ (s) + 8\ H_2O \rightarrow 2SO_4^{-2} + 15\ Fe^{+2} + 16H^+ \qquad \text{(Equation 5-3)}$$

$$2\ Fe^{+3} + 6\ H_2O \leftrightarrow 2Fe(OH)_3 + 6H^+ \qquad \text{(Equation 5-4)}$$

Although the Nelson Tunnel discharge is relatively low in iron, evidence also indicates that other sulfide minerals, such as sphalerite, could undergo a similar process. Sphalerite is a zinc and iron-rich sulfide mineral that is can be oxidized by oxygen (Equation 5) or ferric iron (Equation 6; Balci, 2009).

$$ZnS + 2O_2 \rightarrow Zn^{+2} + SO_4^{-2} \qquad \text{(Equation 5-5)}$$

$$ZnS + 8\ Fe^{+3} + 4\ H_2O \rightarrow Zn^{+2} + SO_4^{-2} + 8Fe^{+2} + 8H^+ \qquad \text{(Equation 5-6)}$$

Cadmium sulfide does exist in a rare mineral form of greenockite, but is more commonly found as an elemental substitution in sphalerite (Balci, 2009). The oxidation of sphalerite is expected to be the largest source of zinc and cadmium in the Nelson Tunnel Mine workings.

Additionally, goslarite, a highly soluble product of sphalerite oxidation and reprecipitation, is found in significant quantities along Mine walls and can be mobilized when Mine pool levels fluctuate.

Mobilization of cadmium and zinc is dependant on pH, redox potential, cationic exchange capacity, and the speciated form present. Zinc and cadmium solubility is inversely related to pH below a pH of 10, (Figure 5-1). Mine pool water in the Nelson Tunnel has an average pH of 4.4, indicating sulfide mineral oxidation and conditions supporting high loads of metals in the water column.

Before mining began in the Creede mineral district, sulfide minerals were present in the underground. In undisturbed mineralization, oxidation occurs slowly and the surrounding water is generally able to buffer the acid generated (Costello, 2003). It was not until oxygen and water were introduced to the ore bodies through mining processes that oxidation and subsequent dissolution of metals occurred on a large scale.

The Nelson Tunnel intersects multiple ore veins within the Mine. Evidence also indicates that the Nelson Tunnel complex could be hydraulically connected not only to mines in the Amethyst Vein, but also to the Bulldog Mine, located in Windy Gulch (Figure 2-5). The large area of interconnecting mine workings results in a wide spread occurrence of source minerals (Graves, 2006).

5.1.2 Waste Rock

The Commodore Waste Rock pile extends along West Willow Creek in the vicinity of the Nelson Tunnel portal. Waste rock on the slope above the Commodore 5 Level is considered part of the Bachelor waste rock and is not within the Site boundaries. The same mechanisms that produce acid mine drainage (Section 5.1.1) are expected to apply to waste rock piles. The Commodore Waste Rock pile was characterized as part of WCRC investigations of waste rock and tailings piles in the Willow Creek watershed (WCRC, 2004c). Deionized (DI) water extraction and Toxicity Characterization Leaching Procedure (TCLP) tests were preformed and are described below.

The Commodore Waste Rock pile has been analyzed for total metals and metal mobility by metal extraction and TCLP measurements. Extraction tests were with a 2:1 liquid (deionized water) to solid ratio on samples from the Commodore Waste Rock pile in accordance with EPA Method ASA No. 10-2.3.2. Test results are expressed as a mass (mg) of dissolved metals per kilogram (kg) of waste rock subjected to testing. Lead, cadmium, and zinc were reported at maximum of 10.7 mg/kg, 1.1 mg/kg, and 177 mg/kg, respectively (WCRC, 2004c). These results are difficult to interpret as no standards or regulatory levels exist such as those applicable to TCLP, discussed below.

Three samples of waste rock were also subjected to TCLP analysis (WCRC, 2004c). This leach test uses acidified water as the solvent and is often used to classify wastes as hazardous or non-hazardous by toxicity. The maximum concentration of metals in TCLP leachate is presented in the table below.

Maximum TCLP Results

Metal	TCLP Result (mg/L)	TCLP Fail (mg/L)
Barium	0.217	100
Cadmium	0.178	1
Copper	0.26	N/A
Lead	**110**	5
Zinc	31	N/A

The Resource Conservation and Recovery Act (RCRA) establishes TCLP pass/fail criteria for many metals; however none have been established for copper and zinc. A review of the table reveals that Commodore Waste Rock sample TCLP results are below RCRA standards for all metals excluding lead.

Additional metals including arsenic, chromium, mercury, selenium and gold were analyzed by TCLP, but the results were under the Method Detection Limit or Practical Quantitation Limit and were not reported (WCRC, 2004c).

A slurry of half waste rock and half deionized water (paste pH test) exhibited a pH of approximately 4, indicating the oxidation chemistry described in Section 5.1.1 (WCRC, 2004c).

Results of the DI extraction tests, paste pH test, and TCLP analysis indicate that Commodore waste rock may be a source of metals, mobilized by runoff flowing through the waste into West Willow Creek.

5.2 FATE AND TRANSPORT

5.2.1 Mine Pool Water

Contaminant transport is primarily advective (moves with the flow of water) through the Nelson Tunnel. Mine pools extend approximately 11,100 ft into the Nelson Tunnel system (Figure 2-11) and include the Nelson Tunnel Portal Pool, Lower Pool and Upper Pool, as described in Section 2.3.2.

Nelson Tunnel water travel time was calculated by Cambrian Groundwater Company from the Berkshire shaft in the back of the upper Mine pool to the portal. This was accomplished by injecting a fluorescent dye tracer. Peak tracer concentration reached the portal in approximately three days with a mean travel time just over seven days. Low concentration of tracer was present in the portal discharge after 20 days, indicating a long residence time for a portion of the water.

Approximately 47% of the injected tracer was recovered at the portal. The loss of tracer could be due to a net loss of water from the Nelson Tunnel to fracture porosity in the surrounding rock, or retardation of dye inside the Mine pools. Some tracer was detected in West Willow Seep, 150 ft downstream and down-gradient of the Nelson Tunnel portal.

5.2.2 Surface Water

Contaminants in surface water are primarily transported downstream with the free flow of water. Few mechanisms exist naturally in the environment to fixate metals.

As discussed in Section 3.8, low concentrations of cadmium and zinc are detected above the Nelson Tunnel portal discharge (Station WW-NT). At the location of the portal discharge, West Willow Creek is steep and flows rapidly. After the confluence of East and West Willow Creeks, the main stream of Willow Creek proceeds rapidly down to the mouth of the canyon and the Town of Creede. Willow Creek is transported through Creede in a masonry flume discharging to a braided floodplain below town. The stream velocity greatly decreases through the floodplain and there is possible exchange or loss of flow to the hyporheic zone.

The Wason Diversion, located in the floodplain, removes water from Willow Creek. The fate of the Wason Diversion water is unknown, although it is probable that some is lost to evaporation during irrigation. The remainder is expected to either infiltrate to the water table or ultimately return to the Rio Grande.

In addition to contamination of the water column by dissolution of metal-rich sulfide material, cadmium and zinc may sorb to settleable iron colloids and be removed. Iron can be released to the environment by the oxidation of pyrite in the process described in Section 5.1.1. The iron can then oxidize, forming colloids with a surface coating that can adsorb transition metals, such as cadmium and zinc. The colloids can settle out of the water column, along with the sorbed material. This phenomenon has been documented in multiple lab studies and in nature in the Animas River (O’Conner, 1964; Kimball, 1997).

Metals originating from the Nelson Tunnel drainage flow into West Willow Creek and subsequently Willow Creek and the Rio Grande. The metals that are not lost to the Wason Diversion may have the following fate:

- Become fixated to the aquifer matrix
- Become fixated to river sediments
- Precipitate as particles
- Remain suspended as colloidal particles
- Settle to riverbed

- Bioaccumulate in organisms
- Flow as dissolved metals or suspended particles downstream to the Gulf of Mexico

6.0 CONCLUSIONS

The RI reached the following general conclusions.

1. Most water enters the Nelson Tunnel as ground water through faults and fractures in undifferentiated ash flow tuff bedrock. Radiocarbon dating of Nelson Tunnel water suggests a medial age on the scale of hundreds to thousands of years.
2. A minor amount of surface water is known to enter the Nelson Tunnel at various locations via Mine workings that extend to the surface.
3. Since 2002, Nelson Tunnel portal discharge ranged between 200 and 380 gallons per minute. Most of this water is thought to enter the tunnel in its upper reaches.
4. The COCs associated with human health include arsenic, chromium (VI), lead and manganese in CR-503 roadbase. The COCs associated with ecological risks include cadmium, copper, lead and zinc.
5. Oxidation of sulfide minerals release cadmium and zinc to Mine pool water. Metals in the water column are transported by advection to West Willow and Willow Creeks and the Rio Grande.
6. West Willow and Willow Creeks and the Rio Grande are currently in compliance with water quality standards. However, Segment 4 of the Rio Grande exceeds the TVS for cadmium and zinc underlying the current temporary modification and is on the 303(d) List of impaired waters.
7. The Nelson Tunnel portal discharge is the largest known point source of cadmium and zinc load to West Willow Creek, Willow Creek, and Segment 4 of the Rio Grand.
8. In periods of the year when low flows are observed (August to mid-May), the Nelson Tunnel contributes approximately 11-48% and 22-78% of the highest load of cadmium and zinc, respectively, measured in Willow Creek. During high-runoff periods (mid-May to July), the Nelson Tunnel contributes between 19-39% and 30-55% of cadmium and zinc loads, respectively. Therefore, the Nelson Tunnel is not always the primary source of zinc and cadmium load in Willow Creek or the Rio Grande.
9. Additional cadmium and zinc load are introduced to Willow Creek, primarily along the floodplain below Creede. However, additional metal load has also been observed entering West Willow Creek between stations WW-E through WW-A. Under most flow conditions, the sum of these contributions exceeds the metals load introduced by the Nelson Tunnel portal discharge.
10. For the adult and child rock hunter, cancer risks and non-cancer effects (including from lead) are below a level of concern.
11. For the adult and child ATV rider, non-cancer effects (including from lead) are above a level of concern. Cancer risks are below a level of concern.

12. The weight of evidence indicates ecological risks above a level of concern for aquatic and some terrestrial receptors from exposure to sediment, water and aquatic plants in Willow Creek at and downstream of the Site. Risks to most terrestrial receptors are hypothetical given their food sources (e.g. fish) are not present in Willow Creek.
13. A benthic survey of the Rio Grande below the confluence with Willow Creek indicates relatively mild mine-related impacts to invertebrates. Impacts to other aquatic receptors in the Rio Grande were based on methods other than population surveys (e.g. site-specific toxicity study for fish). The weight of evidence indicates the potential for ecological risks above a level of concern for water column invertebrates, trout, and aquatic insectivorous birds.

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TABLES

Table 3-1: Data Sources

Document (s)	Years	Measured constituents	Data Source	Laboratory Analytical Report
Surface Water Quality Data				
Report on Surface and Mine Water Sampling and Monitoring in Willow Creek Watershed	1999-2002	Flow, Hardness, Metals	WCRC	No
Site Inspection Results Report - CDPHE	1995	Flow, Hardness, Metals	CDPHE	No
Preliminary Characterization of the Willow Creek Watershed	1995	Flow, Hardness, Metals	WCRC	No
Evaluation of Metal Loading to Streams near Creede, CO - USGS	Aug-Sep 2000	Flow, Hardness, Metals	USGS	No
Analytical Results – Lab Reports	2007 - 2009	Metals	EPA	Yes
Willow Creek Reclamation Committee Spreadsheet	1999-2006	Metals	WCRC	No
Draft Final Rio Grande TMDL Assessment	Undated	Cd and Zn	CDPHE	No
Analytical Results	2010 - 2011	Flow, Hardness, Metals	EPA	Yes
Subsurface Water Quality Data				
Interim Underground Report	2000, 2002, 2003	Flow, Metals	CDRMS	No
Underground Report	2003 (one sample)	Flow, Metals	CDRMS	No
Nelson Tunnel Dewatering Project	2007	Flow, Metals	CDRMS	No
Case Study of Groundwater Flow Within the Commodore Mine Complex and Implications for Source Control	1990-2000	Flow	CDRMS	No
Analytical Results	2007, 2009	Metals	EPA	Yes
Results of Groundwater Tracing Experiments in the Nelson-Wooster-Humphry Tunnel - Cambrian Groundwater	2001	Water Source, Tritium	WCRC	No
Commodore Waste Rock Data				
Site Inspection Results Report	1995	Metals Concentrations	CDPHE	No
Health Consultation	2009	Metals Concentrations	ATSDR	No
Report on Characterization of Waste Rock and Tailings Pile Above Creede, CO	2004	TCLP, Paste	WCRC	No
Enforcement Addendum to Time Critical Removal Action Memo	2008	XRF Metals Concentrations	EPA	No
Analytical Results	2010	Metals Concentrations	EPA	No

CDPHE- Colorado Department of Health and Environment
CDRMS- Colorado Division of Reclamation Mining and Safety
EPA- Environmental Protection Agency
USGS- United States Geological Survey
WCRC- Willow Creek Reclamation Committee

Table 3-2: Nelson Tunnel Average Discharge Characteristics 2001-2010

pH	4.5
Temperature (^{O}C)	16
Total Alkalinity (mg/L)	1.42
Hardness (mg/L)	597
Conductivity (µS/cm[1])	1,415
TDS (mg/L)	1,537
TSS (mg/L)	2.6
Aluminum, Al (Dissolved) [mg/L]	0.78
Aluminum, Al (Total) [mg/L]	0.80
Calcium, Ca (Dissolved) [mg/L]	202
Cadmium, Cd (Dissolved) [mg/L]	0.20
Cadmium, Cd (Total) [mg/L]	0.19
Iron, Fe (Dissolved) [mg/L]	0.30
Iron, Fe (Total) [mg/L]	1.38
Lead, Pb (Dissolved) [mg/L]	0.86
Lead, Pb (Total) [mg/L]	0.81
Magnesium, Mg (Dissolved) [mg/L]	18.81
Magnesium, Mg (Total) [mg/L]	12.69
Manganese, Mn (Dissolved) [mg/L]	13.93
Manganese, Mn (Total) [mg/L]	13.28
Zinc, Zn (Dissolved) [mg/L]	60.55
Zinc, Zn (Total) [mg/L]	55.09
Silicon, SI (Total) [mg/L]	25.87
Sulfate SO_4 (Dissolved) [mg/L]	845

[1] – micro Siemen per centimeter

Table 3-3: Stream Segment Classification

	Stream Segment Description	Designation	Classifications	Numeric Standards	Temporary Modification
Segment 2	Mainstem of the Rio Grande, including all wetlands, tributaries, lakes and reservoirs, from the source to a point immediately above the confluence with Willow Creek except for the specific listings in segments 1 and 3.		Aq Life Cold 1, Recreation E, Water Supply, Agriculture	Physical and Biological, Inorganic, Metals	
Segment 4	Mainstem of the Rio Grande from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line.		Aq Life Cold 1, Recreation E, Water Supply, Agriculture	Physical and Biological, Inorganic, Metals	Temporary Modifications type iii: As(ch)=existing quality Cd(ch)=existing quality Cu(ch)=existing quality Pb(ch)=existing quality Zn(ch)=existing quality Expiration Date of 12/31/2012
Segment 5	All tributaries to the Rio Grande, including all wetlands, lakes and reservoirs, from immediately above the confluence with Willow Creek to State Highway 112 bridge in Del Norte, except for specific listings in segments 6 through 10.		Aq Life Cold 1, Recreation E, Water Supply, Agriculture	Physical and Biological, Inorganic, Metals	
Segment 6	Mainstem of West Willow Creek from immediately above Deerhorn Creek to the Park Regent Mine dump.		Aq Life Cold 1, Recreation E	Physical and Biological, Inorganic, Metals	
Segment 7	Mainstem of West Willow Creek from the Park Regent Mine dump to the confluence with East Willow Creek; mainstem of East Willow Creek from the confluence with Whited Creek to the confluence with West Willow Creek, mainstem of Willow Creek, including all tributaries from the confluence of East and West Willow Creeks to the confluence with the Rio Grande.	Use Protected	Recreation E, Agriculture	Physical and Biological	

Table 3-4 –Mass Balance at the Confluence of East and West Willow Creek

Date	Station	Flow (CFS)	Cd (lbs/day)	Zn (lbs/day)
***5/16/2000**	EW-A	28.2	0.15	18
	WW-A	27.3	2.17	496
	SUM (EW-A+WW-A)	55.4	2.32	514
	W-A	62.5	2.45	551
	- SUM (EW-A+WW-A)	55.4	2.45	514
	Difference	**7.1**	**0.13**	**37**
9/1/2000	EW-A	18.0	0.39	19
	WW-A	7.0	2.18	532
	SUM (EW-A+WW-A)	25.0	2.57	551
	W-A	25.0	2.65	585
	- SUM (EW-A+WW-A)	25.0	0.00	551
	Difference	**0.0**	**0.08**	**34**
5/2/2002	EW-A	8.2	0.13	17
	WW-A	6.0	0.87	300
	SUM (EW-A+WW-A)	14.2	1.00	317
	W-A	13.4	1.07	320
	- SUM (EW-A+WW-A)	14.2	0.00	317
	Difference	**-0.9**	**0.07**	**3**
5/8/2003	EW-A	6.8	0.08	12
	WW-A	5.7	0.70	236
	SUM (EW-A+WW-A)	12.5	0.78	248
	W-A	11.9	0.76	246
	- SUM (EW-A+WW-A)	12.5	0.00	248
	Difference	**-0.6**	**-0.02**	**-2**
5/6/2004	EW-A	25.6	0.18	24
	WW-A	25.6	1.69	307
	SUM (EW-A+WW-A)	51.2	1.87	331
	W-A	52.3	1.91	339
	- SUM (EW-A+WW-A)	51.2	0.00	331
	Difference	**1.1**	**0.04**	**8**

Dissolved metal concentrations reported except where noted.
* Total metal concentration data reported for 5/16/2000 sample.

Table 4-1
Summary of Data Considered in the HHRA

Media/Location		Sampling Date	Sampling Description	Analysis
Soil	Commodore Waste Rock Pile	June 2010	Five-point composite soil samples from 27 locations on the Commodore Waste Rock Pile (see Figure 3-1).	Total recoverable metals
	Background Soil	June 2010	Three surface soil locations adjacent to the Commodore waste rock pile in an undisturbed area absent of past mining activities.	Total recoverable metals
	CR-503 Road Base	October 2010	Seventeen surface soil locations along CR-503 from the limits of the town of Creede to the CR-504 junction (see Figure 3-4).	Total recoverable metals and mercury
Surface Water	West Willow Creek	June 2010	Locations WW-E (below discharge pipe from Commodore waste rock) and WW-F (downstream from Nelson Adit on west side of rock pile; Figure 2-2).	Total recoverable metals & dissolved metals
Air	ATV riding along CR-503	June 2010	Three samples collected while ATV riding along CR-503 between the town of Creede and the Amethyst mine turnaround area (see Figure 3-4).	Arsenic, cadmium, lead, manganese, zinc
	Stationary air samplers	June 2010	Three samplers set up along the side of CR-503 at locations leading to the waste rock pile (see Figure 3-4)	Arsenic, cadmium, lead, manganese, zinc

Table 4-2
Waste Rock Pile Sampling Summary - June 2010 Sampling Event

	Detection Summary				Detection Limits		Maximum Location	Background Concentration (mg/kg)
	Detection Frequency	Min (mg/kg)	Max (mg/kg)	Average (mg/kg)	MDL (mg/kg)	MRL (mg/kg)		
Aluminum	27 of 27	1,980	9,790	5,741	19.4	50.9	CWR-003	8,257
Antimony	27 of 27	9.42	48.1	23	0.484	1.02	CWR-009	0.6
Arsenic	27 of 27	261	1,350	672	0.484	2.04	CWR-011	8.4
Beryllium	27 of 27	0.261	1.1	0.73	0.0969	0.204	CWR-008	0.6
Cadmium	27 of 27	29.3	103	76	0.0969	0.204	CWR-003	0.8
Calcium	27 of 27	1,130	6,710	3,041	96.9	255	CWR-001	4,170
Chromium	27 of 27	1.34	8.4	3.2	0.484	1.02	CWR-002	6.3
Copper	27 of 27	216	2,510	856	1.94	10.2	CWR-011	11
Iron	27 of 27	17,400	47,800	27,041	96.9	255	CWR-003	10,257
Lead	27 of 27	8,050	52,100	25,416	4.84	25.5	CWR-008	52
Magnesium	27 of 27	528	3960	2,220	96.9	255	CWR-003	2440
Manganese	27 of 27	852	5,200	3,647	1.94	5.09	CWR-025	797
Mercury	27 of 27	0.4 J	1.38 J	0.64	0.02	0.11	CWR-004	0.03
Nickel	27 of 27	0.793	9.57	2.7	0.484	1.02	CWR-002	5.4
Potassium	27 of 27	484	1,840	1,155	242	1020	CWR-009	2,133
Selenium	27 of 27	1.18	3.78	2.1	0.484	1.02	CWR-008	0.3
Silica (SiO2)	27 of 27	2,750	5,990	4,587	242	1020	CWR-025	5,440
Silver	27 of 27	30.8	81.3	62	0.0969	0.509	CWR-012	0.3
Sodium	0 of 27	<244	<254	<125	242	509	--	127
Strontium	27 of 27	36.5	64.4	46	1.94	10.2	CWR-001	46
Thallium	27 of 27	3.24	20.4	9.3	0.484	1.02	CWR-004	0.4
Vanadium	27 of 27	6.95	19	13	0.969	2.04	CWR-001	15.5
Zinc	27 of 27	4,990	19,300	13,116	9.69	20.4	CWR-008	111

J – indicates estimated concentration.

Table 4-3
Surface Water Sampling Summary - June 2010

Analyte	Detection Summary				Detection Limits		Maximum Location[3]
	Detection Frequency	Min (ug/L)	Max (ug/L)	Average (ug/L)	MDL[1] (ug/L)	MRL[2] (ug/L)	
Aluminum	2/2	**28.5 J**	**30.2 J**	**29.35**	20.0	50.0	WW-F
Antimony	0/2	<0.500	<0.500	<0.500	0.500	1.00	--
Arsenic	2/2	**0.540 J**	**0.685 J**	**0.61**	0.500	2.00	WW-E
Beryllium	0/2	<0.100	<0.100	<0.100	0.100	0.200	--
Cadmium	2/2	**4.09**	**6.17**	**5.13**	0.100	0.200	WW-E
Calcium	2/2	**11,800**	**12,500**	**12,150**	100	250	WW-E
Chromium	0/2	<0.500	<0.500	<0.500	0.500	1.00	--
Copper	2/2	**1.88**	**3.35**	**2.6**	0.500	1.00	WW-E
Iron	0/2	<100	<100	<100	100	250	--
Lead	2/2	**19.9**	**34.0**	**27**	0.100	0.200	WW-E
Magnesium	2/2	**1,320**	**1,360**	**1,340**	100	250	WW-E
Manganese	2/2	**155**	**172**	**164**	0.200	0.500	WW-E
Mercury	0/2	<0.100	<0.100	<0.100	0.100	0.200	--
Nickel	0/2	<0.500	<0.500	<0.500	0.500	1.00	--
Potassium	2/2	**827 J**	**893 J**	**860**	250	1000	WW-E
Selenium	0/2	<0.500	<0.500	<0.500	0.500	1.00	--
Silica	2/2	**12,500**	**12,800**	**12,700**	250	1000	WW-E
Silver	0/2	<0.100	<0.100	<0.100	0.100	0.500	--
Sodium	2/2	**3,110**	**3,330**	**3,220**	250	500	WW-E
Strontium	2/2	**130**	**136**	**133**	2.00	10.0	WW-E
Thallium	0/2	<0.500	<0.500	<0.500	0.500	1.00	--
Vanadium	0/2	<10.0	<10.0	<10.0	10.0	50.0	--
Zinc	2/2	**963**	**1,450**	**1206.5**	10.0	20.0	WW-E

J – indicates estimated concentration.
[1] – minimum detection limit
[2] – minimum reporting limit
[3]- See Figure 2-2

Table 4-4
CR-503 Road Base Sampling Summary - October 2010 Sampling Event

	Detection Frequency	Min (mg/kg)	Max (mg/kg)	Average (mg/kg)	Maximum [1] Location
Aluminum	17/17	1,620	10,100	6,339.4	CR-503-17
Antimony	6/17	3.06	12.9	5.9	CR-503-8
Arsenic	17/17	5.83	166.0	52.6	CR-503-14
Barium	17/17	120	1,550	404.1	CR-503-14
Beryllium	1/17	0.563	0.563 J	0.563	CR-503-6
Cadmium	13/17	0.574	19.7	3.4	CR-503-2
Calcium	17/17	409	13,200	5,587.9	CR-503-2
Chromium	17/17	3.29	27.7	9.2	CR-503-13
Cobalt	17/17	0.586	6.39	3.9	CR-503-16
Copper	17/17	8.69	112	24.1	CR-503-2
Iron	17/17	5,940	17,400	12,501.8	CR-503-16
Lead	17/17	28.2	2,380	434.9	CR-503-2
Magnesium	17/17	227	4,070	2,148.6	CR-503-16
Manganese	17/17	53.5	3130	701.6	CR-503-14
Molybdenum	16/17	0.541	17.8	3.5	CR-503-8
Nickel	13/17	3.25	10.7	4.7	CR-503-11
Potassium	17/17	1,190	2,110	1,615.9	CR-503-17
Selenium	0/17	ND	ND	ND	N/A
Silver	12/17	1.11	19	3.7	CR-503-14
Sodium	13/17	129	555	310.2	CR-503-1
Strontium	17/17	14.2	91.6	55.5	CR-503-7
Thallium	1/17	4.73	4.73 J	4.73	CR-503-8
Titanium	17/17	15.8	790	298.0	CR-503-1
Vanadium	16/17	6.88	41.2	25.6	CR-503-1
Zinc	17/17	38.7	3290	436.8	CR-503-2

J – indicates estimated concentration.
ND = not detected
[1] – See Figure 2-2

Table 4-5
Air Sampling Summary - June 2010

Analyte	ATV RIDING				STATIONARY AIR SAMPLES			
	Detection Frequency	**Sample # 93853-ATV [a] (ug/m^3)**	**Sample # 92721-ATV [b] (ug/m^3)**	**Sample # 92257-ATV [c] (ug/m^3)**	**Detection Frequency**	**Sample # 92260-ST [d] (ug/m^3)**	**Sample # 92230-ST[d] (ug/m^3)**	**Sample # 92801-ST [d] (ug/m^3)**
Arsenic	0/3	<8.3	<16.7	<8.3	0/3	<4.2	<4.2	<4.2
Cadmium	0/3	<3.3	<6.7	<3.3	0/3	<1.7	<1.7	<1.7
Manganese	3/3	**44.7**	**139**	**67**	0/3	<4.2	<4.2	<4.2
Lead	3/3	**73.0**	**188**	**60.3**	1/3	**11.0**	<4.2	<4.2
Zinc	3/3	**55.0**	**163**	**55.7**	1/3	**7.2**	<4.2	<4.2

[a] Driving on CR-503 near site WW-G to site W-A. ATV drivers continued driving from site W-A up to the Amethyst Mine turnaround area with the remainder of the hour spent driving between site W-A and site WW-G.

[b] Driving on CR-503 from site WW-C to site WW-M (located near sample station CR-503-17 on Figure 3-4) with the majority of the driving between WW-B and the Commodore Waste Rock pile parking lot.

[c] Driving on CR-503 from site W-C to the Amethyst Mine turnaround area with the majority of driving near site WW-B and the Commodore Waste Rock pile parking area.

[d] Stationary air samplers were set up on the side of the road leading to the Commodore Waste Rock Pile (See Figure 3-4). Samplers were set up (1) near the ore loading facility, (2) downhill 50 meters from the ore loading structure on the west side of CR-503, and (3) Near the ATV loading area near surface water sampling site WW-B. Detail regarding which stationary sampling number corresponds to which location is not provided in the Sampling Activities Report (TechLaw, 2010a).

Table 4-6
Soil RBCs

	ATV Riders		Rock Hunters		RBC (mg/kg)
	RBC $_{Noncancer}$ (mg/kg)	**RBC $_{Cancer}$ (mg/kg)**	**RBC $_{Noncancer}$ (mg/kg)**	**RBC $_{Cancer}$ (mg/kg)**	
Aluminum	20,454		2,503,774		20,454
Antimony	511		1,023		511
Arsenic	173	27	1,528	79	27
Beryllium	266	144	5,061	231,293	144
Cadmium	103	192	2,530	308,390	70
Calcium	18,250,000		36,536,354		18,250,000
Chromium	1,070	4	7,648	6,608	4
Copper	51,100		102,302		51,100
Iron	894,250		1,790,281		894,250
Lead	0 [1]		149,017 [1]		0
Magnesium	7,300,000		14,614,541		7,300,000
Manganese	739		275,288		739
Mercury	383		767		383
Nickel	1,270	1,332	49,959	2,135,008	1,270
Potassium	63,875,000		127,877,238		63,875,000
Selenium	6,253		12,787		6,253
Silica(SiO2)	44,542		71,453,590		44,542
Silver	6,388		12,788		6,388
Sodium	43,800,000		87,687,249		43,800,000
Strontium	766,500		1,534,527		766,500
Thallium					
Vanadium	6,388		12,788		6,388
Zinc	383,250		767,263		383,250

$RBC_{(Noncarcinogenic)} = HQ/[(HIF_{NC\ Soil\ Ingest} * RBA)/RfD_{oral} + (TWF_{NC\ Inh}*PEF)/RfC_{inh})]$

$RBC_{(carcinogenic)} = TR/[(HIF_{C\text{-}Soil\ Ingest} * RBA)*SF_{oral} + (TWF_{C\ -\ Inh}*IUR*1{,}000\ \mu g/mg*PEF)]$

HQ = 1E-01

TR = 1E-06

HIF and TWF values - See Tables 4-11 and 4-13 (RME exposure)

RBA = 1 for all analytes except arsenic; RBA for arsenic = 0.5

PEF = 1.18E-06 kg/m^3 for the ATV rider RBC calculations (estimated PEF from ATV riding at Quincy Smelter as referenced in *Baseline HHRA for the Standard Mine Site Gunnison County, CO* (SRC, 2008)) and PEF = 7.35E-10 kg/m^3 for Rock Hunter RBC calculations (EPA recommended default value based on wind erosion (EPA, 1989))

Toxicity values (RfD_{oral}, RfC, SF_{oral}, IUR) – see Table 4-15

[1] Lead RBCs were calculated using the EPA Adult Lead Model (see Appendix C). For the ATV rider RBC calculation, air concentrations for lead from the samples collected during ATV riding are too excessive to allow for a contribution of lead in soil at any concentration.

Table 4-7
Selection of Waste Rock COPCs

	Background Concentration (mg/kg)	Max Detection (mg/kg)	RBC [a] (mg/kg)	Max Detection > RBC?	COPC
Aluminum	8,257	9,790	20,454	No	
Antimony	0.6	48.1	511	No	
Arsenic	**8.4**	**1,350**	**27**	**Yes**	**X**
Beryllium	0.6	1.1	144	No	
Cadmium	**0.8**	**103**	**70**	**Yes**	**X**
Calcium	4,170	6,710	18,250,000	No	
Chromium	**6.3**	**8.4**	**4**	**Yes**	**X**
Copper	11	2,510	51,100	No	
Iron	10,257	47,800	894,250	No	
Lead	**52**	**52,100**	**0**	**Yes**	**X**
Magnesium	2440	3960	7,300,000	No	
Manganese	**797**	**5,200**	**739**	**Yes**	**X**
Mercury	0.03	1.38 J	383	No	
Nickel	5.4	9.57	1,270	No	
Potassium	2,133	1,840	63,875,000	No	
Selenium	0.3	3.78	6,253	No	
Silica (SiO_2)	5,440	5,990	44,542	No	
Silver	0.3	81.3	6,388	No	
Sodium	127	<254	43,800,000	No	
Strontium	46	64.4	766,500	No	
Thallium	0.4	20.4	Not Available	No	
Vanadium	15.5	19	6,388	No	
Zinc	111	19,300	383,250	No	

[a] See Table 4-6.

J Indicates estimated concentration.

Table 4-8
Selection of CR-503 Road Base COPCs

	Max Detection (mg/kg)	RBC [a] (mg/kg)	Max Detection > RBC?	COPC
Aluminum	10,100	20,454	No	
Antimony	12.9	511	No	
Arsenic	**166.0**	**27**	**Yes**	**X**
Beryllium	0.563 J	144	No	
Cadmium	19.7	70	No	
Calcium	13,200	18,250,000	No	
Chromium	**27.7**	**4**	**Yes**	**X**
Copper	112	51,100	No	
Iron	17,400	894,250	No	
Lead	**2,380**	**0**	**Yes**	**X**
Magnesium	4,070	7,300,000	No	
Manganese	**3,130**	**739**	**Yes**	**X**
Nickel	10.7	1,270	No	
Potassium	2,110	63,875,000	No	
Selenium	ND	6,253	No	
Silver	19	6,388	No	
Sodium	555	43,800,000	No	
Strontium	91.6	766,500	No	
Thallium	4.73 J	Not Available	No	
Vanadium	41.2	6,388	No	
Zinc	3,290	383,250	No	

[a] See Table 4-6.

J Indicates estimated concentration.

Table 4-9
Selection of Surface Water COPCs

	Maximum Detection (ug/L)	EPA Regional Screening Level for Tap Water (ug/L)	Max Detection > Screening Level?	COPC
Aluminum	30.2	37,000	No	
Antimony	0.25	15	No	
Arsenic	**0.685**	**0.045**	**Yes**	**X**
Beryllium	0.05	73	No	
Cadmium	6.17	18	No	
Calcium	12,500	40,556 (FDA DV)	No	
Chromium	**0.25**	**0.043**	**Yes**	**X**
Copper	3.35	1,500	No	
Iron	50	26,000	No	
Lead	**34**	**15 (Action Level)**	**Yes**	**X**
Magnesium	1,360	16,222 (FDA DV)	No	
Manganese	172	880	No	
Mercury	0.05	2.0 (MCL)	No	
Nickel	0.25	730	No	
Potassium	893	141,944 (FDA DV)	No	
Selenium	0.25	180	No	
Silica	12,800	Not Established	No	
Silver	0.05	180	No	
Sodium	3,330	97,333 (FDA DV)	No	
Strontium	136	22,000	No	
Thallium	0.25	2.0 (MCL)	No	
Vanadium	5	180	No	
Zinc	1,450	11,000	No	

FDA DV – Food and Drug Administration daily value (Daily Reference Values (DRVs) and Reference Daily Intakes (RDIs)) (http://www.fda.gov)
Action Level = Maximum Contaminant Level, EPA National Primary Drinking Water Regulations
MCL = Maximum Contaminant Level, EPA National Primary Drinking Water Regulations

Table 4-10
Exposure Point Concentrations

	ATV RIDER (Child & Adult)		ROCK HUNTER (Child & Adult)		
	CR-503 Soil EPC [a] mg/kg	Air EPC [b] ug/m^3	Waste Rock Soil EPC [a] mg/kg	Rock Hunter Air EPC [d] ug/m^3	Surface Water EPC [f] ug/L
Arsenic	78.6	4.8 [c]	766	0.0006 [e]	0.685
Cadmium	7.5	0.5 [c]	81.7	0.0001 [e]	--
Chromium	11.6	0.7 [c]	3.8	0.0000 [e]	0.25
Lead	761	188	29,493	11	34
Manganese	1,418	139	4,047	0.0030 [e]	--

[a] EPC calculated as Upper 95[th] percentile confidence limit (UCL95) using ProUCL Version 4.00.05 (see Appx D)

[b] EPC is the maximum detected value from the June 2010 ATV air sampling.

[c] Not detected and/or not analyzed in June 2010 ATV air sampling along CR-503. Analytical detection limits from the air sampling are too great to eliminate as a COPC. In the absence of a measured value, air EPC estimated based on concentration in soil from CR-503 multiplied by a particulate emission factor (PEF). PEF derived from air data from ATV riding along CR-503 coupled with soil data from the segment of CR-503 traveled during air sampling. (PEF = 6.08E-05 kg/m^3 for ATV riding, see Appendix E.)

[d] EPC is the maximum detected value from June 2010 stationary air sampling.

[e] Not detected and/or not analyzed in June 2010 stationary air sampling. Analytical detection limits from the air sampling too great to eliminate as a COPC. In the absence of a measured value, the concentration in air is estimated based on the EPA default PEF for wind erosion (PEF = 7.35E-10 kg/m^3 for rock hunting).

[f] EPC is the maximum detected value from June 2010 surface water sampling.

-- Not a COPCs for this media

Table 4-11
Exposure Parameters for Adult ATV Riders

			Adult CTE	Source	Adult RME	Source
General	Body Weight	kg	70	[1]	70	[1]
	Exposure Frequency	Days/yr	6	[2]	20	[2]
	Exposure Duration	yr	9	[2]	30	[2]
	AT, Cancer	yr	70	[1]	70	[1]
	AT, Noncancer	yr	9	[1]	30	[1]
Inhalation of Particulates	Exposure Time	hr/day	1.5	[2]	2.5	[2]
	TWF (noncancer)	unitless	1.03E-03		5.71E-03	
	TWF (cancer)	unitless	1.32E-04		2.45E-03	
Ingestion of Soil	Ingestion Rate	mg/d	50	[2,3,a]	100	[2,3,b]
	Conversion Factor	kg/mg	1E-06	--	1E-06	--
	Relative Bioavailability	Unitless	See note	[c]	See note	[c]
	HIF (noncancer)	kg/kg-d	1.17E-08		7.38E-08	
	HIF (cancer)	kg/kg-d	1.51E-09		3.35E-08	

[1] USEPA 1989. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. December

[2] SRC 2008. Baseline Human Health Risk Assessment for the Standard Mine Site, Gunnison County, CO (Adult ATV Rider, Table 4-1)

[3] USEPA 1997. Exposure Factors Handbook.

Notes:

[a] Mean soil ingestion rate (USEPA 1997, Table 4-23).

[b] Assumes RME ingestion rate is 2 times CTE ingestion rate (USEPA 1997, Table 4-23).

[c] Relative bioavailability (RBA) data is limited for most metals. As a conservative assumption, an RBA of 1.0 was applied for all metals except arsenic, for which an RBA of 0.5 was applied (based on current EPA Region 8 recommendations from http://www.epa.gov/region8/r8risk/hh_rba.html (EPA, 2011)).

Table 4-12
Exposure Parameters for Child ATV Riders

			Child CTE	Source	Child RME	Source
General	Body Weight	kg	33	[1]	33	[1]
	Exposure Frequency	Days/yr	6	[3]	20	[3]
	Exposure Duration	yr	2	[3]	6	[3]
	AT, Cancer	yr	70	[2]	70	[2]
	AT, Noncancer	yr	2	[2]	6	[2]
Inhalation of Particulates	Exposure Time	hr/day	1.5	[2]	2.5	[2]
	TWF (noncancer)	m^3/kg-d	1.03E-03		5.71E-03	
	TWF (cancer)	m^3/kg-d	2.94E-05		4.89E-04	
Ingestion of Soil	Ingestion Rate	mg/d	50	[1,2,a]	100	[1,2,b]
	Conversion Factor	kg/mg	1E-06	--	1E-06	--
	Relative Bioavailability	Unitless	See note	[c]	See note	[c]
	HIF (noncancer)	kg/kg-d	2.49E-08		1.66E-07	
	HIF (cancer)	kg/kg-d	7. 12E-10		1.42E-08	

[1] USEPA 1997. Exposure Factors Handbook (body weight based on a child 6 to 12 years of age).

[2] USEPA 1989. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. December

[3] SRC 2008. Baseline Human Health Risk Assessment for the Standard Mine Site, Gunnison County, CO (Child ATV Rider, Table 4-1)

Notes:

[a] Mean soil ingestion rate (USEPA 1997, Table 4-23).

[b] Assumes RME ingestion rate is 2 times CTE ingestion rate (USEPA 1997, Table 4-23).

[c] Relative bioavailability (RBA) data is limited for most metals. As a conservative assumption, an RBA of 1.0 was applied for all metals except arsenic, for which an RBA of 0.5 was applied (based on current EPA Region 8 recommendations from http://www.epa.gov/region8/r8risk/hh_rba.html (EPA, 2011)).

Table 4-13
Exposure Parameters for Adult Rock Hunters/Hikers

			Adult CTE	Source	Adult RME	Source
General	Body Weight	kg	70	[1]	70	[1]
	Exposure Frequency	Days/yr	6	[2]	20	[2]
	Exposure Duration	yr	9	[2]	30	[2]
	Averaging Time (AT), Cancer	yr	70	[1]	70	[1]
	AT, Noncancer	yr	9	[1]	30	[1]
Ingestion of Soil	Ingestion Rate	mg/d	25	[2,3,a]	50	[2,3,b]
	Conversion Factor	kg/mg	1E-06		1E-06	
	Relative Bioavailability	Unitless	See note	[c]	See note	[c]
	HIF (noncancer)	kg/kg-d	5.87E-09		3.91E-08	
	HIF (cancer)	kg/kg-d	7.55E-10		1.68E-08	
Ingestion of Surface Water	Ingestion Rate	mL/hour	5	[2,d]	30	[2, e]
	Exposure Time	hr/day	0.5	[2]	1.5	[2]
	Conversion Factor	L/mL	1E-03	--	1E-03	--
	HIF(noncancer)	L/kg-d	5.87E-07		3.52E-05	
	HIF(cancer)	L/kg-d	7.55E-08		1.51E-05	
Inhalation of Particulates	Exposure Time	hr/day	1.5	[2]	2.5	[2]
	TWF (noncancer)	unitless	1.03E-03		5.71E-03	
	TWF (cancer)	unitless	1.32E-04		2.45E-03	

[1] USEPA 1989. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. December

[2] SRC 2008. Baseline Human Health Risk Assessment for the Standard Mine Site, Gunnison County, CO (Adult Hiker Rider, Table 4-2)

[3] USEPA 1997. Exposure Factors Handbook.

[a] Assumes CTE soil ingestion is one half of the adult ingestion rate from USEPA 1997, Table 4-23

[b] Assumes RME soil ingestion is equal to adult ingestion rate from USEPA 1997, Table 4-23

[c] Relative bioavailability (RBA) data is limited for most metals. As a conservative assumption, an RBA of 1.0 was applied for all metals except arsenic, for which an RBA of 0.5 was applied (based on current EPA Region 8 recommendations from http://www.epa.gov/region8/r8risk/hh_rba.html (EPA, 2011)).

[d] Incidental ingestion from splashing or hand-to-face contact during wading assumed to be 10% of USEPA (1989) recommended default (50 ml/hr) incidentally ingested during swimming.

[e] 30 mL/hr is the basis for the 10 mL/day value proposed for a recreational scenario by the Draft Water Quality Criteria Methodology Revisions (USEPA 1998).

Table 4-14
Exposure Parameters for Child Rock Hunters/Hikers

			Child CTE	Source	Child RME	Source
General	Body Weight	kg	33	[1]	33	[1]
	Exposure Frequency	Days/yr	6	[2]	20	[2]
	Exposure Duration	yr	2	[2]	6	[2]
	Averaging Time (AT), Cancer	yr	70	[1]	70	[1]
	AT, Noncancer	yr	2	[1]	6	[1]
Ingestion of Soil	Ingestion Rate	mg/d	25	[1,2,a]	50	[1,2,b]
	Conversion Factor	kg/mg	1E-06		1E-06	
	Relative Bioavailability	Unitless	See note	[c]	See note	[c]
	HIF (noncancer)	kg/kg-d	5.87E-09		3.91E-08	
	HIF (cancer)	kg/kg-d	7.55E-10		1.68E-08	
Ingestion of Surface Water	Ingestion Rate	mL/hour	5	[2,d]	30	[2, e]
	Exposure Time	hr/day	0.5	[2]	1.5	[2]
	Conversion Factor	L/mL	1E-03	--	1E-03	--
	HIF(noncancer)	L/kg-d	5.87E-07		3.52E-05	
	HIF(cancer)	L/kg-d	7.55E-08		1.51E-05	
Inhalation of Particulates	Exposure Time	hr/day	1.5	[2]	2.5	[2]
	HIF (noncancer)	m^3/kg-d	1.03E-03		5.71E-03	
	HIF (cancer)	m^3/kg-d	2.94E-05		4.89E-04	

[1] USEPA 1997. Exposure Factors Handbook (body weight based on a child 6 to 12 years of age).

[2] SRC 2008. Baseline Human Health Risk Assessment for the Standard Mine Site, Gunnison County, CO (Child Recreations Visitor, Table 4-4)

[3] USEPA 1989. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. December

[a] Assumes CTE soil ingestion is one half of the adult ingestion rate from USEPA 1997, Table 4-23

[b] Assumes RME soil ingestion is equal to adult ingestion rate from USEPA 1997, Table 4-23

[c] Relative bioavailability (RBA) data is limited for most metals. As a conservative assumption, an RBA of 1.0 was applied for all metals except arsenic, for which an RBA of 0.5 was applied (based on current EPA Region 8 recommendations from http://www.epa.gov/region8/r8risk/hh_rba.html (EPA, 2011)).

[d] Incidental ingestion from splashing or hand-to-face contact during wading assumed to be 10% of USEPA (1989) recommended default (50 ml/hr) incidentally ingested during swimming.

[e] 30 mL/hr is the basis for the 10 mL/day value proposed for a recreational scenario by the Draft Water Quality Criteria Methodology Revisions (USEPA 1998).

Table 4-15
Toxicity Values

	Oral SF (mg/kg-day)$^{-1}$	Source	Oral RfD mg/kg-day	Source	Inhalation Unit Risk (µg/m^3)$^{-1}$	Source	Inhalation RfC mg/m^3	Source
Aluminum	--	--	1.00E+00	P [1]	--	--	5.0E-03	P [1]
Antimony	--	--	4.00E-04	I [1]	--	--	--	--
Arsenic	1.50E+00	I [1]	3.00E-04	I [1]	4.3E-03	I [1]	1.5E-05	C [1]
Beryllium	--	--	2.00E-03	I [1]	2.4E-03	I [1]	2.0E-05	I
Cadmium-food	--	--	1.00E-03	I [1]	1.8E-03	I [1]	1.0E-05	A [1]
Cadmium-water	--	--	5.00E-04	I [1]	1.8E-03	I [1]	1.0E-05	A [1]
Calcium	--	--	1.4E+01	FDA	--	--	--	--
ChromiumIII	--	--	1.50E+00	I [1]	--	--	--	--
ChromiumVI	--	--	3.00E-03	I [1]	8.4E-02	I [1]	1.0E-04	I [1]
Copper	--	--	4.00E-02	H [1]	--	--	--	--
Iron	--	--	7.00E-01	P [1]	--	--	--	--
Magnesium	--	--	5.7E+00	FDA	--	--	--	--
Manganese-food	--	--	1.40E-01	I [1]	--	--	5.0E-05	I [1]
Manganese-water	--	--	2.40E-02	I [1]	--	--		I [1]
Mercury	--	--	3.00E-04	I [1]	--	--	--	--
Nickel	--	--	2.00E-02	I [1,2]	2.6E-04	I [1,2]	9.0E-05	I [1,2]
Potassium	--	--	5.0E+01	FDA	--	--	--	--
Selenium	--	--	5.00E-03	I [1]	--	--	2.0E-02	C [1]
Silica(SiO2)	--	--	--		--	--	3.0E-03	C [1]
Silver	--	--	5.00E-03	I [1]	--	--	--	--
Sodium	--	--	3.4E+01	FDA	--	--	--	--
Strontium	--	--	6.00E-01	I	--	--	--	--
Thallium	--	--	--	--	--	--	--	--
Vanadium	--	--	5.00E-03	[1, 3]	--	--	--	--
Zinc	--	--	3.00E-01	I [1]	--	--	--	--

SF = Cancer Slope Factor RfC – Noncancer Reference Concentration RfD = Noncancer Reference Dose
I – IRIS P - EPA Provisional Peer-Reviewed Value A – ATSDR C – Cal EPA FDA – Food and Drug Administration Daily Reference Values (DRVs)/Reference Daily Intakes (RDIs) (http://www.fda.gov)
[1] - As cited in EPA Regional Screening Levels, May 2010
[2] – Value for Nickel Soluble Salts
[3] – Derived from IRIS oral RfD for Vanadium Pentoxide by factoring out molecular weight of oxide ion.

Table 4-16
Risk Summary – Adult Rock Hunter

	EPCs			CTE Exposure Cancer Risk				RME Exposure Cancer Risk			
	Soil EPC (mg/kg)	**Air EPC [a] (ug/m^3)**	**Surface Water (mg/L)**	**Soil Ingestion**	**Inhalation**	**Water Ingestion**	**Total**	**Soil Ingestion**	**Inhalation**	**Water Ingestion**	**Total**
Arsenic	766	0.0006	0.685	8.7E-07	3.2E-13	7.8E-11	8.7E-07	1.9E-05	5.9E-12	1.6E-08	1.9E-05
Cadmium	81.7	0.0001	--	--	1.4E-14	--	1.4E-14	--	2.6E-13	--	2.6E-13
Chromium [b]	3.8	0.0000	0.25	--	4.6E-15	--	4.6E-15	--	1.2E-14	--	1.2E-14
Manganese	4,047	0.0030	--	--		--	--	--	--	--	
Total Risk				**8.7E-07**	**3.4E-13**	**7.8E-11**	**8.7E-07**	**1.9E-05**	**6.2E-12**	**1.6E-08**	**1.9E-05**
	EPCs			**CTE Exposure Non-Cancer Hazards**				**RME Exposure Non-Cancer Hazards**			
	Soil EPC (mg/kg)	**Air EPC [a] (ug/m^3)**	**Surface Water (mg/L)**	**Soil Ingestion HQ**	**Inhalation HQ**	**Water Ingestion**	**Hazard Index**	**Soil Ingestion HQ**	**Inhalation HQ**	**Water Ingestion HQ**	**Hazard Index**
Arsenic	766	0.0006	0.685	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1
Cadmium	81.7	0.0001	--	<0.1	<0.1	--	<0.1	<0.1	<0.1		<0.1
Chromium [b]	3.8	0.0000	0.25	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	4,047	0.0030	--	<0.1	<0.1	--	<0.1	<0.1	<0.1		<0.1
Cumulative HI				**<0.1**	**<0.1**	**<0.1**	**<0.1**	**0.1**	**<0.1**	**<0.1**	**0.1**

[a] Either not detected or not included in stationary air sampling. Air EPC calculated from soil EPC multiplied by EPA default PEF for wind erosion.
[b] Because the valence state of chromium in soil at the site is not known, it was assumed that 85% of the chromium in soil exists in the trivalent form and 15% exists in the more toxic hexavalent form (assumes 6:1 ratio for hexavalent to trivalent forms).

Table 4-17
Risk Summary – Child Rock Hunter

	EPCs			CTE Exposure Cancer Risk				RME Exposure Cancer Risk			
	Soil EPC (mg/kg)	**Air EPC [a] (ug/m^3)**	**Surface Water (mg/L)**	**Soil Ingestion**	**Inhalation**	**Water Ingestion**	**Total**	**Soil Ingestion**	**Inhalation**	**Water Ingestion**	**Total**
Arsenic	766	0.0006	0.685	4.1E-07	7.1E-14	3.7E-11	4.1E-07	8.2E-06	1.2E-12	6.6E-09	8.2E-06
Cadmium	81.7	0.0001	--	--	3.2E-15	--	3.2E-15	--	5.3E-14	--	5.3E-14
Chromium [b]	3.8	0.0000	0.25	--	1.0E-15	--	1.0E-15	--	1.7E-14	--	1.7E-14
Manganese	4,047	0.0030	--	--		--	--	--	--	--	
Total Risk				**4.1E-07**	**7.5E-14**	**3.7E-11**	**4.1E-07**	**8.2E-06**	**1.3E-12**	**6.6E-09**	**8.2E-06**
	EPCs			**CTE Exposure Non-Cancer Hazards**				**RME Exposure Non-Cancer Hazards**			
	Soil EPC (mg/kg)	**Air EPC [a] (ug/m^3)**	**Surface Water (mg/L)**	**Soil Ingestion HQ**	**Inhalation HQ**	**Water Ingestion**	**Hazard Index**	**Soil Ingestion HQ**	**Inhalation HQ**	**Water Ingestion HQ**	**Hazard Index**
Arsenic	766	0.0006	0.685	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.2
Cadmium	81.7	0.0001	--	<0.1	<0.1	--	<0.1	<0.1	<0.1		<0.1
Chromium [b]	3.8	0.0000	0.25	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	4,047	0.0030	--	<0.1	<0.1	--	<0.1	<0.1	<0.1		<0.1
Cumulative HI				**<0.1**	**<0.1**	**<0.1**	**<0.1**	**0.2**	**<0.1**	**<0.1**	**0.2**

[a] Either not detected or not included in stationary air sampling. Air EPC calculated from soil EPC multiplied by EPA default PEF for wind erosion.
[b] Because the valence state of chromium in soil at the site is not known, it was assumed that 85% of the chromium in soil exists in the trivalent form and 15% exists in the more toxic hexavalent form (assumes 6:1 ratio for hexavalent to trivalent forms).

Table 4-18
Risk Summary – Adult ATV Rider[a]

	EPCs		CTE Exposure Cancer Risk			RME Exposure Cancer Risk		
	Soil EPC (mg/kg)	**Air EPC (ug/m^3)**	**Soil Ingestion**	**Inhalation**	**Total**	**Soil Ingestion**	**Inhalation**	**Total**
Arsenic	78.6	4.8[b]	1.8E-07	2.7E-09	1.8E-07	4.0E-06	5.0E-08	4.0E-06
Cadmium	7.5	0.5 [b]	--	1.1E-10	1.1E-10	--	2.0E-09	2.0E-09
Chromium [c]	11.6	0.7 [b]	--	1.2E-09	1.2E-09	--	2.2E-08	2.2E-08
Manganese	1,418	139.0	--	--	--	--	--	--
Total Risk			**1.8E-07**	**4.0E-09**	**1.8E-07**	**4.0E-06**	**7.4E-08**	**4.0E-06**
	EPCs		**CTE Exposure Non-Cancer Hazards**			**RME Exposure Non-Cancer Hazards**		
	Soil EPC (mg/kg)	**Air EPC (ug/m^3)**	**Soil Ingestion HQ**	**Inhalation HQ**	**Hazard Index**	**Soil Ingestion HQ**	**Inhalation HQ**	**Hazard Index**
Arsenic	78.6	4.8[b]	<0.1	0.3	0.3	<0.1	1.8	1.8
Cadmium	7.5	0.5 [b]	--	<0.1	<0.1	--	0.3	0.3
Chromium [c]	11.6	0.7 [b]	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	1,418	139.0	<0.1	2.9	2.9	<0.1	15.9	15.9
Cumulative HI			**<0.1**	**3.2**	**3.2**	**<0.1**	**18.0**	**18.0**

[a] On-site ATV rider is assumed to travel along CR-503 within the site boundary and immediately near the site boundary in the area traversed by ATV riding during the June 2010 ABS sampling (See Figure 3-4). Risks are estimated using CR-503 road base soil sampling data (UCL95 concentrations) and air data from ATV riding on CR-503 (maximum detected concentrations).

[b] COPC was either not detected or not included in air sampling. Air EPC calculated from soil EPC multiplied by a site-specific PEF derived from air data collected while ATV riding along CR-503 near the Commodore waste rock pile coupled with soil data from the portion of CR-503 traversed during the air sampling.

[c] Because the valence state of chromium in soil at the site is not known, it was assumed that 85% of the chromium in soil exists in the trivalent form and 15% exists in the more toxic hexavalent form (assumes 6:1 ratio for hexavalent to trivalent forms).

Table 4-19
Risk Summary – Child ATV Rider[a]

	EPCs		CTE Exposure Cancer Risk			RME Exposure Cancer Risk		
	Soil EPC (mg/kg)	**Air EPC (ug/m^3)**	**Soil Ingestion**	**Inhalation**	**Total**	**Soil Ingestion**	**Inhalation**	**Total**
Arsenic	78.6	4.8 [b]	8.4E-08	6.0E-10	8.5E-08	1.7E-06	1.0E-08	1.7E-06
Cadmium	7.5	0.5 [b]	--	2.4E-11	2.4E-11	--	4.0E-10	4.0E-10
Chromium [c]	11.6	0.7 [b]	--	2.6E-10	2.6E-10	--	4.3E-09	4.3E-09
Manganese	1,418	139.0	--	--	--	--	--	--
Total Risk			**8.4E-08**	**8.9E-10**	**8.5E-08**	**1.7E-06**	**1.5E-08**	**1.7E-06**
	EPCs		**CTE Exposure Non-Cancer Hazards**			**RME Exposure Non-Cancer Hazards**		
	Soil EPC (mg/kg)	**Air EPC (ug/m^3)**	**Soil Ingestion HQ**	**Inhalation HQ**	**Hazard Index**	**Soil Ingestion HQ**	**Inhalation HQ**	**Hazard Index**
Arsenic	78.6	4.8 [b]	<0.1	0.3	0.3	<0.1	1.8	1.8
Cadmium	7.5	0.5 [b]	--	<0.1	<0.1	--	0.3	0.3
Chromium [c]	11.6	0.7 [b]	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Manganese	1,418	139.0	<0.1	2.9	2.9	<0.1	15.9	15.9
Cumulative HI			**<0.1**	**3.2**	**3.2**	**<0.1**	**18.0**	**18.0**

[a] On-site ATV rider is assumed to travel along CR-503 within the site boundary and immediately near the site boundary in the area traversed by ATV riding during the June 2010 ABS sampling (See Figure 3-4). Risks are estimated using CR-503 road base soil sampling data (UCL95 concentrations) and air data from ATV riding on CR-503 (maximum detected concentrations).

[b] COPC was either not detected or not included in air sampling. Air EPC calculated from soil EPC multiplied by a site-specific PEF derived from air data collected while ATV riding along CR-503 near the Commodore waste rock pile coupled with soil data from the portion of CR-503 traversed during the air sampling.

[c] Because the valence state of chromium in soil at the site is not known, it was assumed that 85% of the chromium in soil exists in the trivalent form and 15% exists in the more toxic hexavalent form (assumes 6:1 ratio for hexavalent to trivalent forms).

Table 4-20
Evaluation of Lead Risks

Inputs	Units	Rock Hunter	ATV Rider
Ratio	ug/dL per ug/dL	0.9	0.9
GSD	--	1.8	1.8
PbB0	ug/dL	1.0	1.0
BKSF	ug/dL per ug/day	0.4	0.4
AT	days/yr	365	365
Csoil (95% UCL)	ug/g	29,493	761
IRsoil	g/day	0.025	0.05
AFsoil	ug absorbed per ug ingested	0.12	0.12
EF	days/yr	6	6
Cair (Max Detection)	ug/m3	11	188
BR	m3/hr	2.4	2.4
ET	hr/day	1.5	1.5
AFa		1	1
EF	days/yr	6	6
Csw (Max Detection)	ug/L	34	
IRsw	L/day	0.0025	
AF		0.2	
EF	days/yr	6	
Results			
Absorbed Dose from Soil	ug/day	1.45	0.08
Absorbed Dose from Inhalation	ug/day	0.65	11.13
Absorbed Dose from Surface Water	ug/day	0.00	
PbBmother	ug/dL	1.8	5.5
P10 (fetus)		**0.11%**	**11.5%**

Table 4-21
Adult Lead Model Inputs

Parameter	Units	ATV Rider	Rock Hunter	Source
Ratio	ug/dL per ug/dL	0.9	0.9	USEPA 2003 (default)
GSD	--	1.8	1.8	USEPA 2009
PbB0	ug/dL	1.0	1.0	USEPA 2009
BKSF	ug/dL per ug/day	0.4	0.4	USEPA 2003 (default)
IRsoil	g/day	0.05	0.025	Exposure parameter (see Tables 4-11 & 4-13)
AFsoil		0.12	0.12	USEPA 2003 (default)
EF	days/yr	6	6	Exposure parameter (see Tables 4-11 & 4-13)
Cair	ug/m3	188	11	Air concentration (see Note 1)
BR	m3/hr	2.4	2.4	Exposure parameter (see Tables 4-11 & 4-13)
ET	hr/day	1.5	1.5	Exposure parameter (see Tables 4-11 & 4-13)
EF	days/yr	6	6	Exposure parameter (see Tables 4-11 & 4-13)
AFair		1.0	1.0	Professional judgment
Csw	ug/L	--	34	Max surface water concentration for lead from June 2010 sampling
IRsw	L/day	--	0.0025	Exposure parameter (see Tables 4-11 & 4-13)
AFw		--	0.2	USEPA 2003 (default)
EF	days/yr	--	6	Exposure parameter (see Tables 4-11 & 4-13)
AT	days/yr	365	365	USEPA 2003

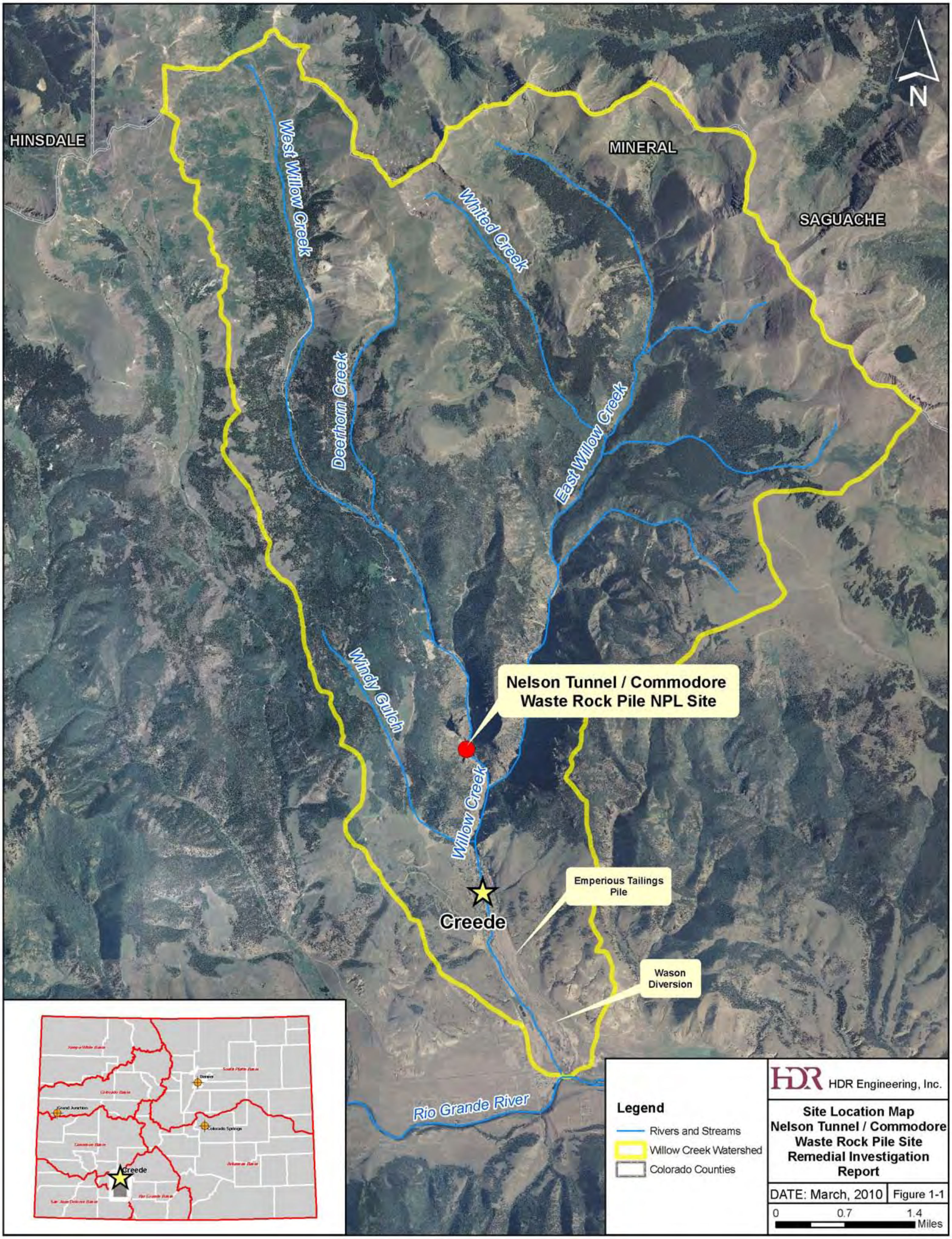
[1] Max air concentration for lead from June 2010 ATV riding samples (ATV scenario); max air concentration for lead from June 2010 stationary air samples (Rock Hunter scenario).

-- = Model input not applicable to this receptor.

USEPA 2003, Recommendations of the TRW for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil

USEPA 2009b, Update of the Adult Lead Methodology's default Baseline Blood Lead Concentration and Geometric Standard Deviation Parameters. OSWER 9200.2-82.

FIGURES



HINSDALE
MINERAL
SAGUACHE
N
West Willow Creek
Whited Creek
Deerhorn Creek
East Willow Creek
Windy Gulch
Willow Creek
Nelson Tunnel / Commodore Waste Rock Pile NPL Site
Emperious Tailings Pile
Creede
Wason Diversion
Rio Grande River
Denver
Grand Junction
Colorado Springs
Creede
Legend
Rivers and Streams
Willow Creek Watershed
Colorado Counties
HDR Engineering, Inc.
Site Location Map
Nelson Tunnel / Commodore
Waste Rock Pile Site
Remedial Investigation
Report
DATE: March, 2010
Figure 1-1
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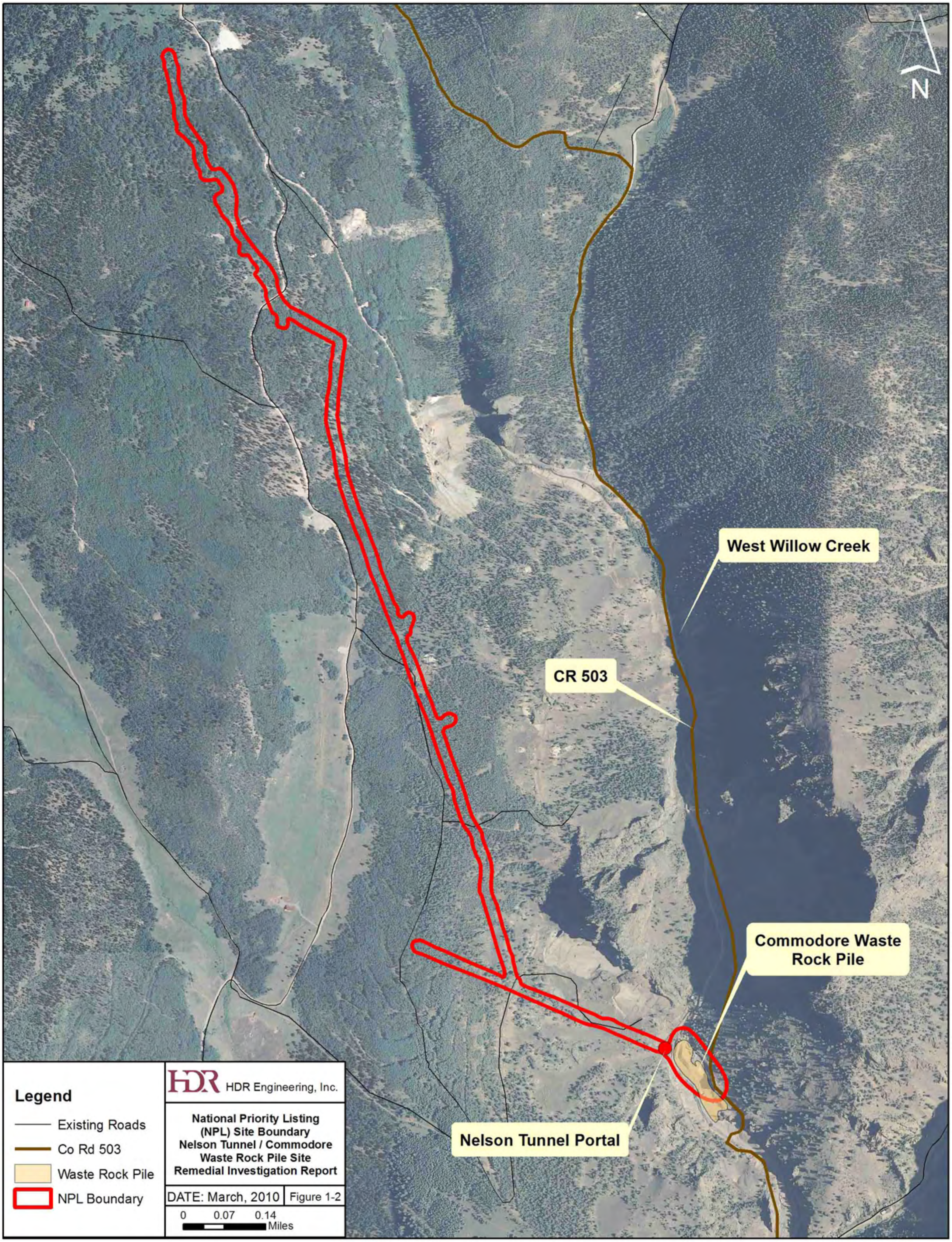
0.7
1.4
Miles



N
West Willow Creek
CR 503
Commodore Waste Rock Pile
Nelson Tunnel Portal
Legend
Existing Roads
Co Rd 503
Waste Rock Pile
NPL Boundary
HDR Engineering, Inc.
National Priority Listing (NPL) Site Boundary Nelson Tunnel / Commodore Waste Rock Pile Site Remedial Investigation Report
DATE: March, 2010
Figure 1-2
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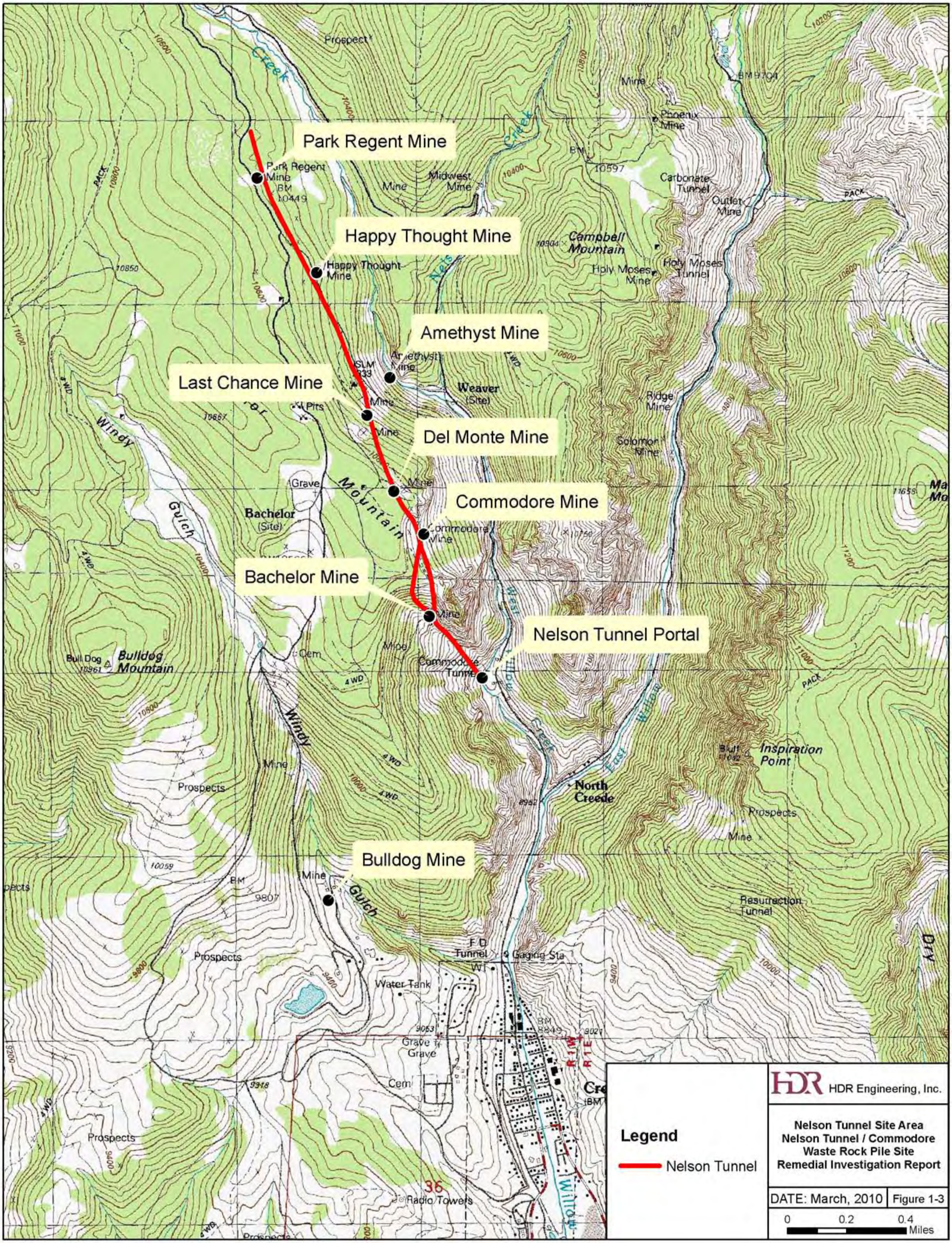

HDR Engineering, Inc.

Nelson Tunnel Site Area
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: March, 2010 | Figure 1-3

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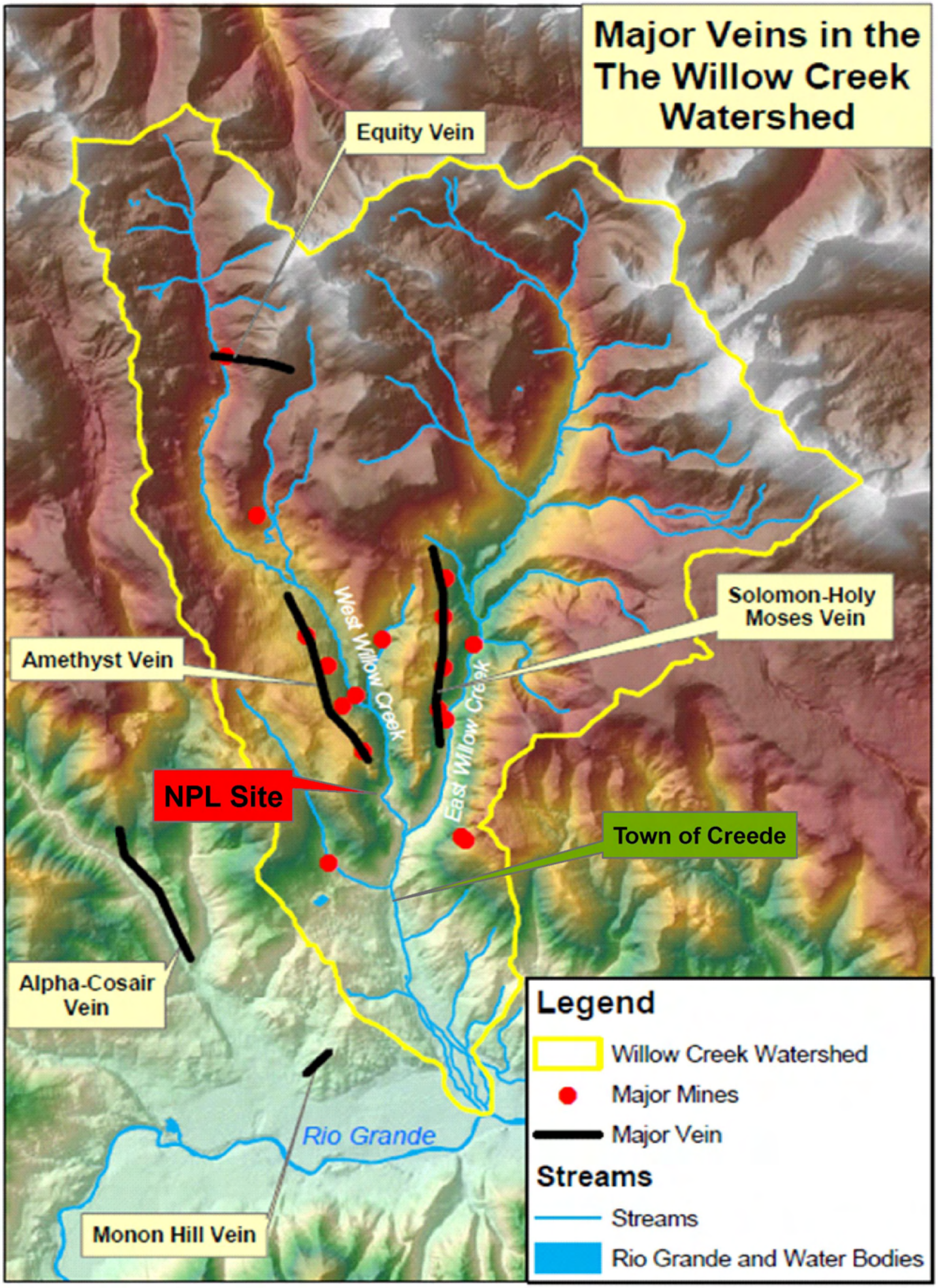
Nelson Tunnel Portal
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010

Figure 1-4



NOTE: Modified from EPA (2005).

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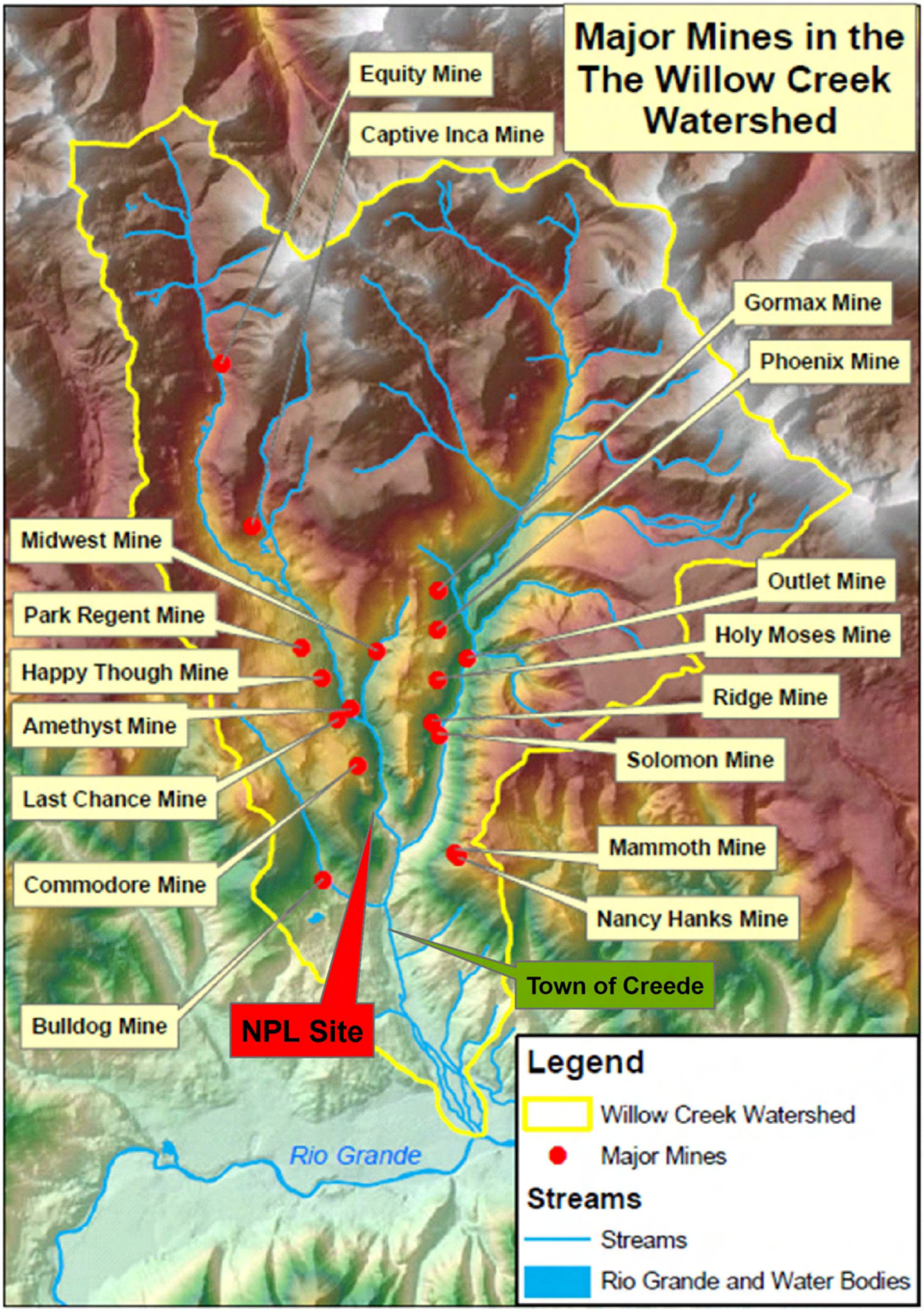
Major Veins in the Willow Creek Watershed
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010 | Figure 1-5



NOTE: Modified from EPA (2005).

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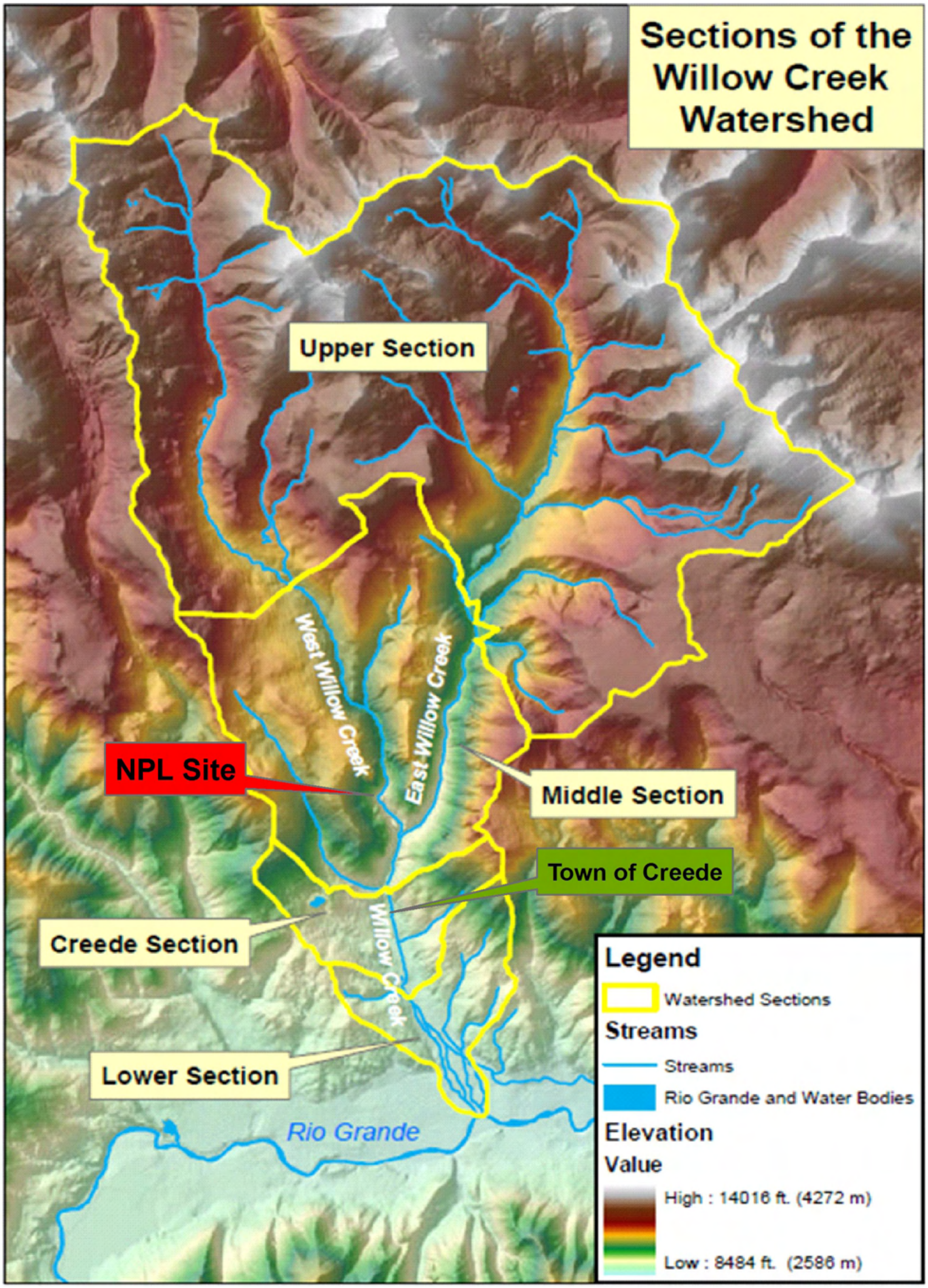
Major Mines in the Willow Creek Watershed
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010 | Figure 1-6



NOTE: Modified from EPA (2005).

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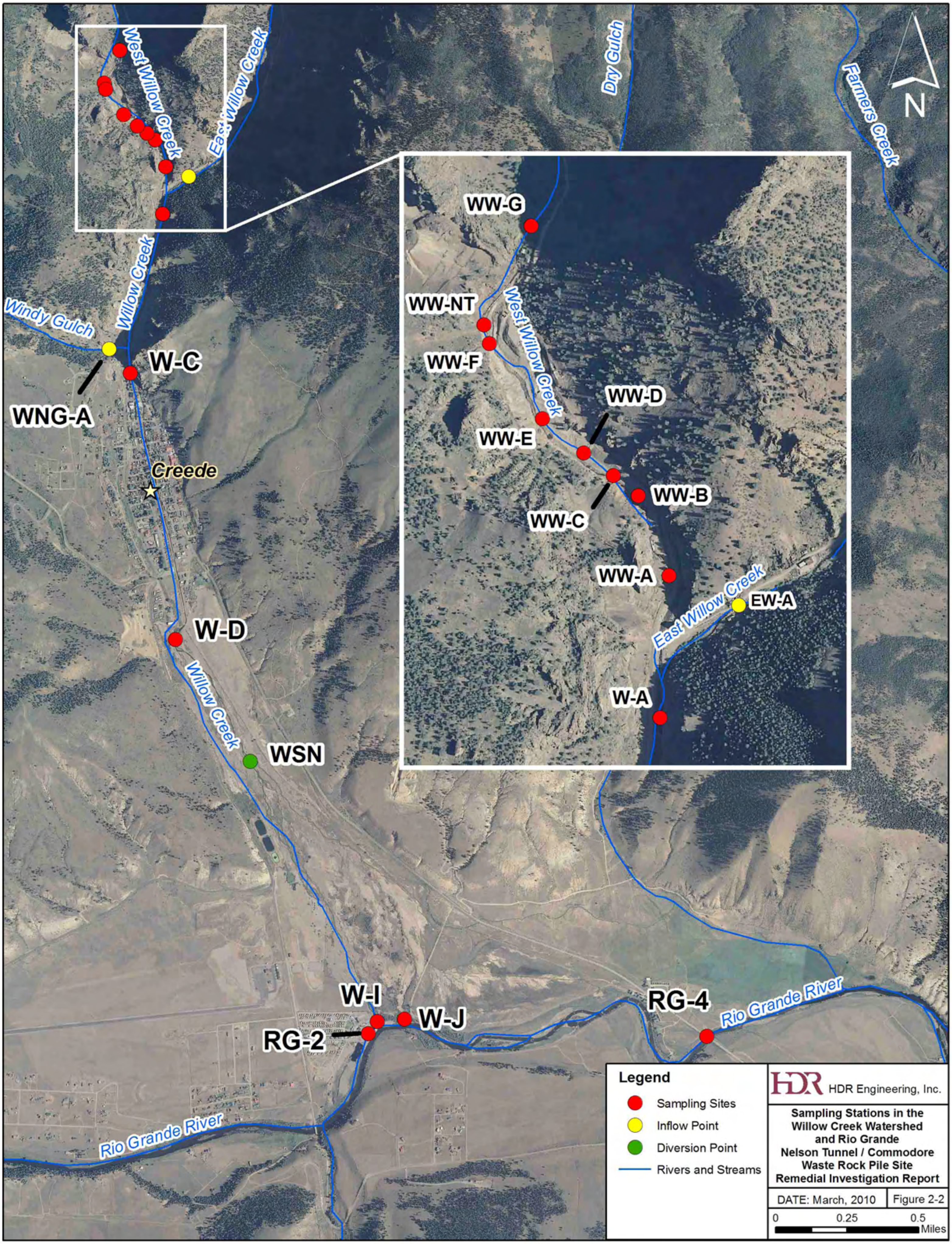
Sections of the Willow Creek Watershed
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010 | Figure 2-1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East Willow Creek
Dry Gulch
Farmers Creek
N
Willow Creek
Windy Gulch
W-C
WNG-A
Creede
W-D
Willow Creek
WSN
WW-G
WW-NT
WW-F
West Willow Creek
WW-D
WW-E
WW-B
WW-C
WW-A
East Willow Creek
EW-A
W-A
W-I
W-J
RG-2
RG-4
Rio Grande River
Rio Grande River
Legend
Sampling Sites
Inflow Point
Diversion Point
Rivers and Streams
HDR Engineering, Inc.
Sampling Stations in the Willow Creek Watershed and Rio Grande
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: March, 2010
Figure 2-2
0
0.25
0.5
Miles

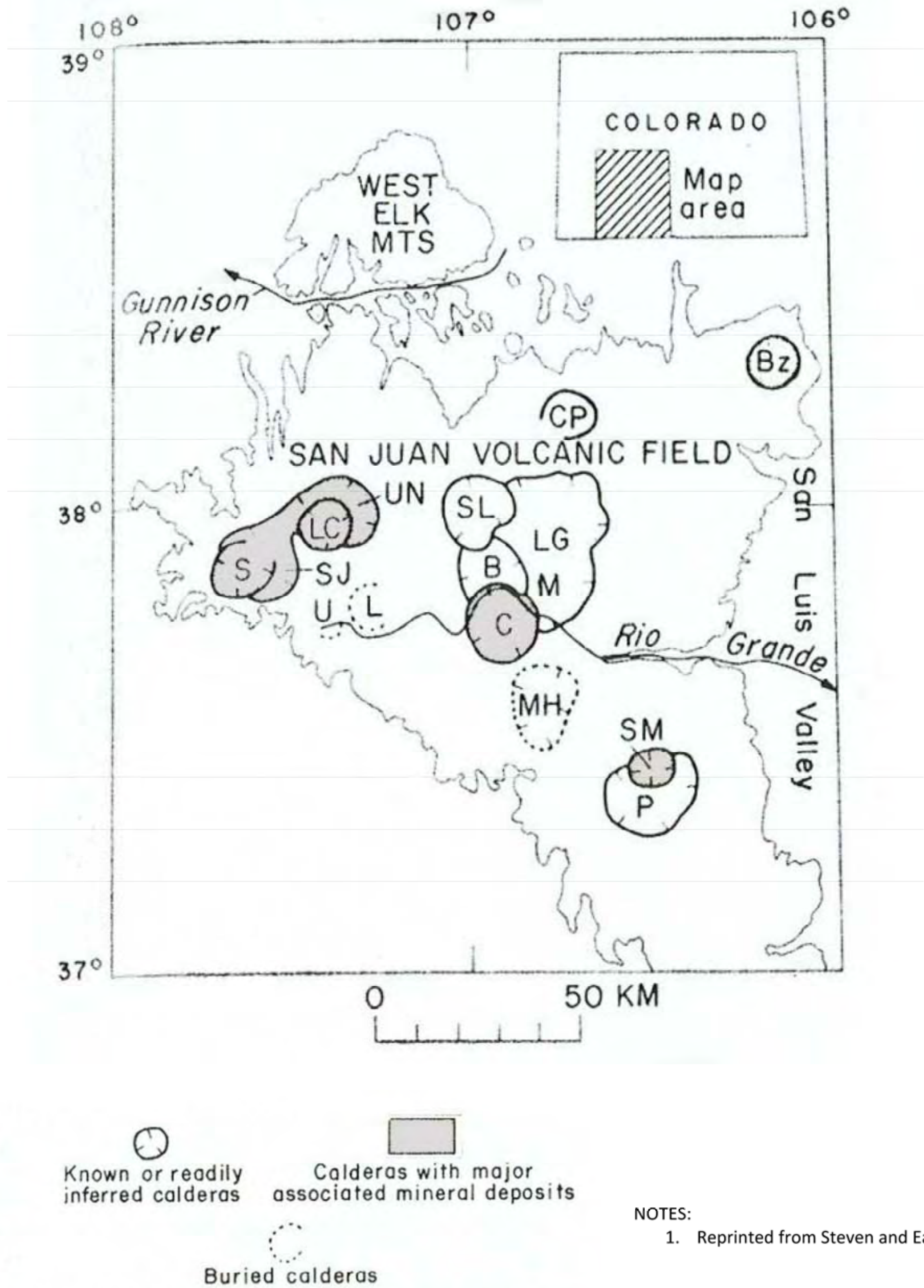

FIG. 1. Map of San Juan volcanic field showing calderas: S, Silverton; LC, Lake City; CP, Cochetopa Park; Bz, Bonanza; LG, La Garita; SL, San Luis; B, Bachelor; C, Creede; MH, Mount Hope; P, Platoro; SM, Summitville; L, Lost Lake; U, Ute Creek; SJ, San Juan; UN, Uncompahgre; M, general location of the Mammoth Mountain caldera.

NOTES:

1. Reprinted from Steven and Eaton, 1975.

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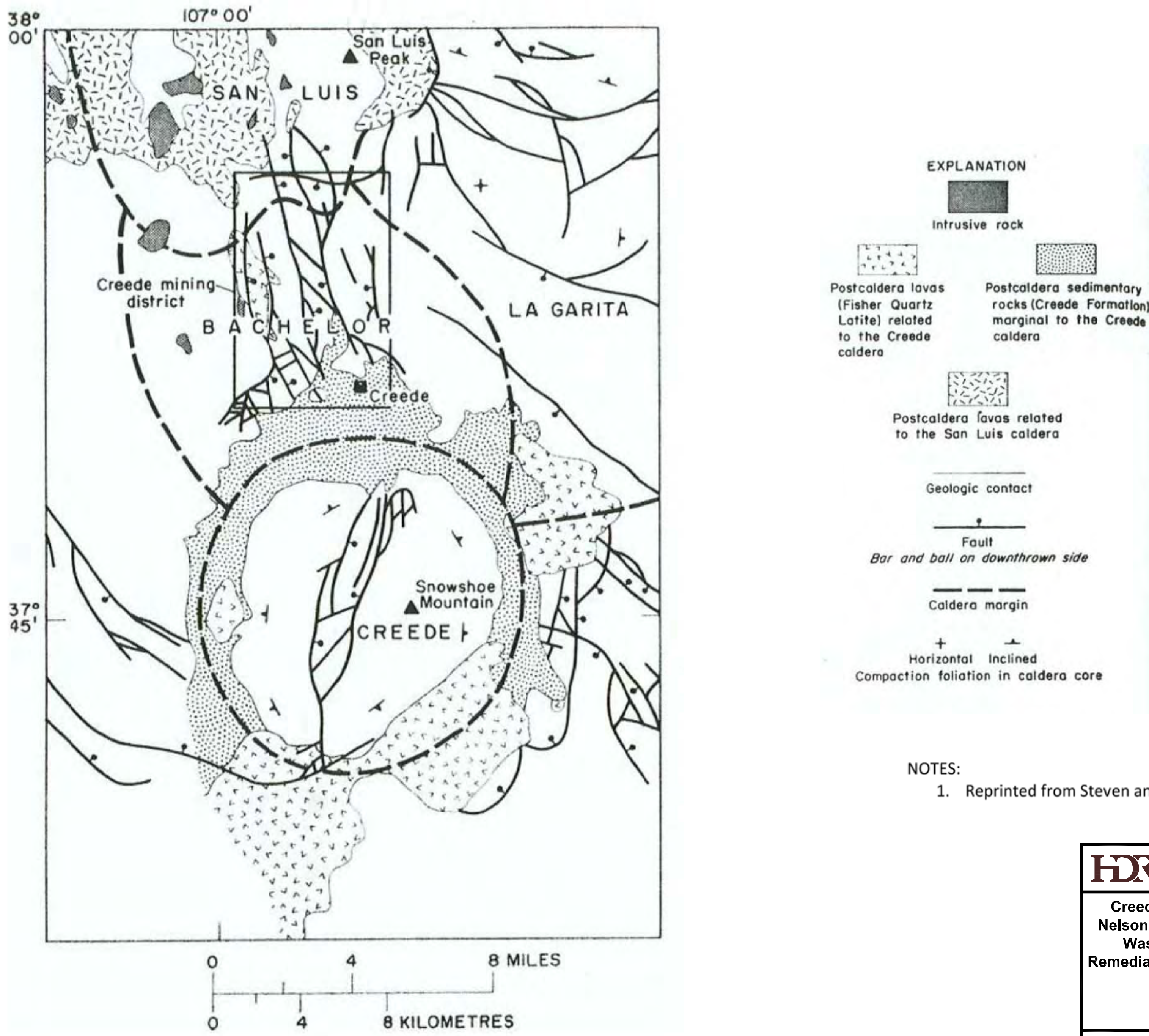
Calderas of the San Juan Mountains, Colorado
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010	Figure 2-3



NOTES:

1. Reprinted from Steven and Eaton, 1975.

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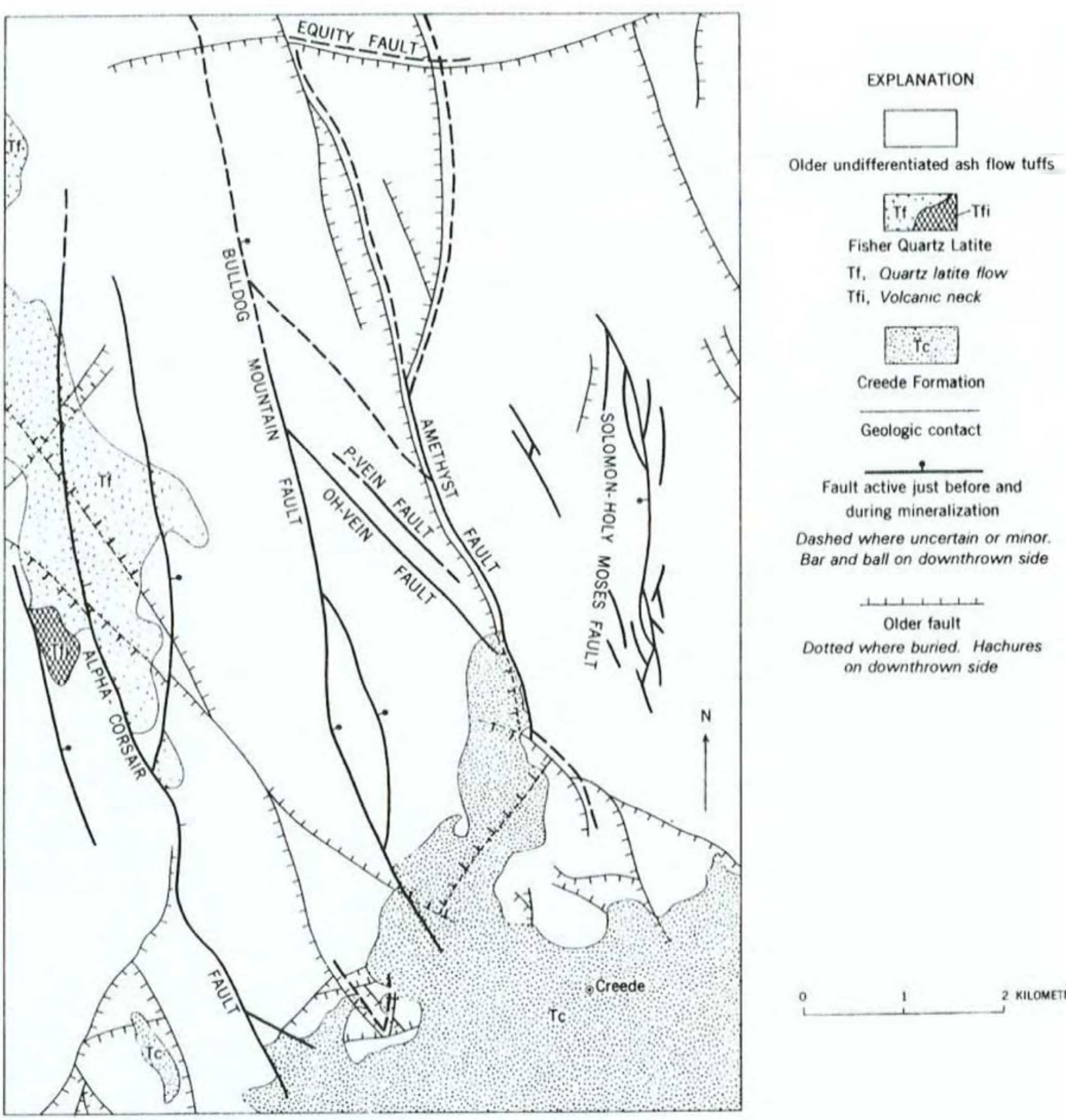
Creede District Geology
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010 | Figure 2-4



NOTES:

1. Reprinted from Bethke and Rye, 1979.

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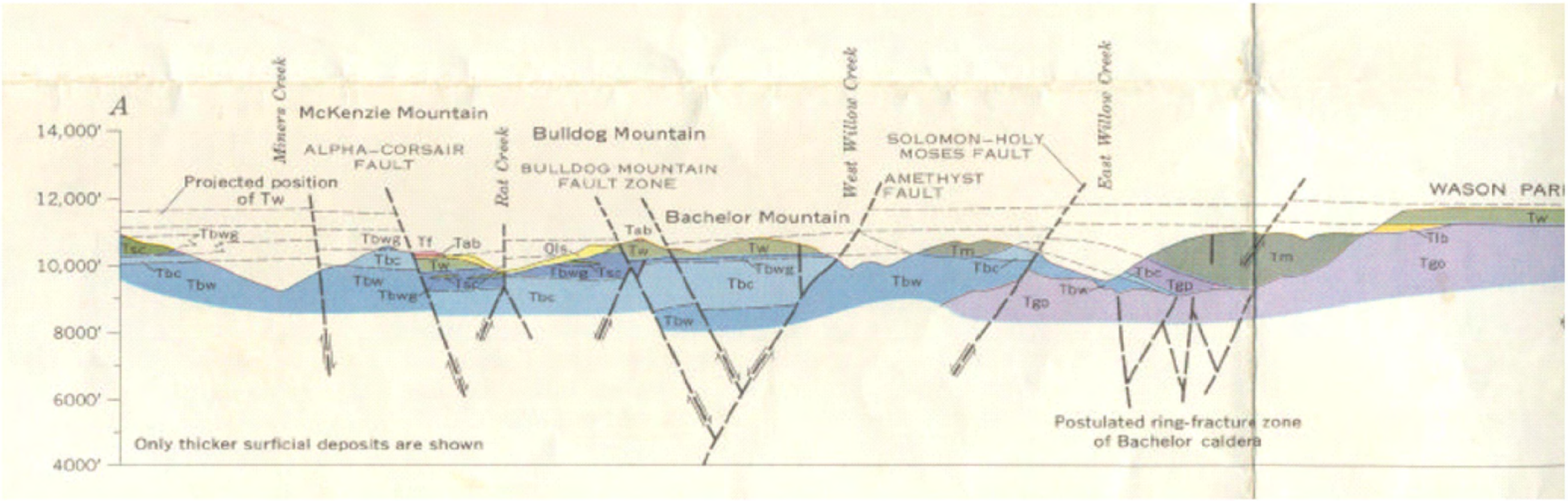
Creede District Faults
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010	Figure 2-5



- Qa - Alluvium and Terrace Gravels
- Qf - Alluvia-fan deposits
- Qls - Landslide Debris
- Qd - Glacial Drift
- Ts - Snowshoe Mountain Tuff
- Tn - Nelson Mountain Tuff
- Trc - Rat Creek Tuff
- Tw - Wason Park Tuff
- Tm - Mammoth Mountain Tuff
- Tbi, Tbwg. Tbc, Tbw - Bachelor Mountain Tuff
- Tc, Tct - Creede Formation
- Tib - Landslide Debris with tuff
- Tab - Andesite of Bristol Head
- Tf, Tfi - Fisher Quartz Latite
- Tqf, Tqi - Quartz latitic to rhyolitic lavas
- Tgp - Phoenix Park Member of La Garita Tuff
- Tgo - Outlet Tunnel Member of La Garita Tuff

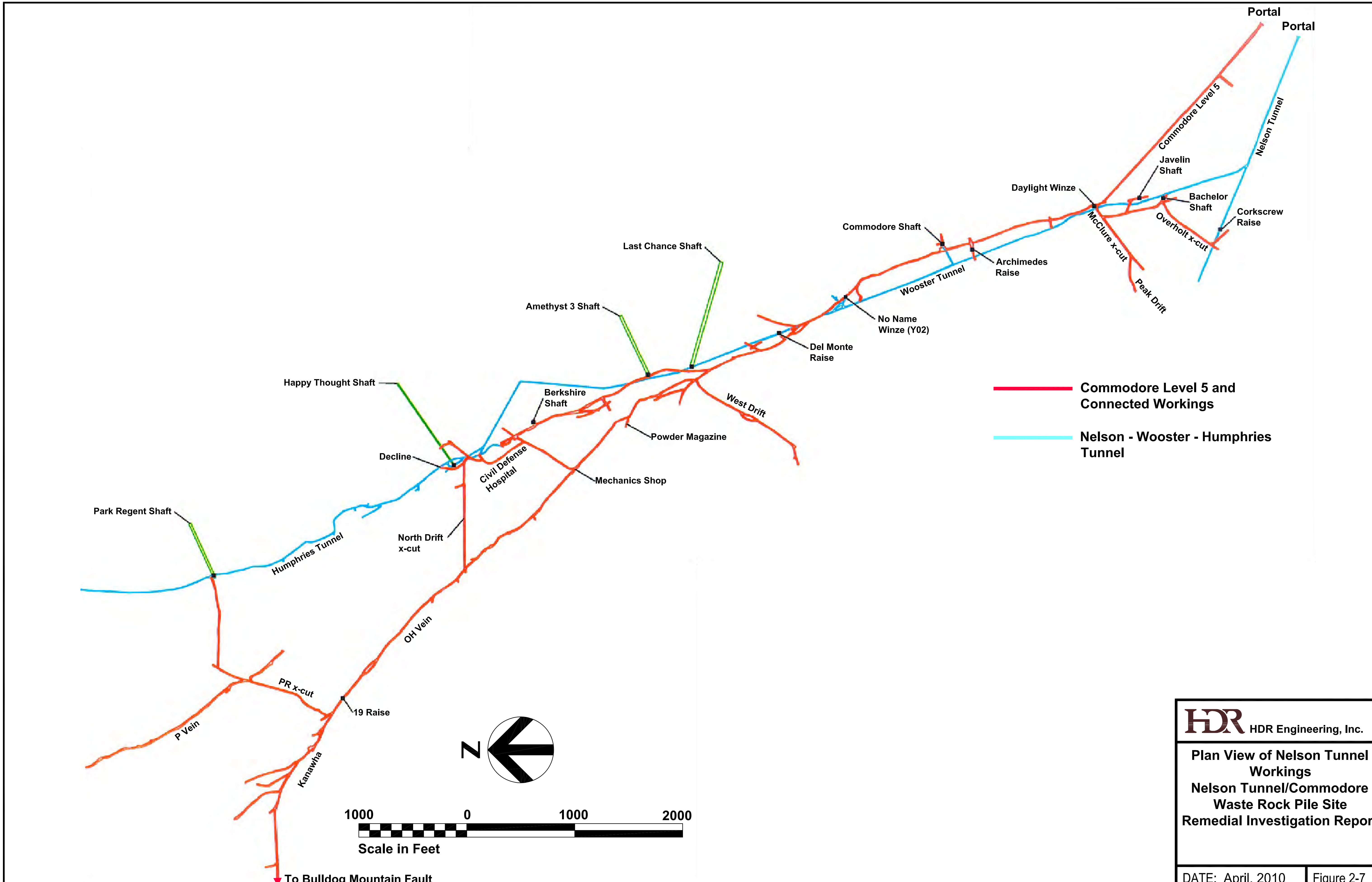
NOTES:

1. Reprinted from Aquatic Resources Assessment of the Willow Creek Watershed, EPA, 2005

HDR Engineering, Inc.

Geologic Cross-Section of the Willow Creek Watershed Nelson Tunnel / Commodore Waste Rock Pile Site Remedial Investigation Report

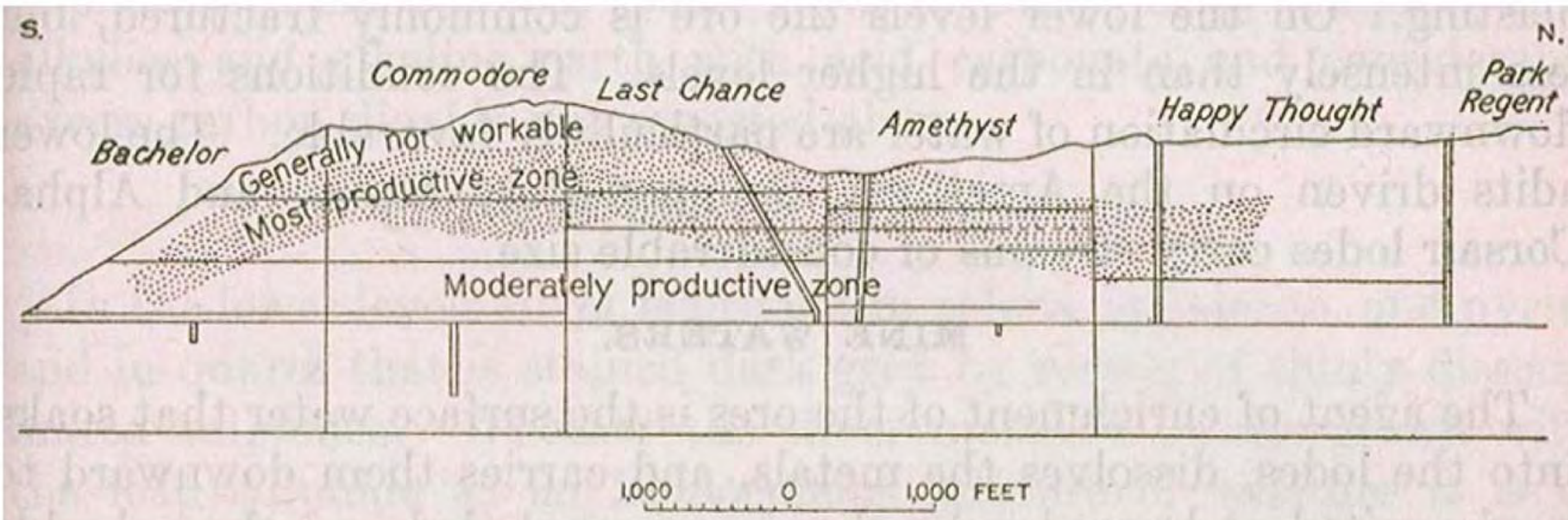
DATE: April, 2010 | Figure 2-6



HDR Engineering, Inc.

Plan View of Nelson Tunnel Workings
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010	Figure 2-7



NOTES:

1. Reprinted from Emmons and Larsen, 1923.

HDR Engineering, Inc.

Cross-Section of the Amethyst Lode
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010 | Figure 2-8

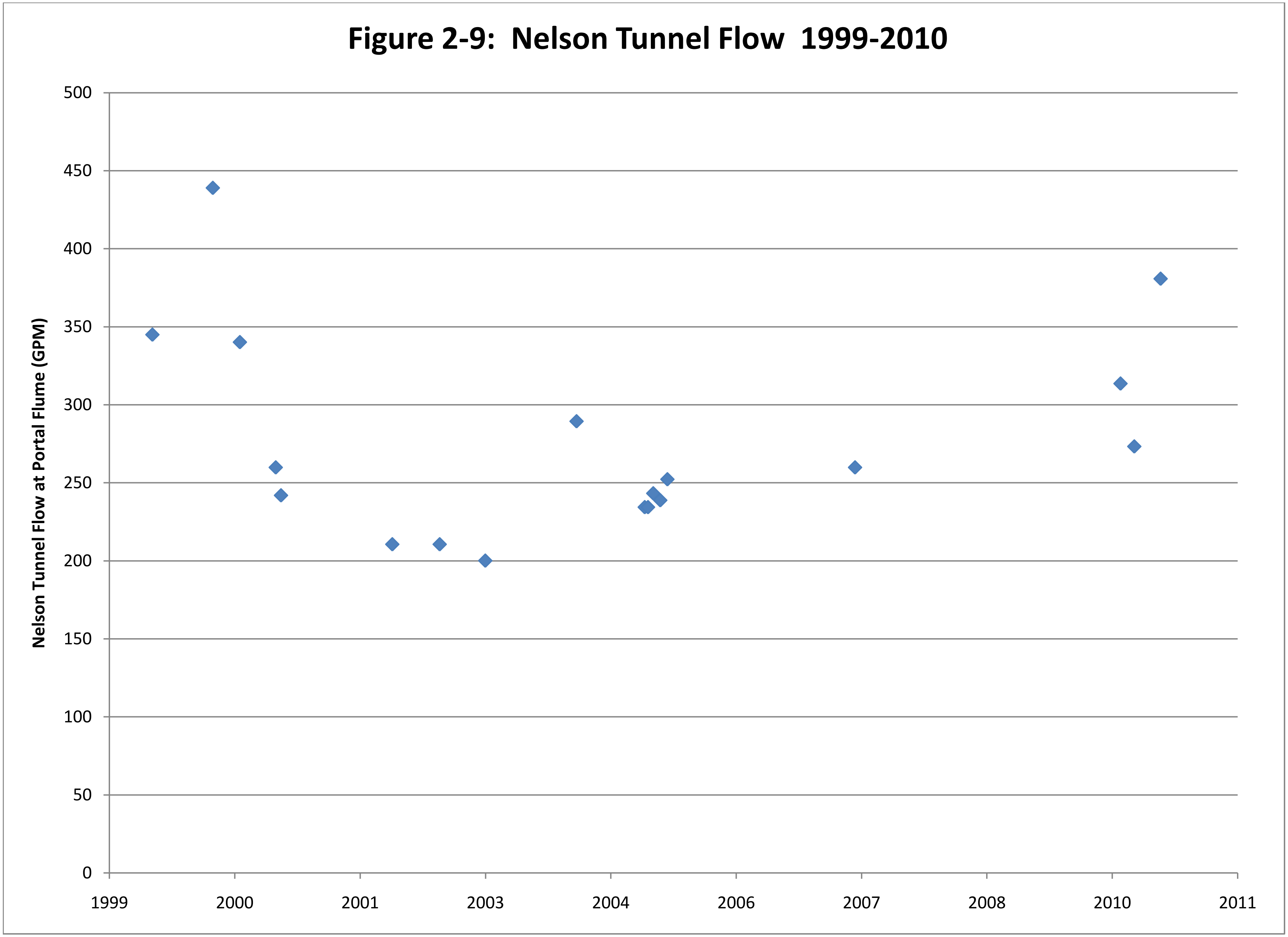
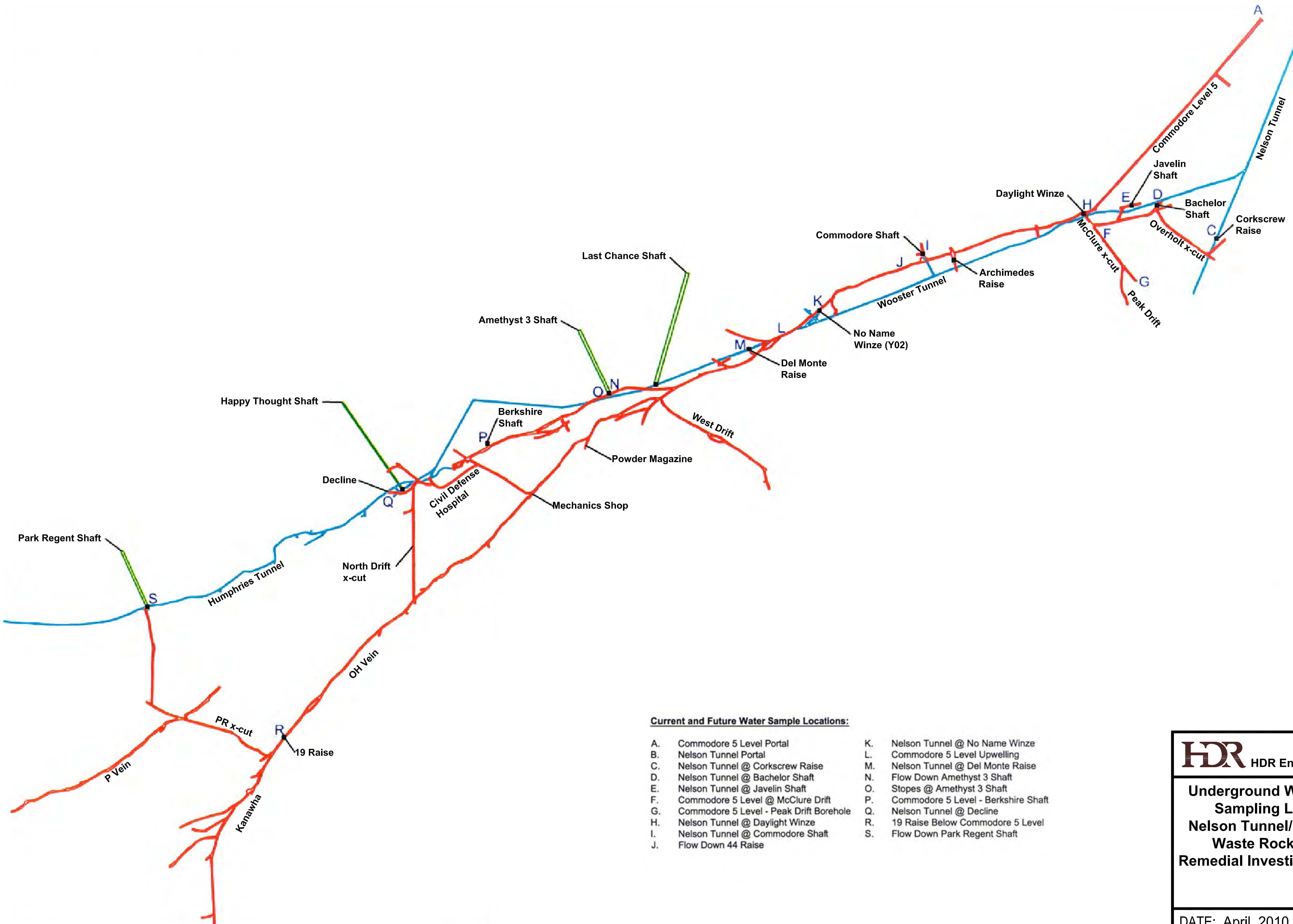


Figure 2-9: Nelson Tunnel Flow 1999-2010
Nelson Tunnel Flow at Portal Flume (GPM)
0
50
100
150
200
250
300
350
400
450
500
1999
2000
2001
2003
2004
2006
2007
2008
2010
2011



Current and Future Water Sample Locations:

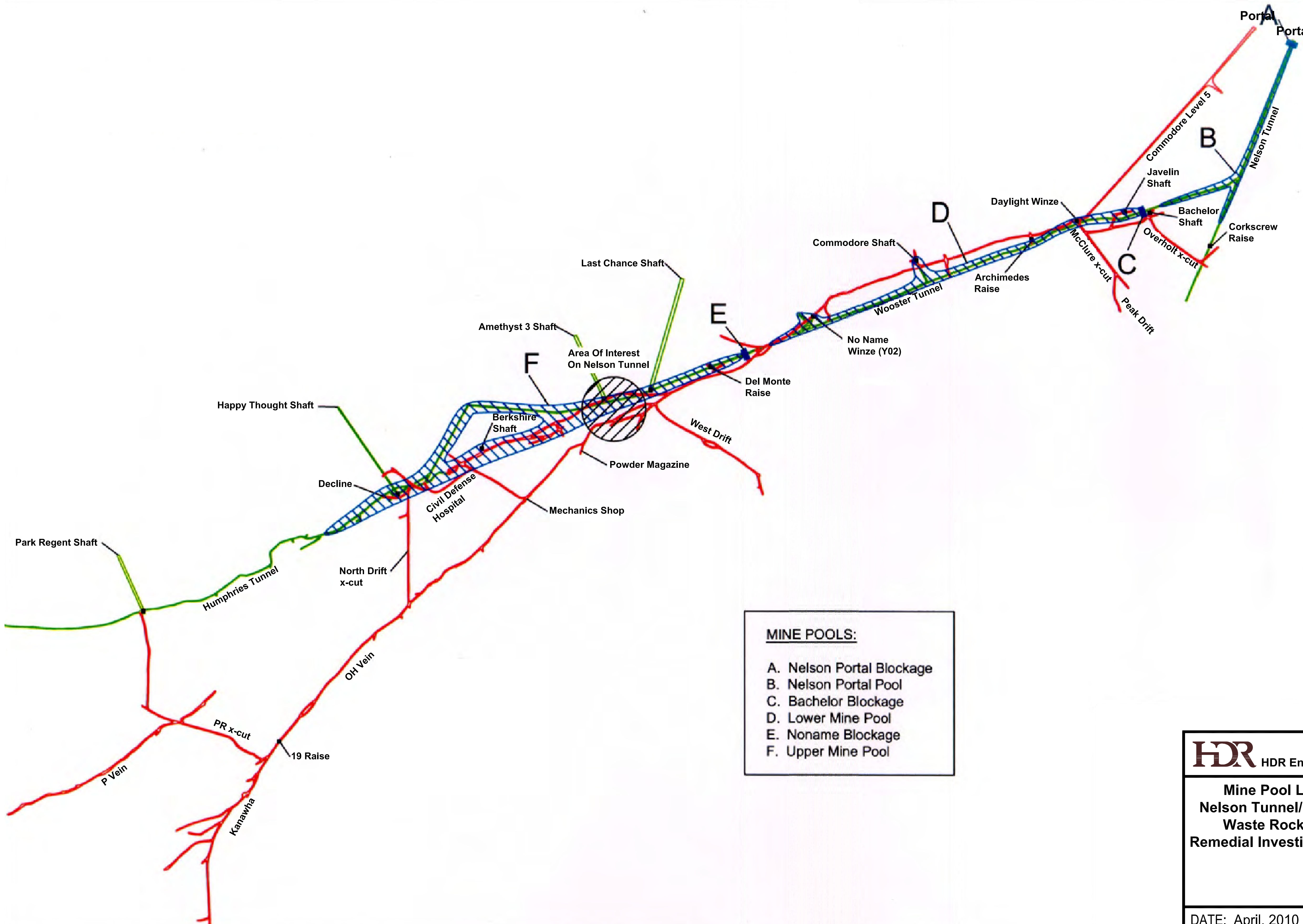
A. Commodore 5 Level Portal
B. Nelson Tunnel Portal
C. Nelson Tunnel @ Corkscrew Raise
D. Nelson Tunnel @ Bachelor Shaft
E. Nelson Tunnel @ Javelin Shaft
F. Commodore 5 Level @ McClure Drift
G. Commodore 5 Level - Peak Drift Borehole
H. Nelson Tunnel @ Daylight Winze
I. Nelson Tunnel @ Commodore Shaft
J. Flow Down 44 Raise
K. Nelson Tunnel @ No Name Winze
L. Commodore 5 Level Upwelling
M. Nelson Tunnel @ Del Monte Raise
N. Flow Down Amethyst 3 Shaft
O. Stopes @ Amethyst 3 Shaft
P. Commodore 5 Level - Berkshire Shaft
Q. Nelson Tunnel @ Decline
R. 19 Raise Below Commodore 5 Level
S. Flow Down Park Regent Shaft

HDR Engineering, Inc.

Underground Water Quality Sampling Locations Nelson Tunnel/Commodore Waste Rock Pile Site Remedial Investigation Report

DATE: April, 2010

Figure 2-10



MINE POOLS:

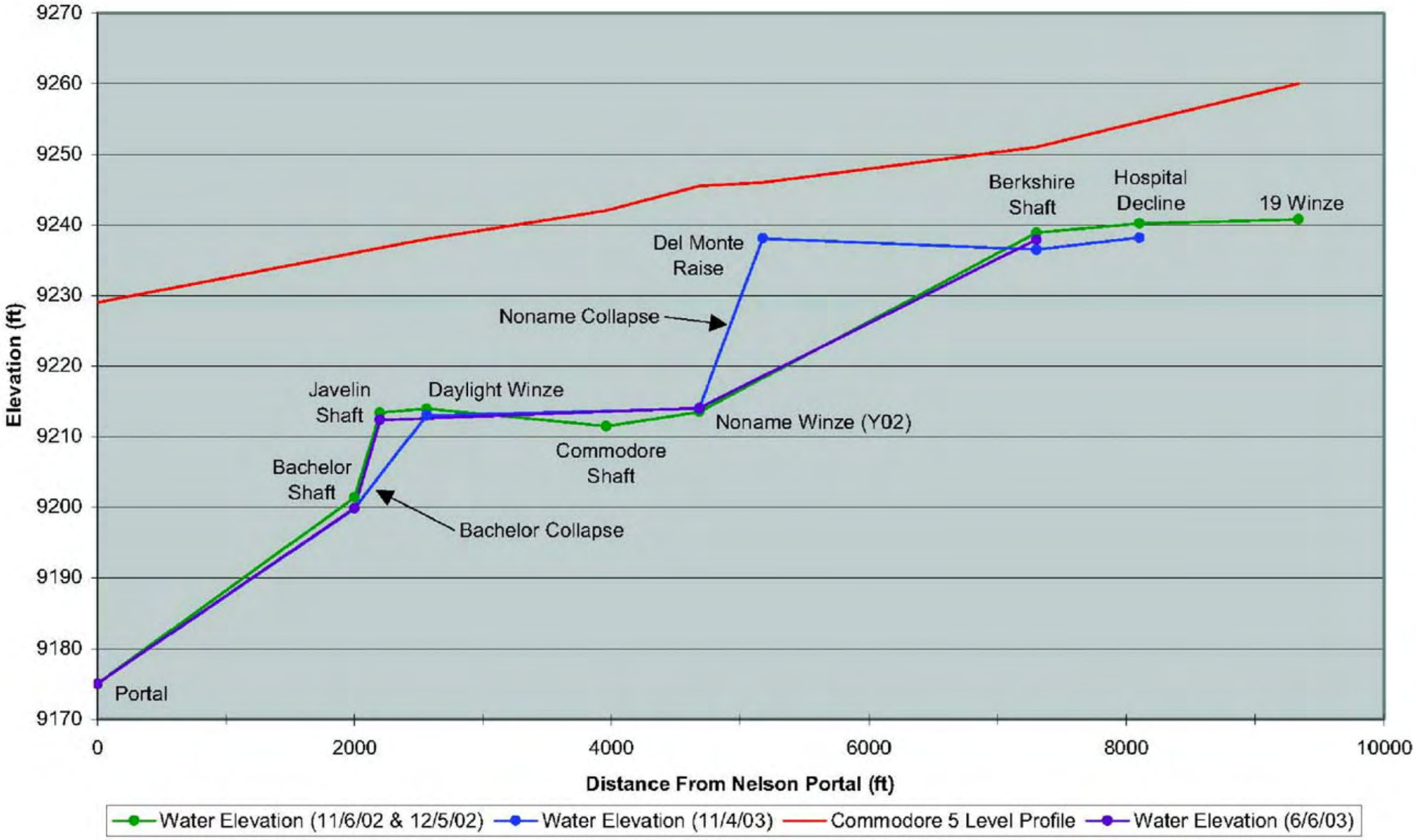
A. Nelson Portal Blockage
B. Nelson Portal Pool
C. Bachelor Blockage
D. Lower Mine Pool
E. Noname Blockage
F. Upper Mine Pool

HDR Engineering, Inc.

Mine Pool Locations
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010

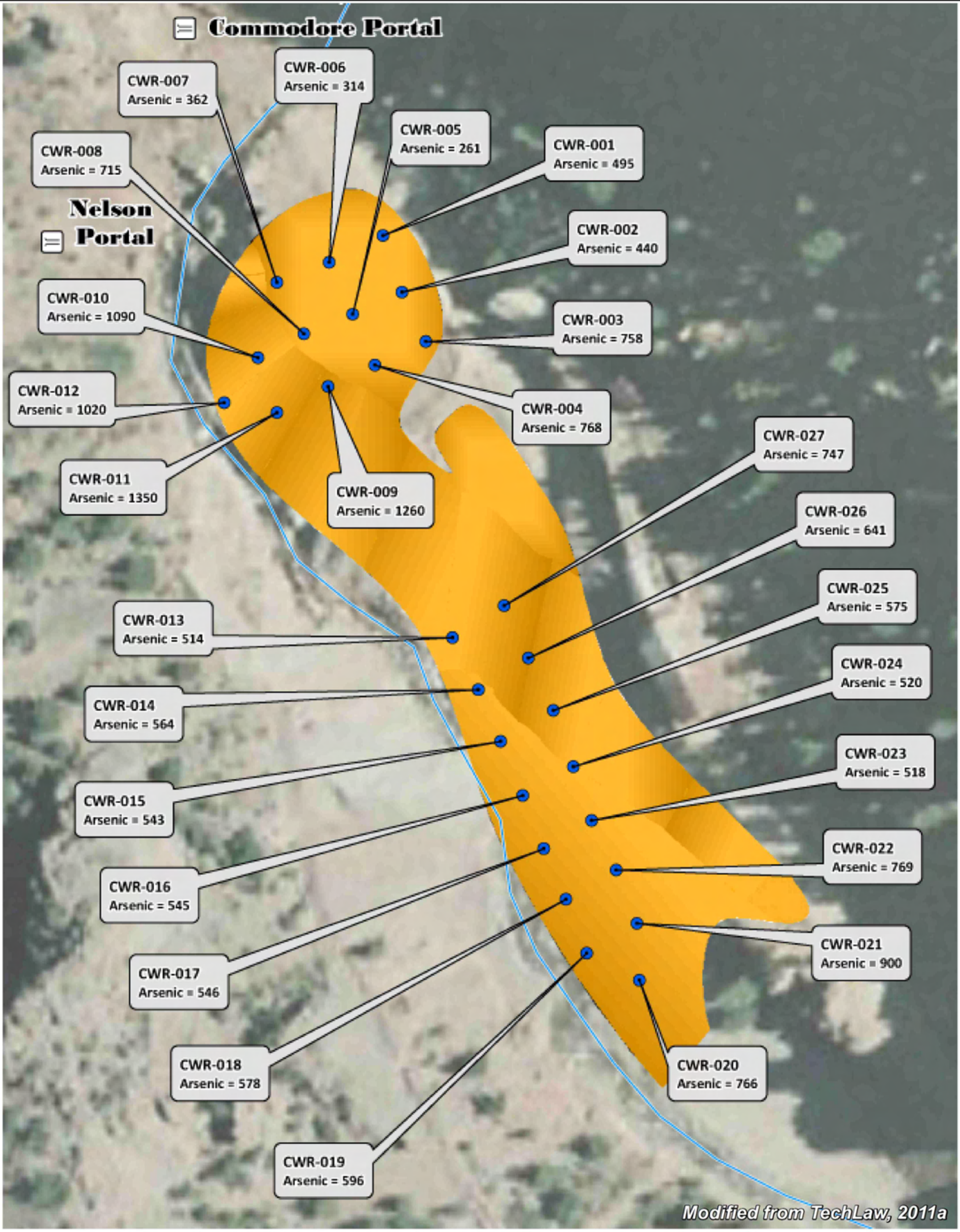
Figure 2-11



HDR Engineering, Inc.

Mine Pool Elevations
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010 | Figure 2-12



Waste Rock Sampling Locations (5 point composite)

Mine Portals

Rivers & Streams

Commodore Waste Rock Pile

0 50 100 Feet

Date: Aug 27th, 2010

Data Sources:

Waste Rock Sample Locations - ESAT (2010)

Commodore Waste Rock Pile- ESAT (2010)

Mine Portals- Digitized from Park Mining Co (1969)

Streams- Colorado Division of Wildlife (2004)

Imagery - Aerial photograph from NAIP (2009)

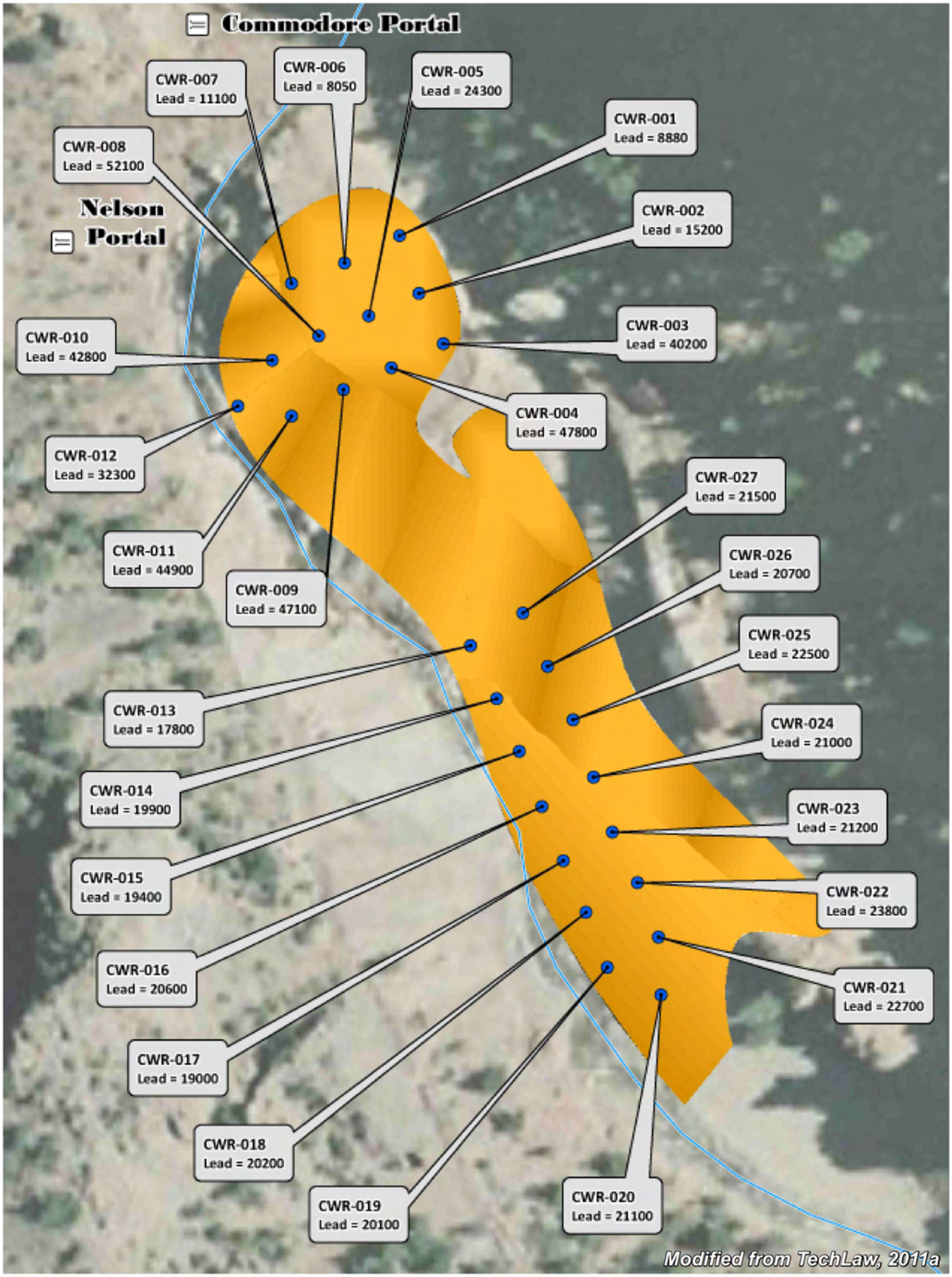
Projection/Coordinate System:
UTM, Meters,
Zone 13 North, NAD 83

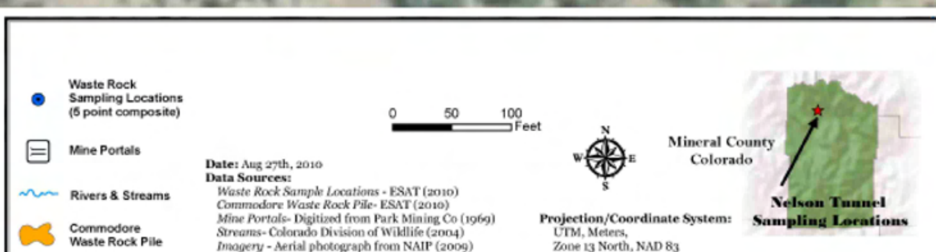
HDR Engineering, Inc.

Commodore Waste Rock Arsenic Concentrations June 2010 Sampling Remedial Investigation Report

DATE: May, 2011

Figure 3-1





HDR Engineering, Inc.

Commodore Waste Rock Lead Concentrations June 2010 Sampling Remedial Investigation Report

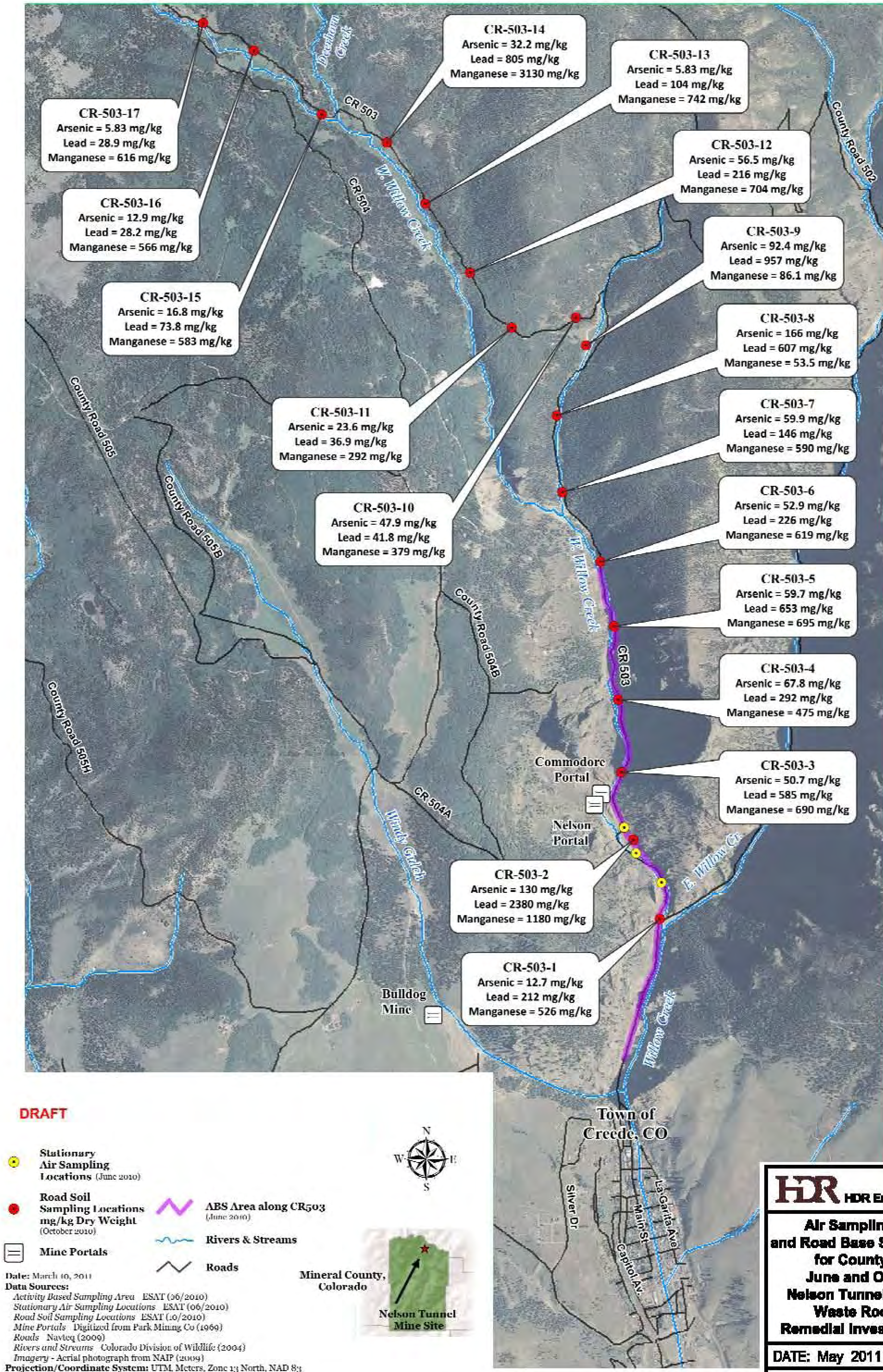
DATE: May, 2011 | Figure 3-2

HDR Engineering, Inc.

Photo of Post-Removal Action
Commodore Waste Rock Pile
View to South - April 2011

Nelson Tunnel / Commodore
Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2011 | Figure 3-3



HDR Engineering, Inc.

Air Sampling Locations and Road Base Sampling Results for County Road 503 June and October 2010 Nelson Tunnel / Commodore Waste Rock Pile Site Remedial Investigation Report

DATE: May 2011 | Figure 3-4

SCALE: 0 500 1,000 Feet

Modified From TechLaw, 2010a

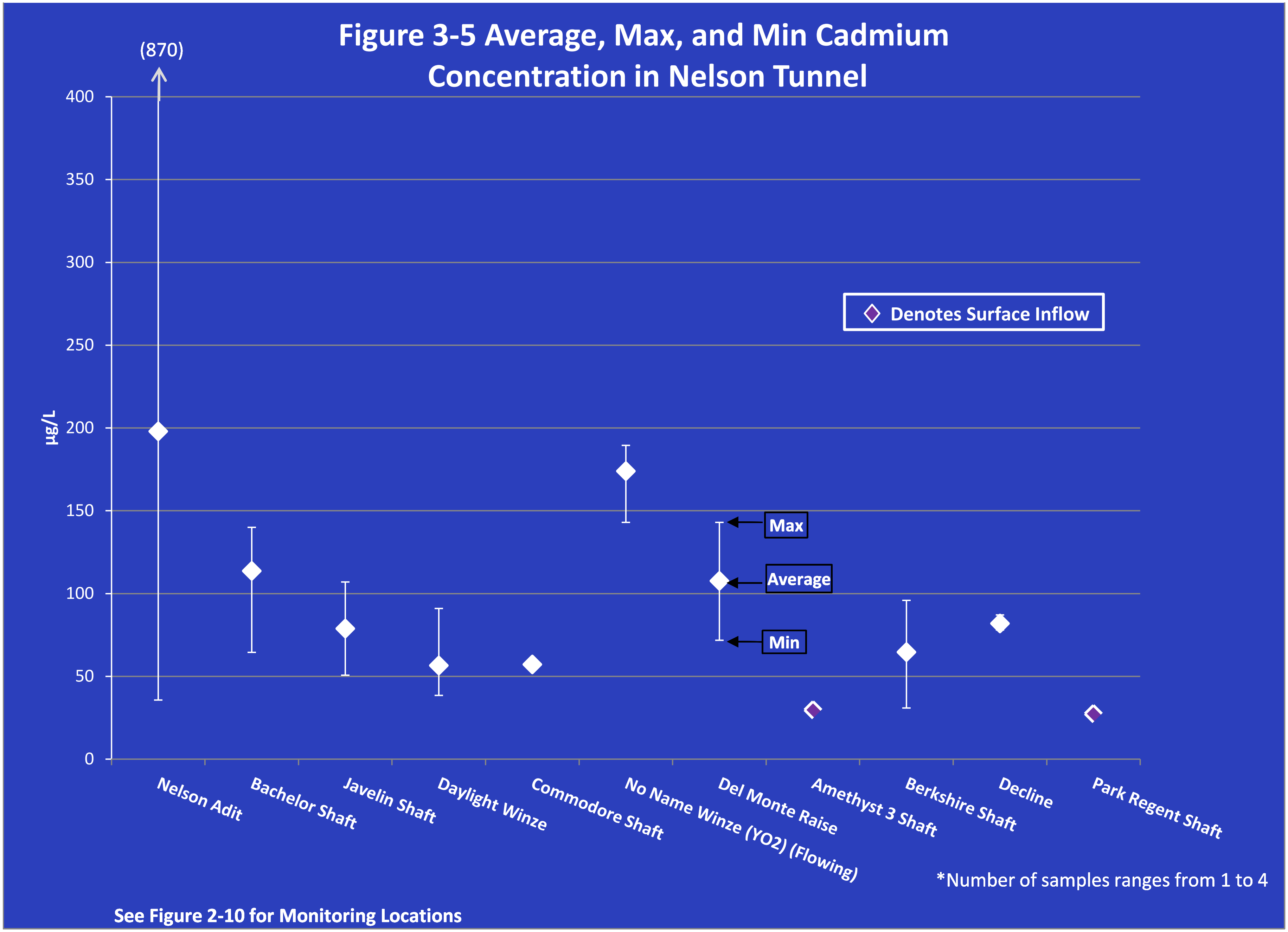


Figure 3-5 Average, Max, and Min Cadmium Concentration in Nelson Tunnel
(870)
400
350
300
250
200
150
100
50
0
µg/L
Denotes Surface Inflow
Max
Average
Min
Nelson Adit
Bachelor Shaft
Javelin Shaft
Daylight Winze
Commodore Shaft
No Name Winze (YO2) (Flowing)
Del Monte Raise
Amethyst 3 Shaft
Berkshire Shaft
Decline
Park Regent Shaft
*Number of samples ranges from 1 to 4
See Figure 2-10 for Monitoring Locations

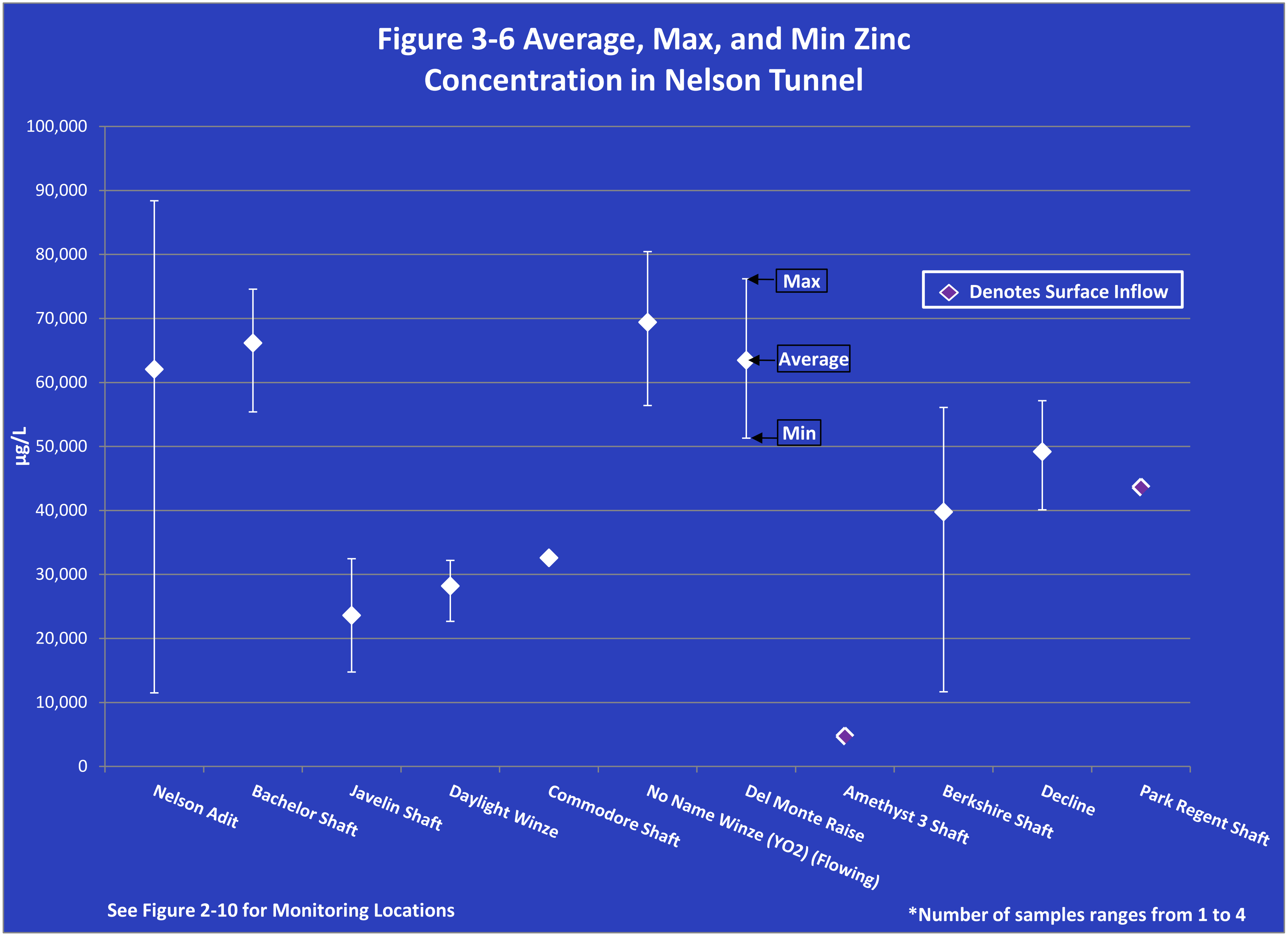
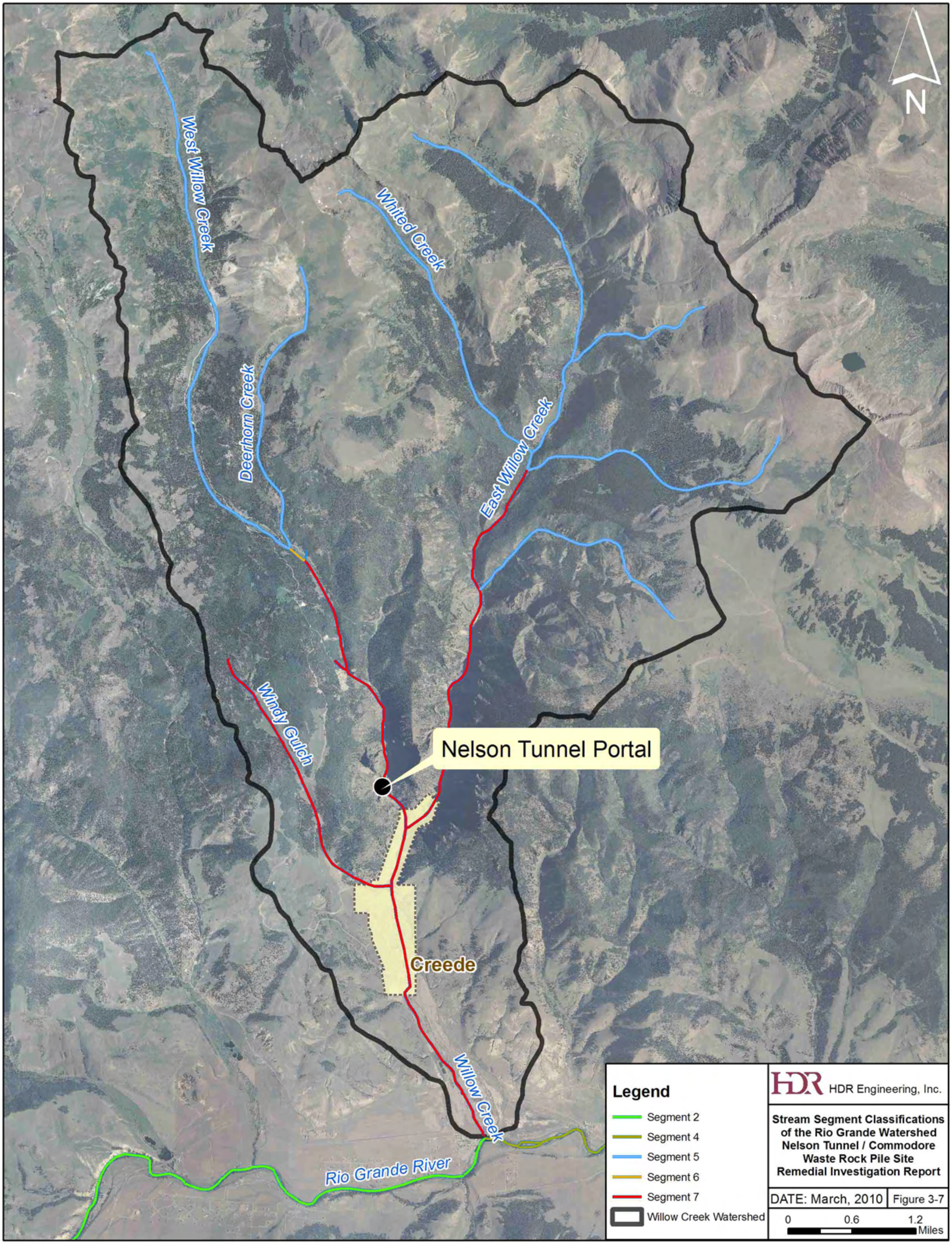
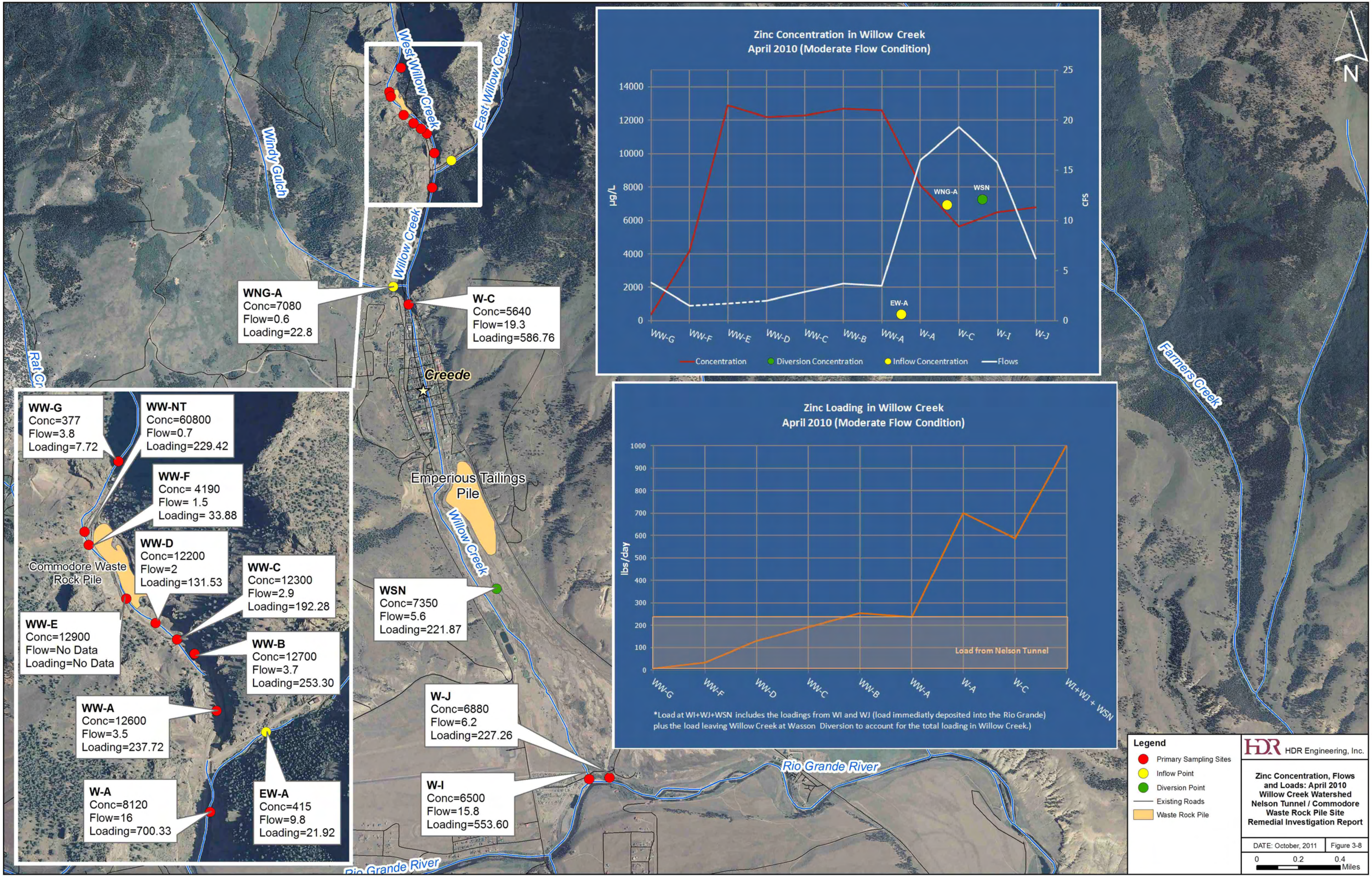
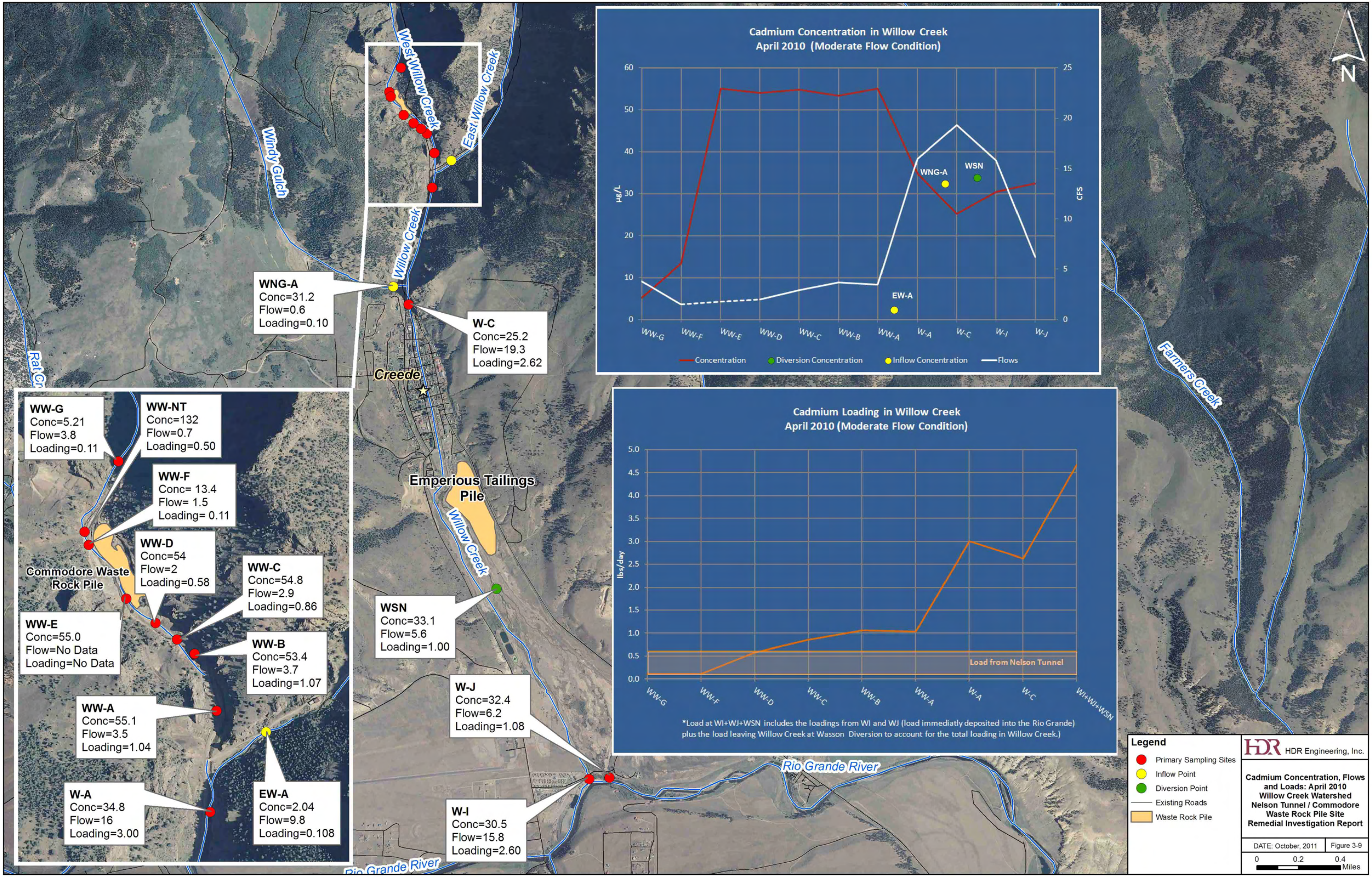
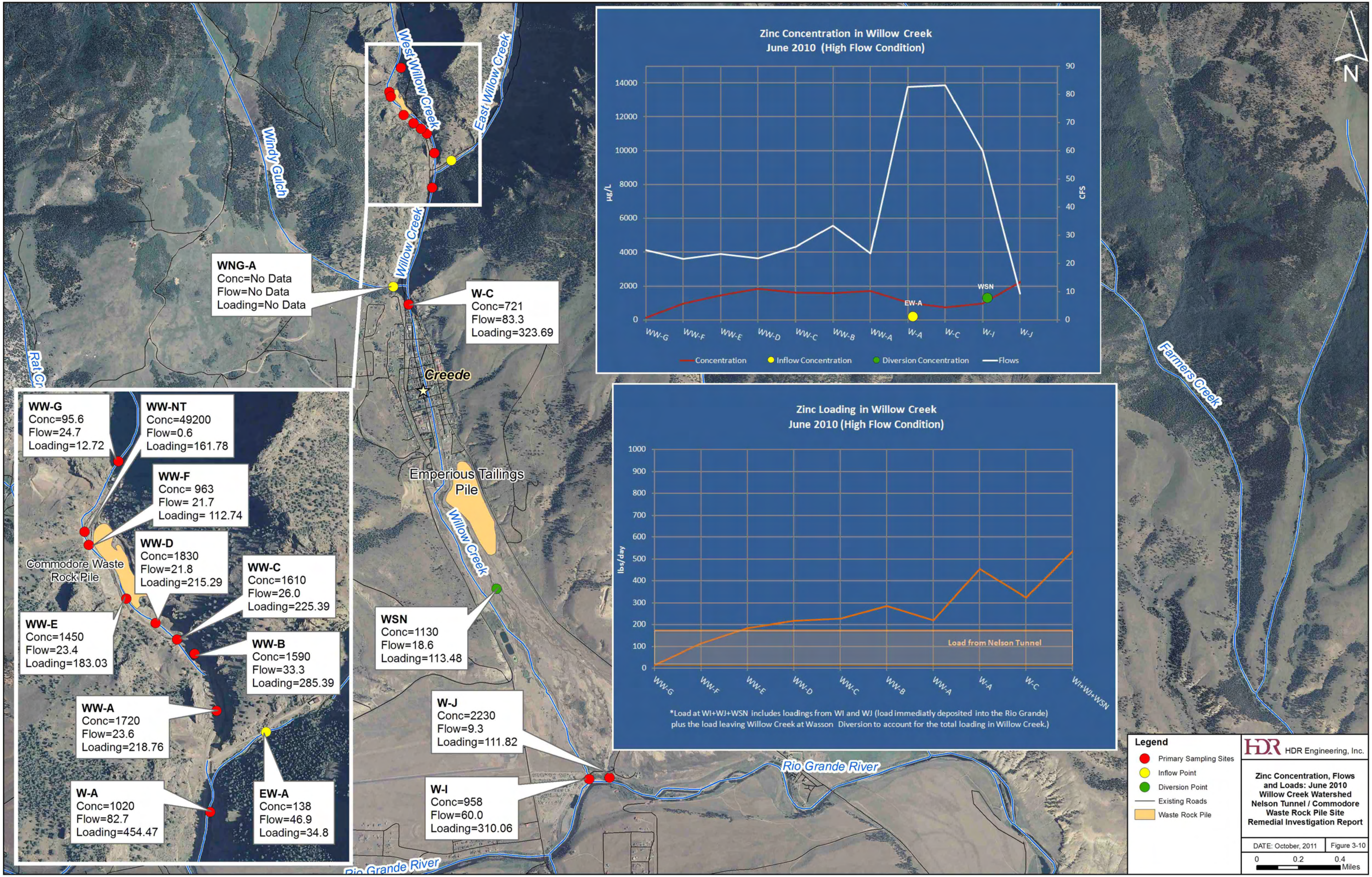


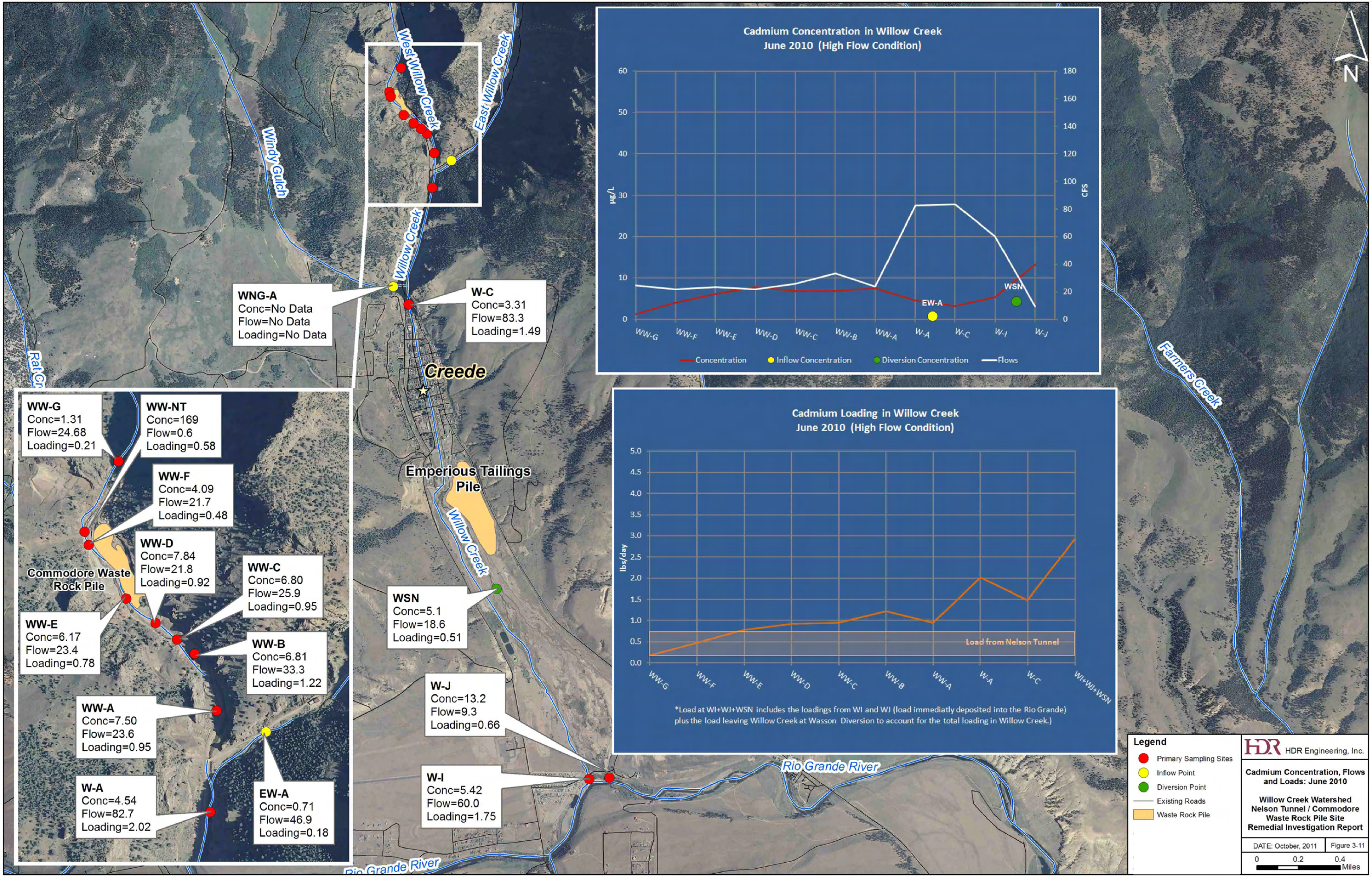
Figure 3-6 Average, Max, and Min Zinc Concentration in Nelson Tunnel
μg/L
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Max
Average
Min
Denotes Surface Inflow
Nelson Adit
Bachelor Shaft
Javelin Shaft
Daylight Winze
Commodore Shaft
No Name Winze (YO2) (Flowing)
Del Monte Raise
Amethyst 3 Shaft
Berkshire Shaft
Decline
Park Regent Shaft
See Figure 2-10 for Monitoring Locations
*Number of samples ranges from 1 to 4

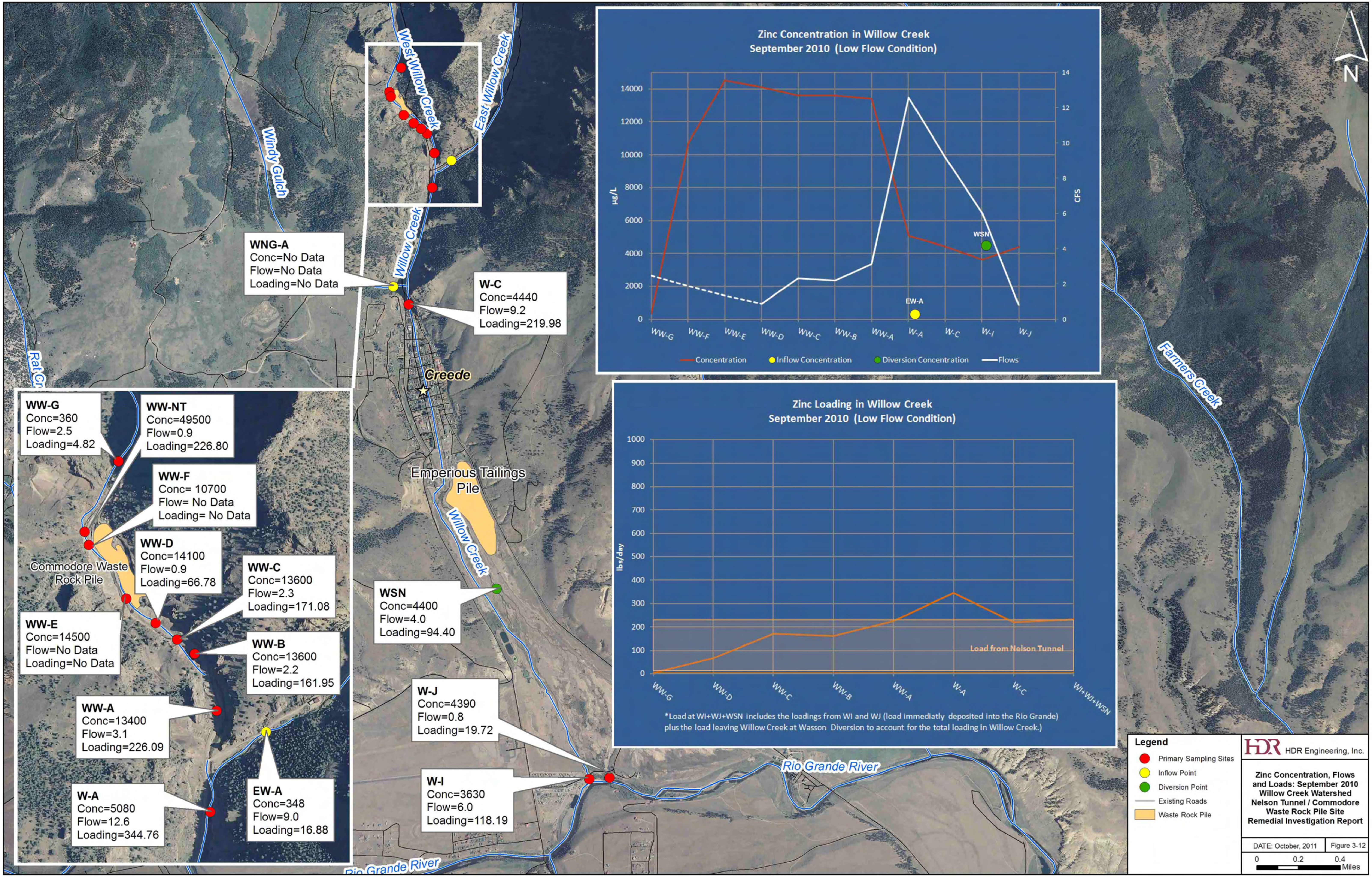

N
West Willow Creek
Whited Creek
Deerhorn Creek
East Willow Creek
Windy Gulch
Nelson Tunnel Portal
Creede
Willow Creek
Rio Grande River
Legend
Segment 2
Segment 4
Segment 5
Segment 6
Segment 7
Willow Creek Watershed
HDR Engineering, Inc.
Stream Segment Classifications of the Rio Grande Watershed Nelson Tunnel / Commodore Waste Rock Pile Site Remedial Investigation Report
DATE: March, 2010
Figure 3-7
0
0.6
1.2
Miles

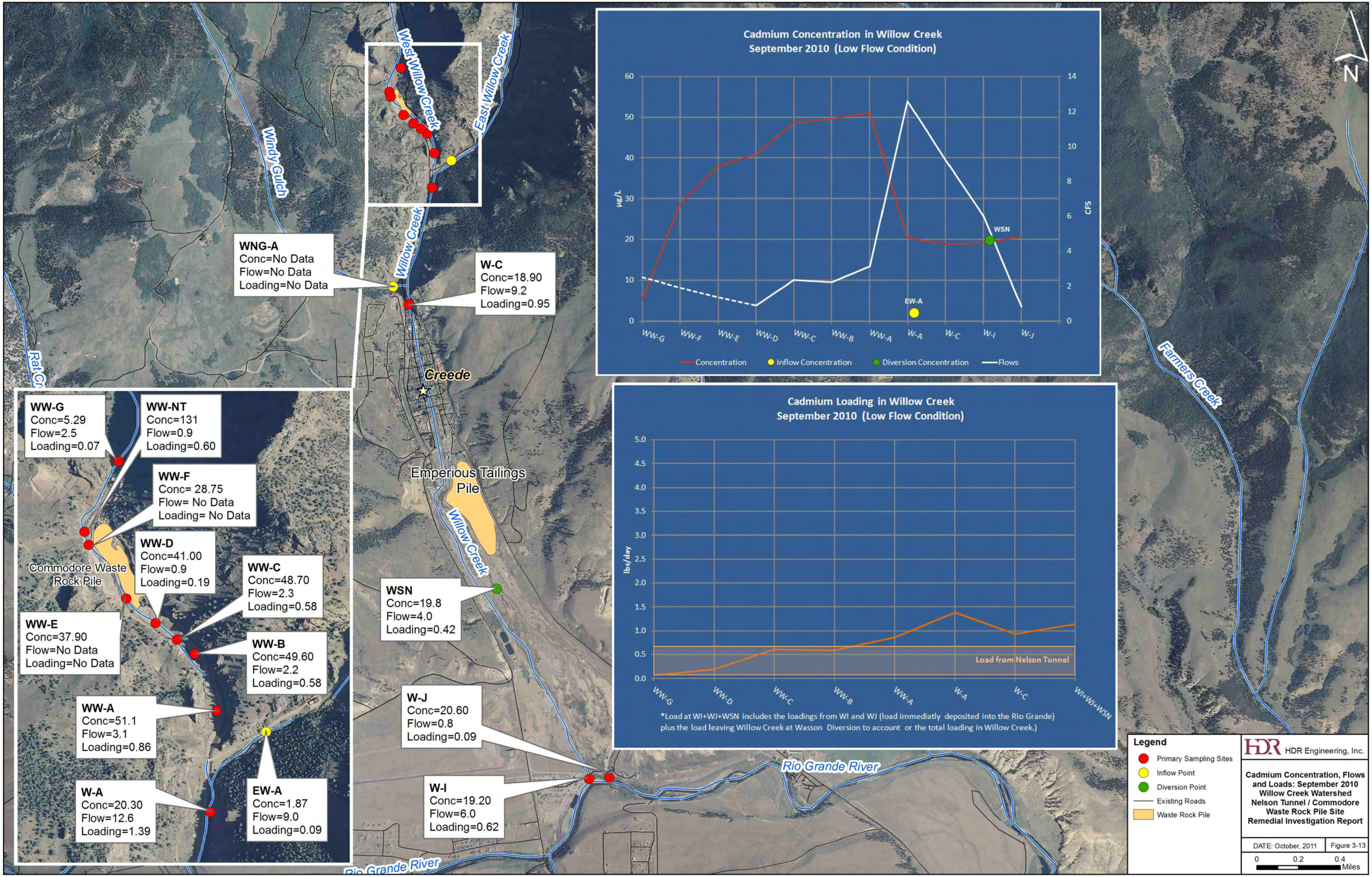

Zinc Concentration in Willow Creek
April 2010 (Moderate Flow Condition)
µg/L
CFS
14000
12000
10000
8000
6000
4000
2000
0
25
20
15
10
5
0
WW-G
WW-F
WW-E
WW-D
WW-C
WW-B
WW-A
W-A
W-C
W-I
W-J
WNG-A
WSN
EW-A
Concentration
Diversion Concentration
Inflow Concentration
Flows
Zinc Loading in Willow Creek
April 2010 (Moderate Flow Condition)
lbs/day
1000
900
800
700
600
500
400
300
200
100
0
Load from Nelson Tunnel
WW-G
WW-F
WW-D
WW-C
WW-B
WW-A
W-A
W-C
WI+WJ + WSN
*Load at WI+WJ+WSN includes the loadings from WI and WJ (load immediatly deposited into the Rio Grande) plus the load leaving Willow Creek at Wasson Diversion to account for the total loading in Willow Creek.)
West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Rat Creek
Farmers Creek
Creede
Emperious Tailings Pile
Rio Grande River
N
WNG-A
Conc=7080
Flow=0.6
Loading=22.8
W-C
Conc=5640
Flow=19.3
Loading=586.76
WW-G
Conc=377
Flow=3.8
Loading=7.72
WW-NT
Conc=60800
Flow=0.7
Loading=229.42
WW-F
Conc= 4190
Flow= 1.5
Loading= 33.88
WW-D
Conc=12200
Flow=2
Loading=131.53
Commodore Waste Rock Pile
WW-C
Conc=12300
Flow=2.9
Loading=192.28
WW-E
Conc=12900
Flow=No Data
Loading=No Data
WW-B
Conc=12700
Flow=3.7
Loading=253.30
WW-A
Conc=12600
Flow=3.5
Loading=237.72
W-A
Conc=8120
Flow=16
Loading=700.33
EW-A
Conc=415
Flow=9.8
Loading=21.92
WSN
Conc=7350
Flow=5.6
Loading=221.87
W-J
Conc=6880
Flow=6.2
Loading=227.26
W-I
Conc=6500
Flow=15.8
Loading=553.60
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Zinc Concentration, Flows and Loads: April 2010 Willow Creek Watershed Nelson Tunnel / Commodore Waste Rock Pile Site Remedial Investigation Report
DATE: October, 2011
Figure 3-8
0
0.2
0.4
Miles

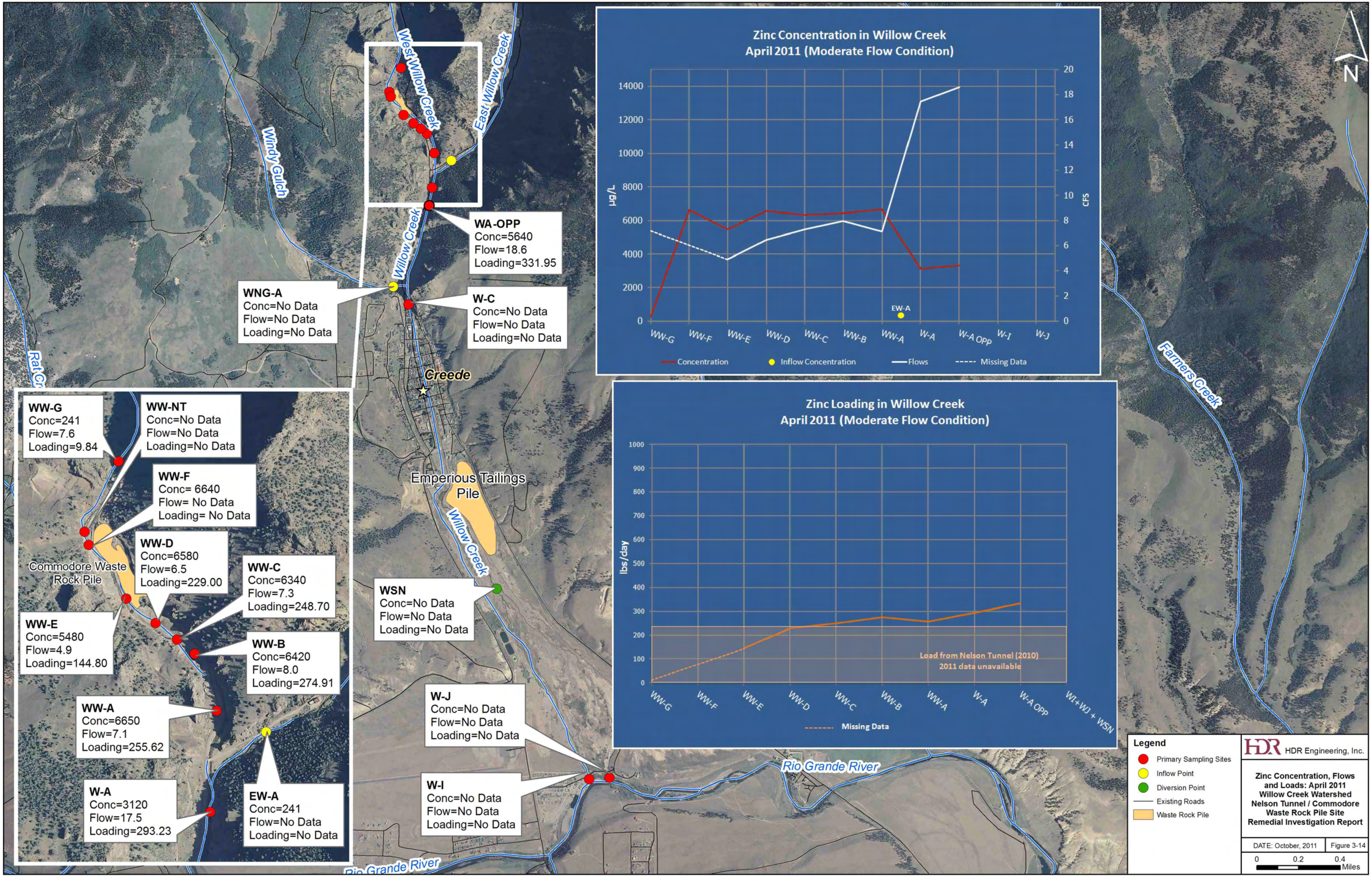

West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Rat Creek
Farmers Creek
Creede
Emperious Tailings Pile
Commodore Waste Rock Pile
Rio Grande River
WNG-A Conc=31.2 Flow=0.6 Loading=0.10
W-C Conc=25.2 Flow=19.3 Loading=2.62
WW-G Conc=5.21 Flow=3.8 Loading=0.11
WW-NT Conc=132 Flow=0.7 Loading=0.50
WW-F Conc= 13.4 Flow= 1.5 Loading= 0.11
WW-D Conc=54 Flow=2 Loading=0.58
WW-C Conc=54.8 Flow=2.9 Loading=0.86
WW-E Conc=55.0 Flow=No Data Loading=No Data
WW-B Conc=53.4 Flow=3.7 Loading=1.07
WW-A Conc=55.1 Flow=3.5 Loading=1.04
W-A Conc=34.8 Flow=16 Loading=3.00
EW-A Conc=2.04 Flow=9.8 Loading=0.108
WSN Conc=33.1 Flow=5.6 Loading=1.00
W-J Conc=32.4 Flow=6.2 Loading=1.08
W-I Conc=30.5 Flow=15.8 Loading=2.60
Cadmium Concentration in Willow Creek
April 2010 (Moderate Flow Condition)
µg/L
CFS
WW-G WW-F WW-E WW-D WW-C WW-B WW-A W-A W-C W-I W-J
WNG-A
WSN
EW-A
Concentration
Diversion Concentration
Inflow Concentration
Flows
Cadmium Loading in Willow Creek
April 2010 (Moderate Flow Condition)
lbs/day
WW-G WW-F WW-D WW-C WW-B WW-A W-A W-C WI+WJ+WSN
Load from Nelson Tunnel
*Load at WI+WJ+WSN includes the loadings from WI and WJ (load immediatly deposited into the Rio Grande) plus the load leaving Willow Creek at Wasson Diversion to account for the total loading in Willow Creek.)
N
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Cadmium Concentration, Flows and Loads: April 2010
Willow Creek Watershed
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: October, 2011
Figure 3-9
0 0.2 0.4 Miles

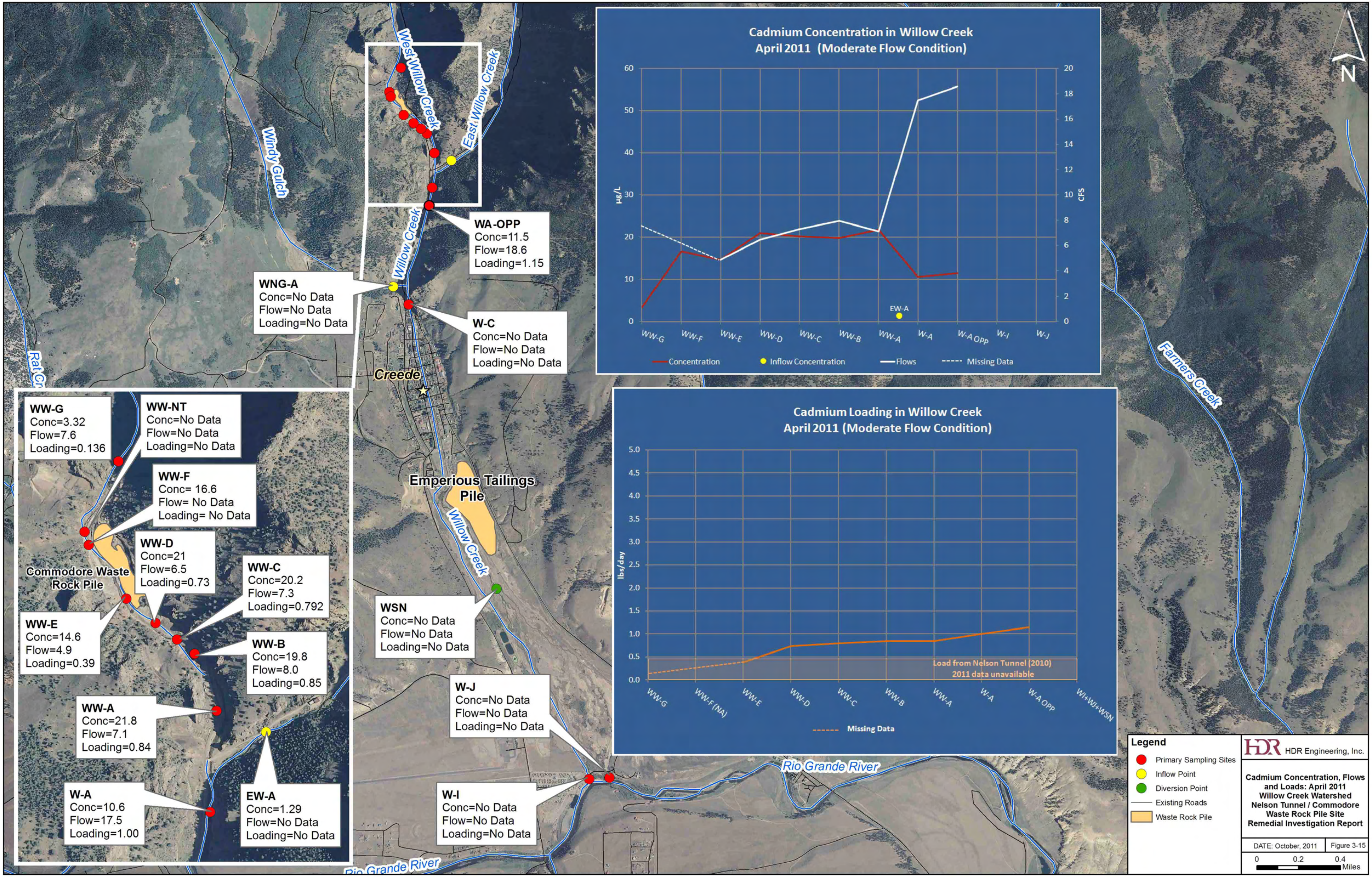

West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
WNG-A
Conc=No Data
Flow=No Data
Loading=No Data
W-C
Conc=721
Flow=83.3
Loading=323.69
Creede
Rat Cr
Emperious Tailings Pile
Willow Creek
WSN
Conc=1130
Flow=18.6
Loading=113.48
W-J
Conc=2230
Flow=9.3
Loading=111.82
W-I
Conc=958
Flow=60.0
Loading=310.06
Rio Grande River
Rio Grande River
Farmers Creek
N
WW-G
Conc=95.6
Flow=24.7
Loading=12.72
WW-NT
Conc=49200
Flow=0.6
Loading=161.78
WW-F
Conc= 963
Flow= 21.7
Loading= 112.74
Commodore Waste Rock Pile
WW-D
Conc=1830
Flow=21.8
Loading=215.29
WW-C
Conc=1610
Flow=26.0
Loading=225.39
WW-E
Conc=1450
Flow=23.4
Loading=183.03
WW-B
Conc=1590
Flow=33.3
Loading=285.39
WW-A
Conc=1720
Flow=23.6
Loading=218.76
W-A
Conc=1020
Flow=82.7
Loading=454.47
EW-A
Conc=138
Flow=46.9
Loading=34.8
Zinc Concentration in Willow Creek
June 2010 (High Flow Condition)
µg/L
CFS
0 2000 4000 6000 8000 10000 12000 14000
0 10 20 30 40 50 60 70 80 90
WW-G WW-F WW-E WW-D WW-C WW-B WW-A W-A W-C W-I W-J
EW-A
WSN
Concentration
Inflow Concentration
Diversion Concentration
Flows
Zinc Loading in Willow Creek
June 2010 (High Flow Condition)
lbs/day
0 100 200 300 400 500 600 700 800 900 1000
WW-G WW-F WW-E WW-D WW-C WW-B WW-A W-A W-C WI+WJ+WSN
Load from Nelson Tunnel
*Load at WI+WJ+WSN includes loadings from WI and WJ (load immediatly deposited into the Rio Grande) plus the load leaving Willow Creek at Wasson Diversion to account for the total loading in Willow Creek.)
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Zinc Concentration, Flows and Loads: June 2010
Willow Creek Watershed
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: October, 2011
Figure 3-10
0 0.2 0.4
Miles

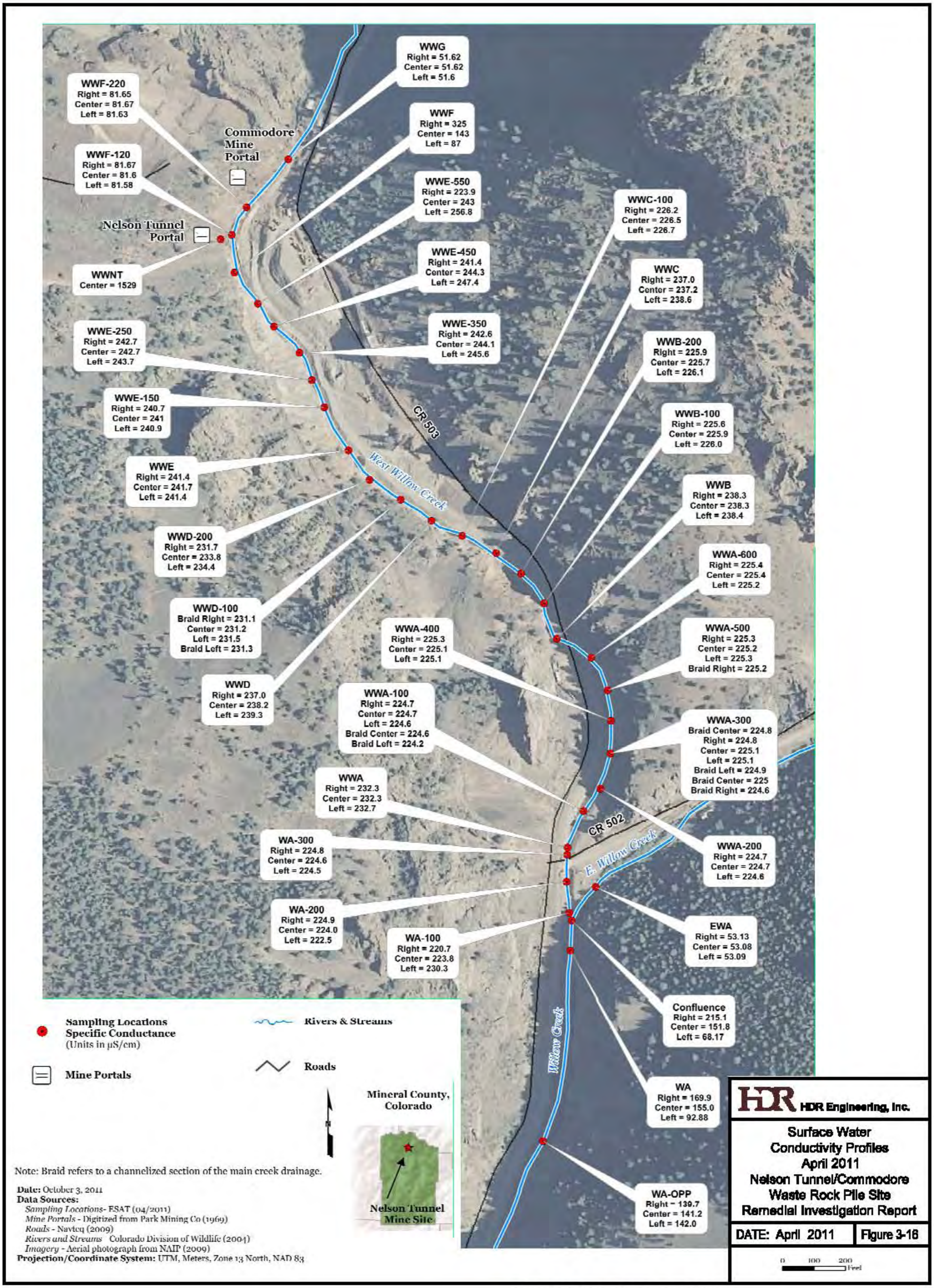

Cadmium Concentration in Willow Creek
June 2010 (High Flow Condition)
µg/L
CFS
0 10 20 30 40 50 60
0 20 40 60 80 100 120 140 160 180
WW-G WW-F WW-E WW-D WW-C WW-B WW-A W-A W-C W-I W-J
EW-A
WSN
Concentration
Inflow Concentration
Diversion Concentration
Flows
Cadmium Loading in Willow Creek
June 2010 (High Flow Condition)
lbs/day
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Load from Nelson Tunnel
WW-G WW-F WW-E WW-D WW-C WW-B WW-A W-A W-C WI+WJ+WSN
*Load at WI+WJ+WSN includes the loadings from WI and WJ (load immediatly deposited into the Rio Grande) plus the load leaving Willow Creek at Wasson Diversion to account for the total loading in Willow Creek.)
West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Rat Creek
Farmers Creek
Creede
Emperious Tailings Pile
Rio Grande River
Commodore Waste Rock Pile
WNG-A
Conc=No Data
Flow=No Data
Loading=No Data
W-C
Conc=3.31
Flow=83.3
Loading=1.49
WW-G
Conc=1.31
Flow=24.68
Loading=0.21
WW-NT
Conc=169
Flow=0.6
Loading=0.58
WW-F
Conc=4.09
Flow=21.7
Loading=0.48
WW-D
Conc=7.84
Flow=21.8
Loading=0.92
WW-C
Conc=6.80
Flow=25.9
Loading=0.95
WW-E
Conc=6.17
Flow=23.4
Loading=0.78
WW-B
Conc=6.81
Flow=33.3
Loading=1.22
WW-A
Conc=7.50
Flow=23.6
Loading=0.95
W-A
Conc=4.54
Flow=82.7
Loading=2.02
EW-A
Conc=0.71
Flow=46.9
Loading=0.18
WSN
Conc=5.1
Flow=18.6
Loading=0.51
W-J
Conc=13.2
Flow=9.3
Loading=0.66
W-I
Conc=5.42
Flow=60.0
Loading=1.75
N
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Cadmium Concentration, Flows and Loads: June 2010
Willow Creek Watershed
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: October, 2011
Figure 3-11
0 0.2 0.4
Miles


Zinc Concentration in Willow Creek
September 2010 (Low Flow Condition)
µg/L
CFS
WW-G WW-F WW-E WW-D WW-C WW-B WW-A W-A W-C W-I W-J
WSN
EW-A
Concentration
Inflow Concentration
Diversion Concentration
Flows
Zinc Loading in Willow Creek
September 2010 (Low Flow Condition)
lbs/day
Load from Nelson Tunnel
WW-G WW-D WW-C WW-B WW-A W-A W-C WI+WJ+WSN
*Load at WI+WJ+WSN includes the loadings from WI and WJ (load immediatly deposited into the Rio Grande) plus the load leaving Willow Creek at Wasson Diversion to account for the total loading in Willow Creek.)
West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Creede
Emperious Tailings Pile
Farmers Creek
Rio Grande River
Commodore Waste Rock Pile
WNG-A
Conc=No Data
Flow=No Data
Loading=No Data
W-C
Conc=4440
Flow=9.2
Loading=219.98
WW-G
Conc=360
Flow=2.5
Loading=4.82
WW-NT
Conc=49500
Flow=0.9
Loading=226.80
WW-F
Conc= 10700
Flow= No Data
Loading= No Data
WW-D
Conc=14100
Flow=0.9
Loading=66.78
WW-C
Conc=13600
Flow=2.3
Loading=171.08
WW-E
Conc=14500
Flow=No Data
Loading=No Data
WW-B
Conc=13600
Flow=2.2
Loading=161.95
WW-A
Conc=13400
Flow=3.1
Loading=226.09
W-A
Conc=5080
Flow=12.6
Loading=344.76
EW-A
Conc=348
Flow=9.0
Loading=16.88
WSN
Conc=4400
Flow=4.0
Loading=94.40
W-J
Conc=4390
Flow=0.8
Loading=19.72
W-I
Conc=3630
Flow=6.0
Loading=118.19
N
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Zinc Concentration, Flows and Loads: September 2010
Willow Creek Watershed
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: October, 2011
Figure 3-12
0 0.2 0.4 Miles


N
West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Rat Cr
Creede
Emperious Tailings Pile
Farmers Creek
Rio Grande River
WNG-A
Conc=No Data
Flow=No Data
Loading=No Data
W-C
Conc=18.90
Flow=9.2
Loading=0.95
WSN
Conc=19.8
Flow=4.0
Loading=0.42
W-J
Conc=20.60
Flow=0.8
Loading=0.09
W-I
Conc=19.20
Flow=6.0
Loading=0.62
WW-G
Conc=5.29
Flow=2.5
Loading=0.07
WW-NT
Conc=131
Flow=0.9
Loading=0.60
WW-F
Conc= 28.75
Flow= No Data
Loading= No Data
Commodore Waste Rock Pile
WW-D
Conc=41.00
Flow=0.9
Loading=0.19
WW-C
Conc=48.70
Flow=2.3
Loading=0.58
WW-E
Conc=37.90
Flow=No Data
Loading=No Data
WW-B
Conc=49.60
Flow=2.2
Loading=0.58
WW-A
Conc=51.1
Flow=3.1
Loading=0.86
W-A
Conc=20.30
Flow=12.6
Loading=1.39
EW-A
Conc=1.87
Flow=9.0
Loading=0.09
Cadmium Concentration in Willow Creek
September 2010 (Low Flow Condition)
µg/L
CFS
WSN
EW-A
WW-G WW-F WW-E WW-D WW-C WW-B WW-A W-A W-C W-I W-J
Concentration
Inflow Concentration
Diversion Concentration
Flows
Cadmium Loading in Willow Creek
September 2010 (Low Flow Condition)
lbs/day
Load from Nelson Tunnel
WW-G WW-D WW-C WW-B WW-A W-A W-C WI+WJ+WSN
*Load at WI+WJ+WSN includes the loadings from WI and WJ (load immediatly deposited into the Rio Grande) plus the load leaving Willow Creek at Wasson Diversion to account or the total loading in Willow Creek.)
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Cadmium Concentration, Flows and Loads: September 2010 Willow Creek Watershed Nelson Tunnel / Commodore Waste Rock Pile Site Remedial Investigation Report
DATE: October, 2011
Figure 3-13
0 0.2 0.4 Miles


Zinc Concentration in Willow Creek
April 2011 (Moderate Flow Condition)
µg/L
CFS
0
2000
4000
6000
8000
10000
12000
14000
0
2
4
6
8
10
12
14
16
18
20
WW-G
WW-F
WW-E
WW-D
WW-C
WW-B
WW-A
W-A
W-A OPP
W-I
W-J
EW-A
Concentration
Inflow Concentration
Flows
Missing Data
Zinc Loading in Willow Creek
April 2011 (Moderate Flow Condition)
lbs/day
0
100
200
300
400
500
600
700
800
900
1000
Load from Nelson Tunnel (2010)
2011 data unavailable
WW-G
WW-F
WW-E
WW-D
WW-C
WW-B
WW-A
W-A
W-A OPP
WI+WJ + WSN
Missing Data
N
West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Rat Creek
Farmers Creek
Creede
Emperious Tailings Pile
Rio Grande River
Commodore Waste Rock Pile
WA-OPP
Conc=5640
Flow=18.6
Loading=331.95
WNG-A
Conc=No Data
Flow=No Data
Loading=No Data
W-C
Conc=No Data
Flow=No Data
Loading=No Data
WW-G
Conc=241
Flow=7.6
Loading=9.84
WW-NT
Conc=No Data
Flow=No Data
Loading=No Data
WW-F
Conc= 6640
Flow= No Data
Loading= No Data
WW-D
Conc=6580
Flow=6.5
Loading=229.00
WW-C
Conc=6340
Flow=7.3
Loading=248.70
WW-E
Conc=5480
Flow=4.9
Loading=144.80
WW-B
Conc=6420
Flow=8.0
Loading=274.91
WW-A
Conc=6650
Flow=7.1
Loading=255.62
W-A
Conc=3120
Flow=17.5
Loading=293.23
EW-A
Conc=241
Flow=No Data
Loading=No Data
WSN
Conc=No Data
Flow=No Data
Loading=No Data
W-J
Conc=No Data
Flow=No Data
Loading=No Data
W-I
Conc=No Data
Flow=No Data
Loading=No Data
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Zinc Concentration, Flows and Loads: April 2011
Willow Creek Watershed
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: October, 2011
Figure 3-14
0
0.2
0.4
Miles


Cadmium Concentration in Willow Creek
April 2011 (Moderate Flow Condition)
μg/L
CFS
WW-G
WW-F
WW-E
WW-D
WW-C
WW-B
WW-A
W-A
W-A OPP
W-I
W-J
EW-A
Concentration
Inflow Concentration
Flows
Missing Data
Cadmium Loading in Willow Creek
April 2011 (Moderate Flow Condition)
lbs/day
Load from Nelson Tunnel (2010)
2011 data unavailable
WW-G
WW-F (NA)
WW-E
WW-D
WW-C
WW-B
WW-A
W-A
W-A OPP
WI+WJ+WSN
Missing Data
West Willow Creek
East Willow Creek
Windy Gulch
Willow Creek
Rat Creek
Farmers Creek
Creede
Emperious Tailings Pile
Commodore Waste Rock Pile
Rio Grande River
WA-OPP
Conc=11.5
Flow=18.6
Loading=1.15
WNG-A
Conc=No Data
Flow=No Data
Loading=No Data
W-C
Conc=No Data
Flow=No Data
Loading=No Data
WW-G
Conc=3.32
Flow=7.6
Loading=0.136
WW-NT
Conc=No Data
Flow=No Data
Loading=No Data
WW-F
Conc= 16.6
Flow= No Data
Loading= No Data
WW-D
Conc=21
Flow=6.5
Loading=0.73
WW-C
Conc=20.2
Flow=7.3
Loading=0.792
WW-E
Conc=14.6
Flow=4.9
Loading=0.39
WW-B
Conc=19.8
Flow=8.0
Loading=0.85
WW-A
Conc=21.8
Flow=7.1
Loading=0.84
W-A
Conc=10.6
Flow=17.5
Loading=1.00
EW-A
Conc=1.29
Flow=No Data
Loading=No Data
WSN
Conc=No Data
Flow=No Data
Loading=No Data
W-J
Conc=No Data
Flow=No Data
Loading=No Data
W-I
Conc=No Data
Flow=No Data
Loading=No Data
N
Legend
Primary Sampling Sites
Inflow Point
Diversion Point
Existing Roads
Waste Rock Pile
HDR Engineering, Inc.
Cadmium Concentration, Flows and Loads: April 2011
Willow Creek Watershed
Nelson Tunnel / Commodore Waste Rock Pile Site
Remedial Investigation Report
DATE: October, 2011
Figure 3-15
0 0.2 0.4 Miles



Modified From TechLaw, 2011b

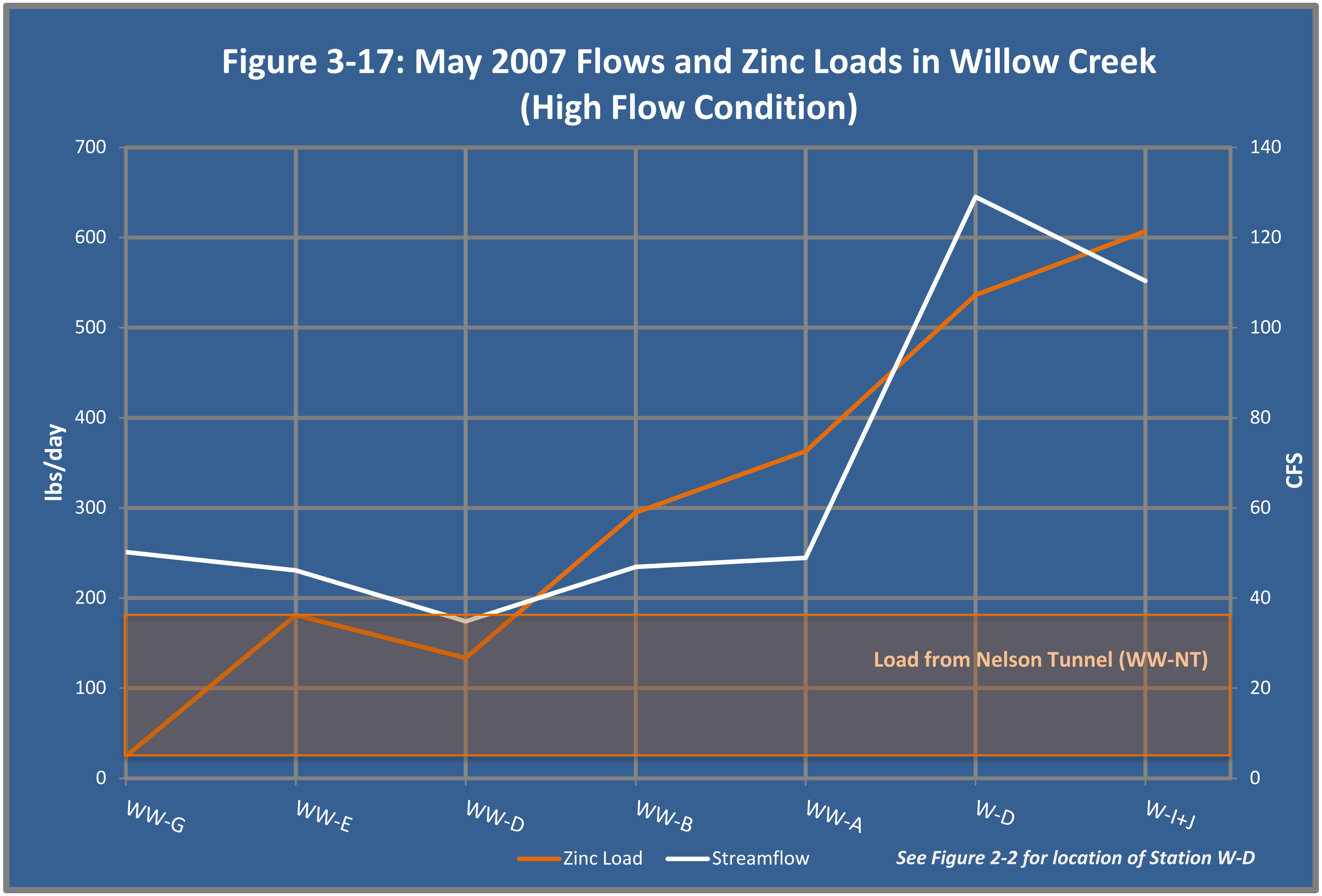


Figure 3-17: May 2007 Flows and Zinc Loads in Willow Creek
(High Flow Condition)
lbs/day
CFS
700
600
500
400
300
200
100
0
140
120
100
80
60
40
20
0
Load from Nelson Tunnel (WW-NT)
WW-G
WW-E
WW-D
WW-B
WW-A
W-D
W-I+J
Zinc Load
Streamflow
See Figure 2-2 for location of Station W-D

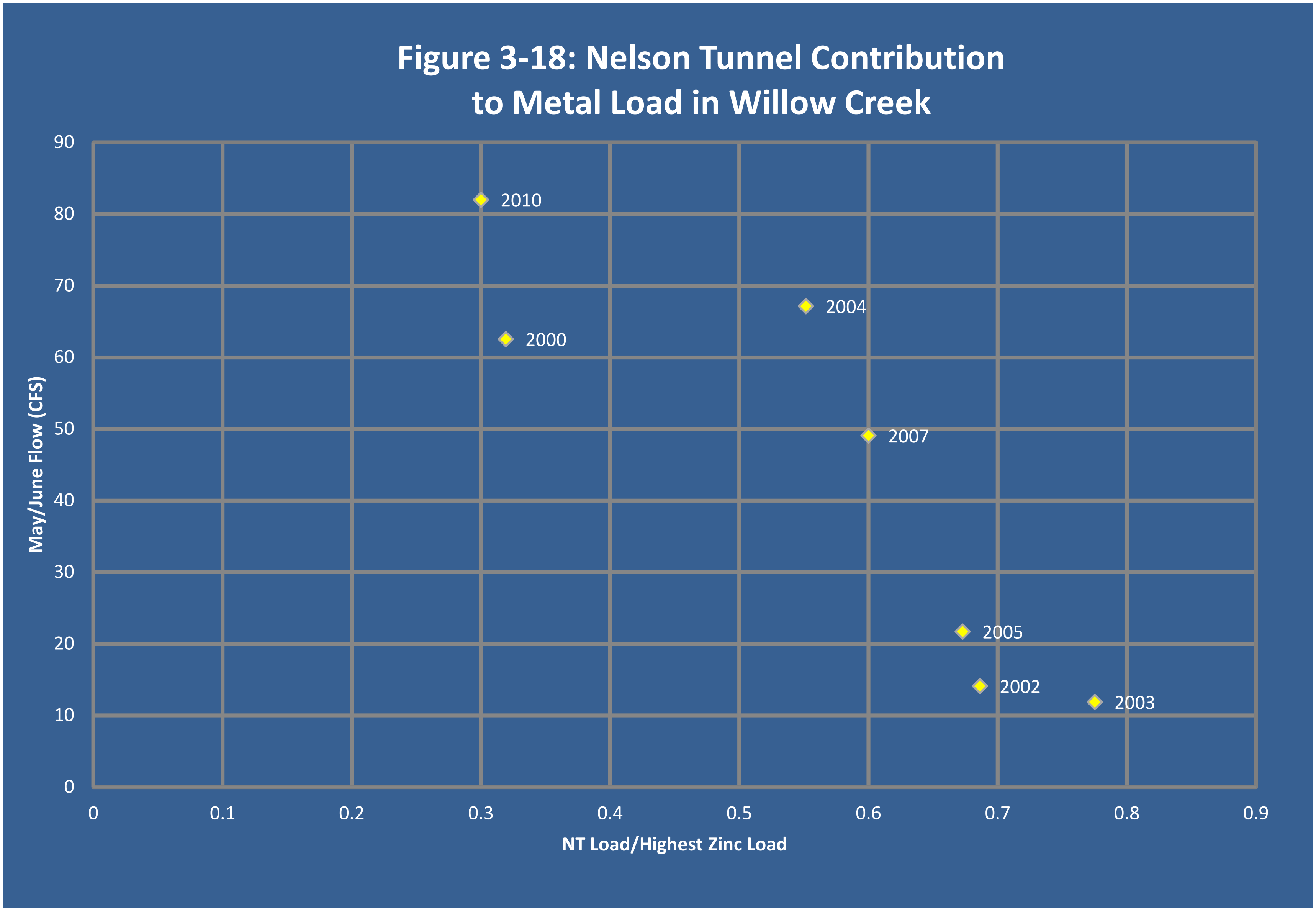
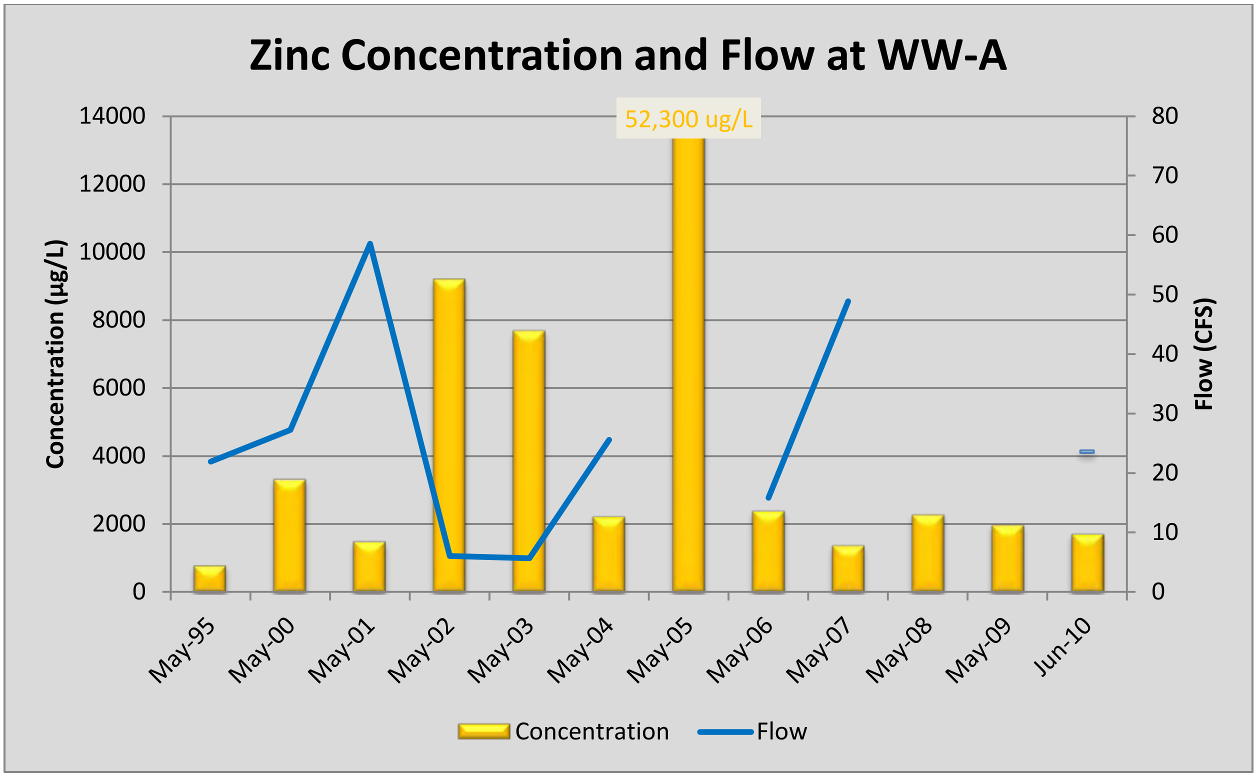
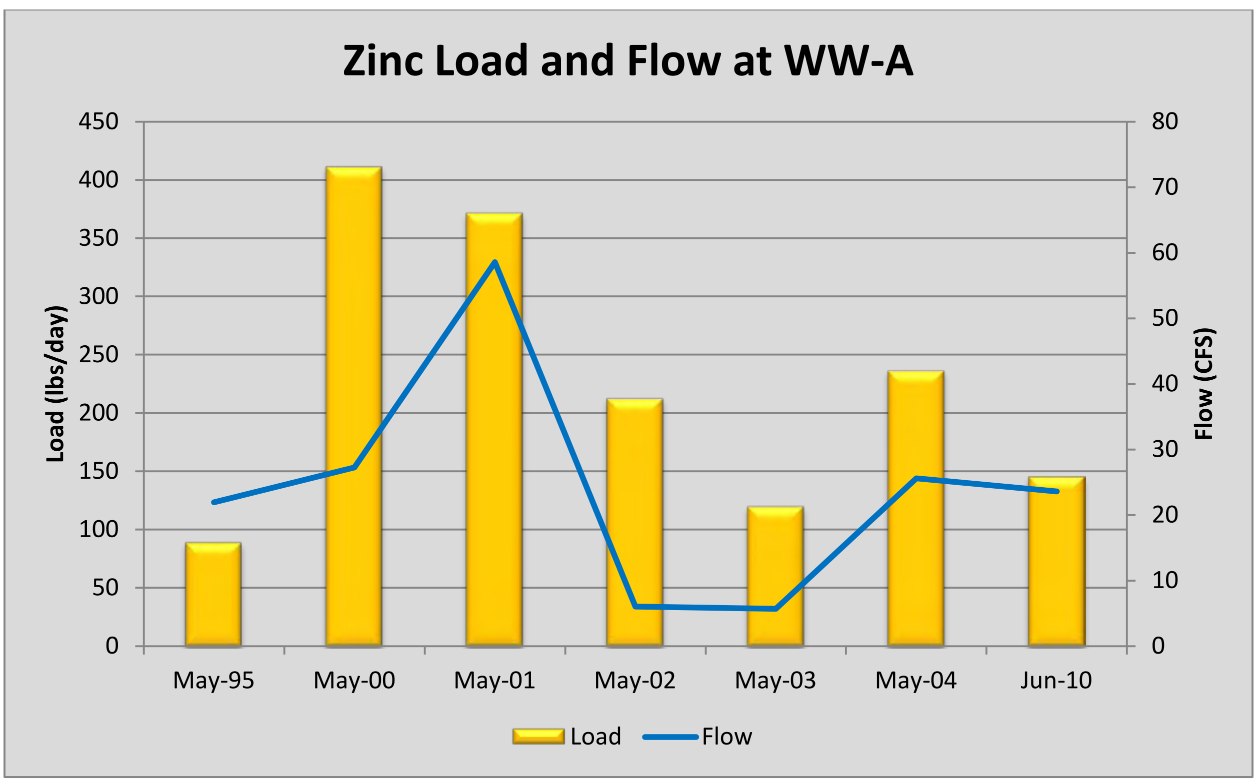


Figure 3-18: Nelson Tunnel Contribution
to Metal Load in Willow Creek
May/June Flow (CFS)
NT Load/Highest Zinc Load
0
10
20
30
40
50
60
70
80
90
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
2010
2000
2004
2007
2005
2002
2003

Figure 3-19 – Effects of Commodore Waste Rock Removal Action on Water Quality





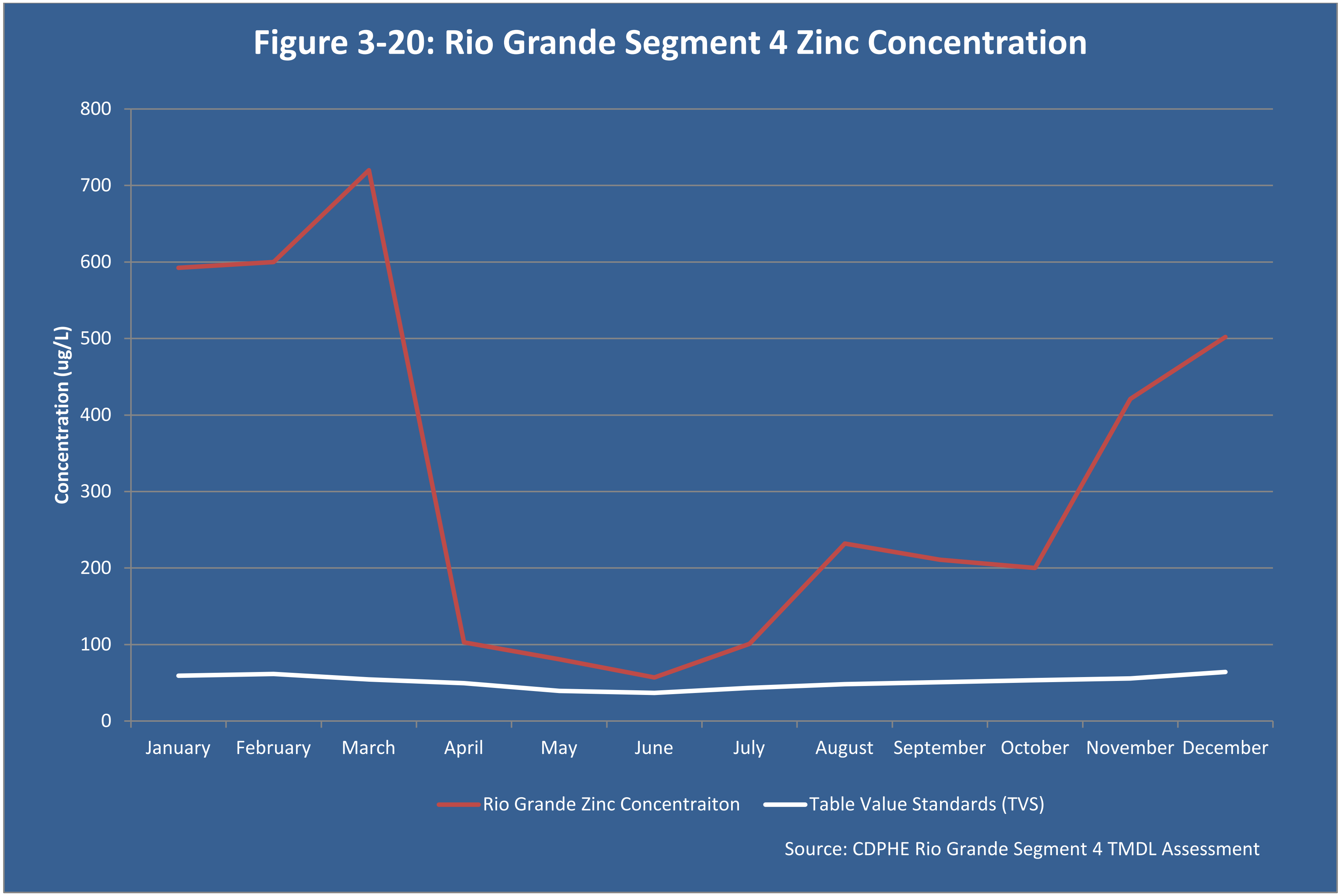


Figure 3-20: Rio Grande Segment 4 Zinc Concentration
Concentration (ug/L)
800
700
600
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December
Rio Grande Zinc Concentraiton
Table Value Standards (TVS)
Source: CDPHE Rio Grande Segment 4 TMDL Assessment

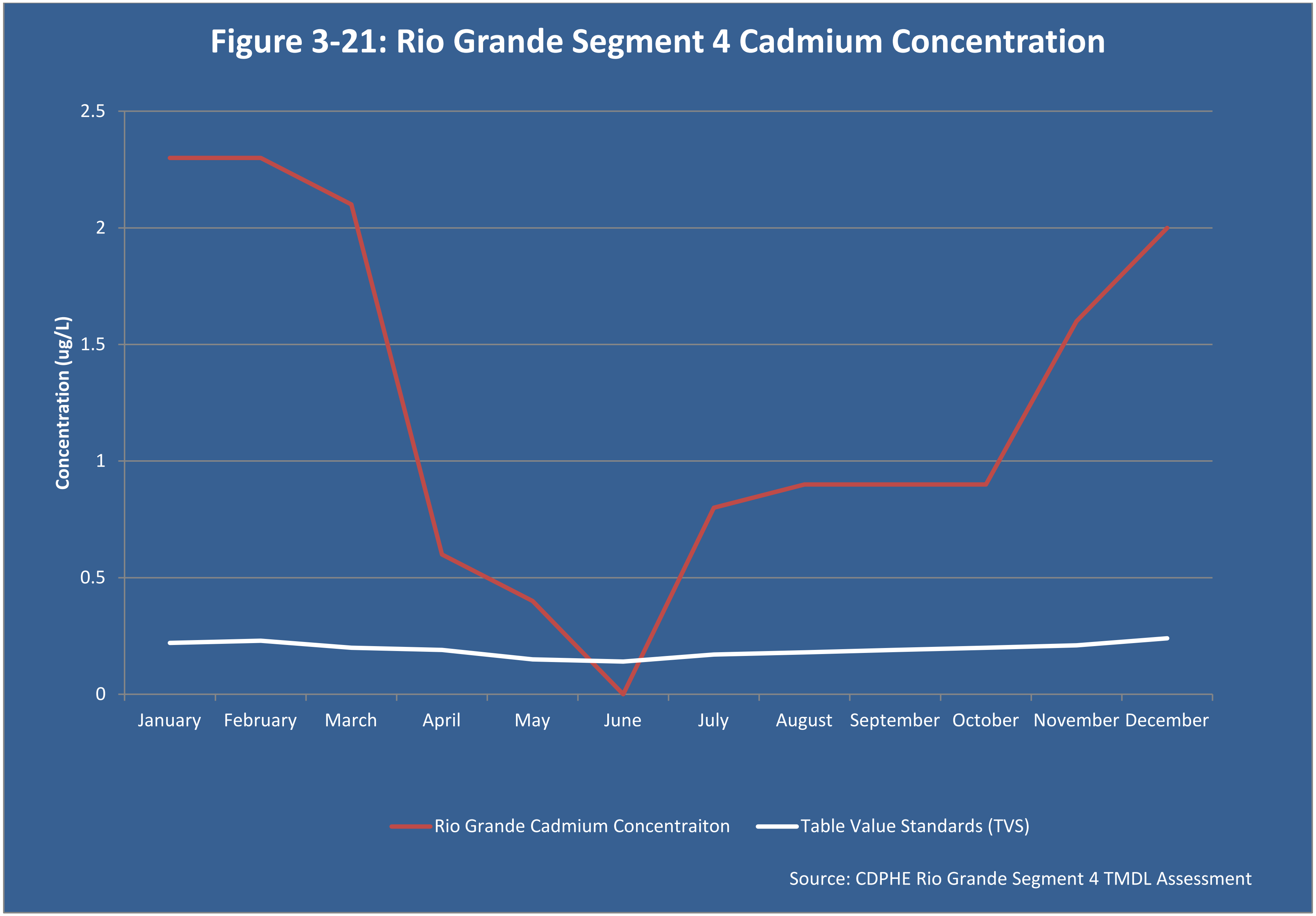
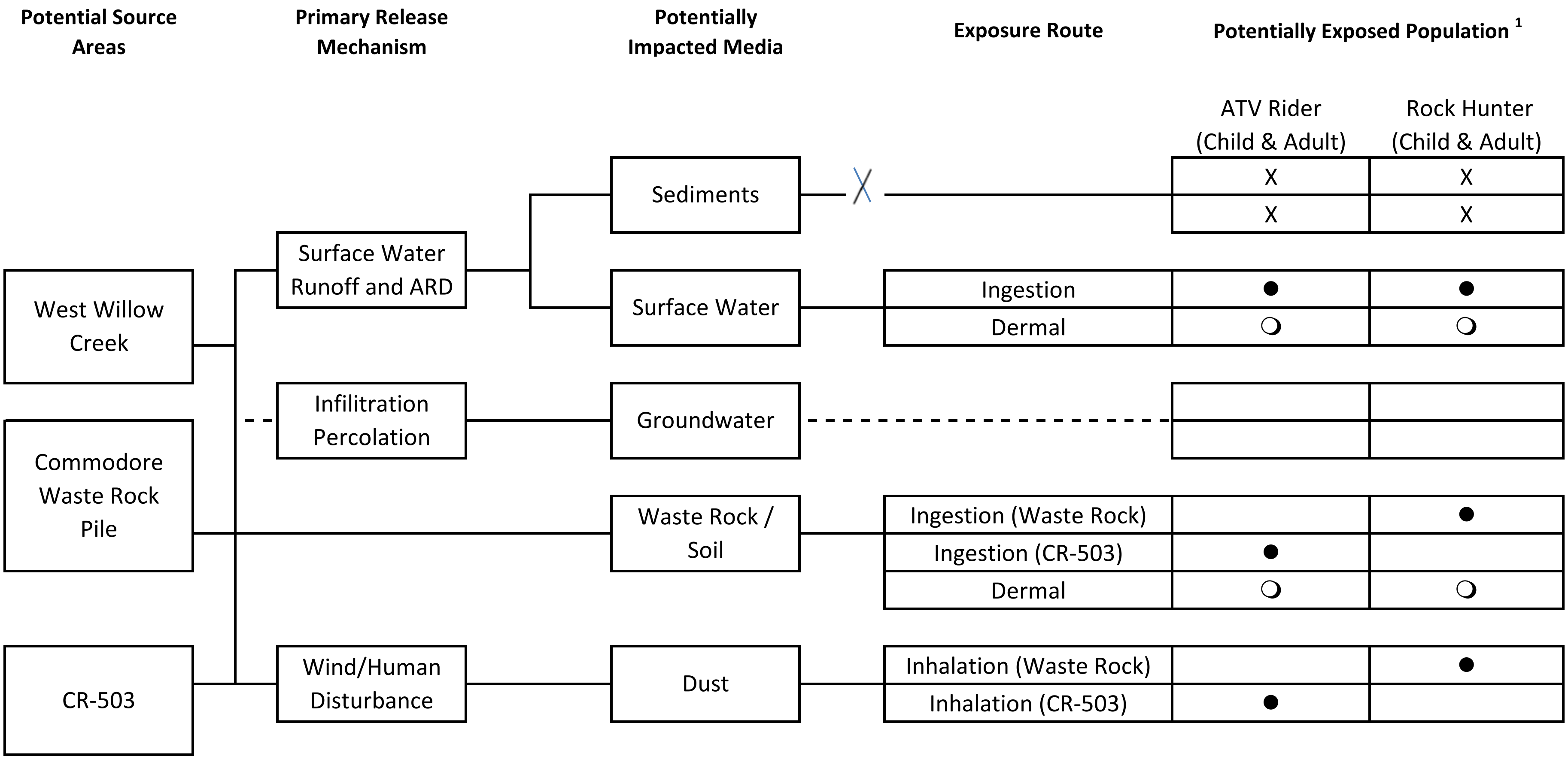


Figure 3-21: Rio Grande Segment 4 Cadmium Concentration
Concentration (ug/L)
2.5
2
1.5
1
0.5
0
January
February
March
April
May
June
July
August
September
October
November
December
Rio Grande Cadmium Concentraiton
Table Value Standards (TVS)
Source: CDPHE Rio Grande Segment 4 TMDL Assessment

Figure 4-1. Site Conceptual Exposure Model for Human Receptors
Nelson Tunnel/Commodore Waste Rock Pile



[1] Child receptors are assumed to be mainly older children/adolescents (ages 6 - 12 yeards old)

●	Potentially complete pathway, quantitiave evaluation.
❍	Potentailly complete pathway but judged to be minor, qualitative evaluation.
X	Pathway not complete, no evauation required (no sediment present).
- - - - - - - - - -	Pathway not included in scope of investigation.

ARD Acid Rock Drainage

Figure 4-2: Cd chronic-based HQs for water column invertebrates (maximum exposure scenario)

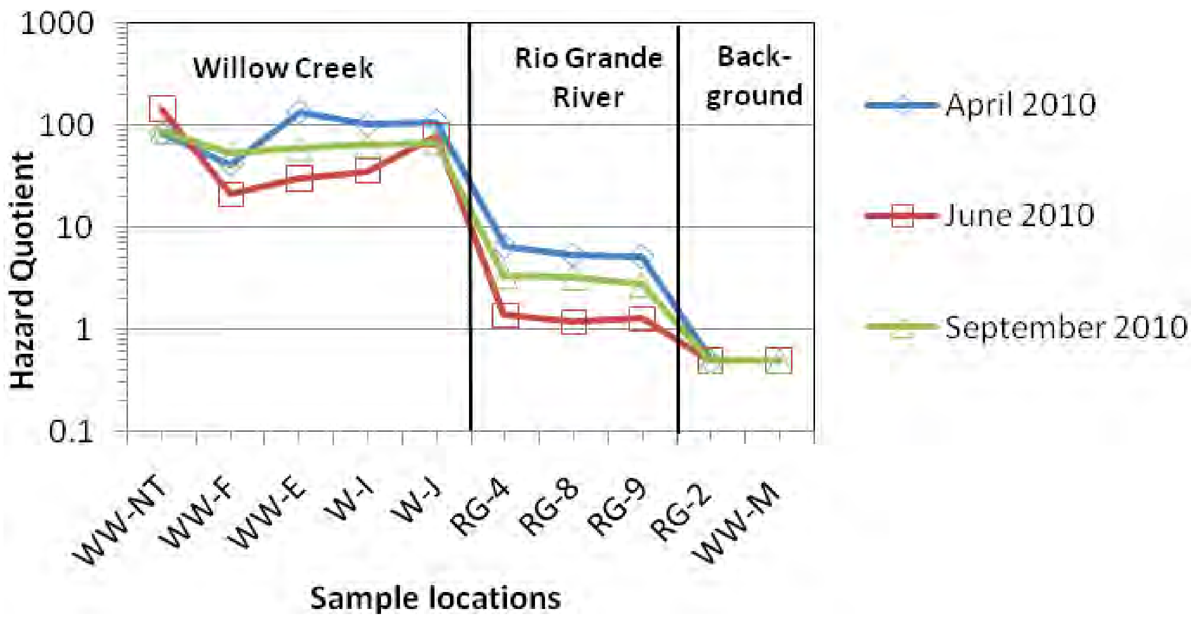
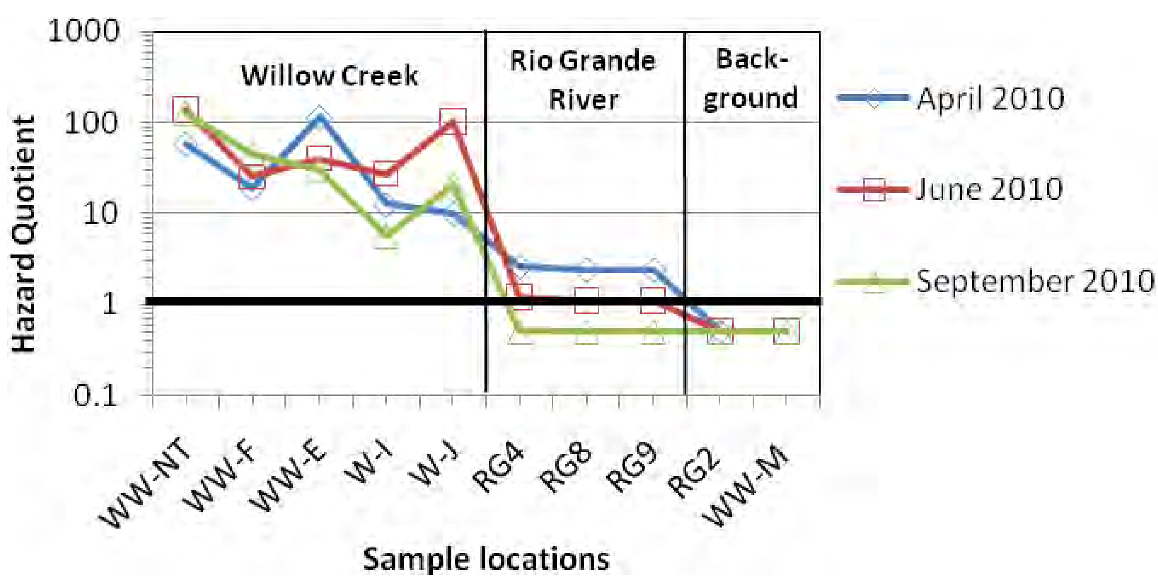


Figure 4-3: Pb chronic-based HQs for water column invertebrates (maximum exposure scenario)



From TechLaw, 2011c

Figure 4-4: Zn chronic-based HQs for water column invertebrates (maximum exposure scenario)

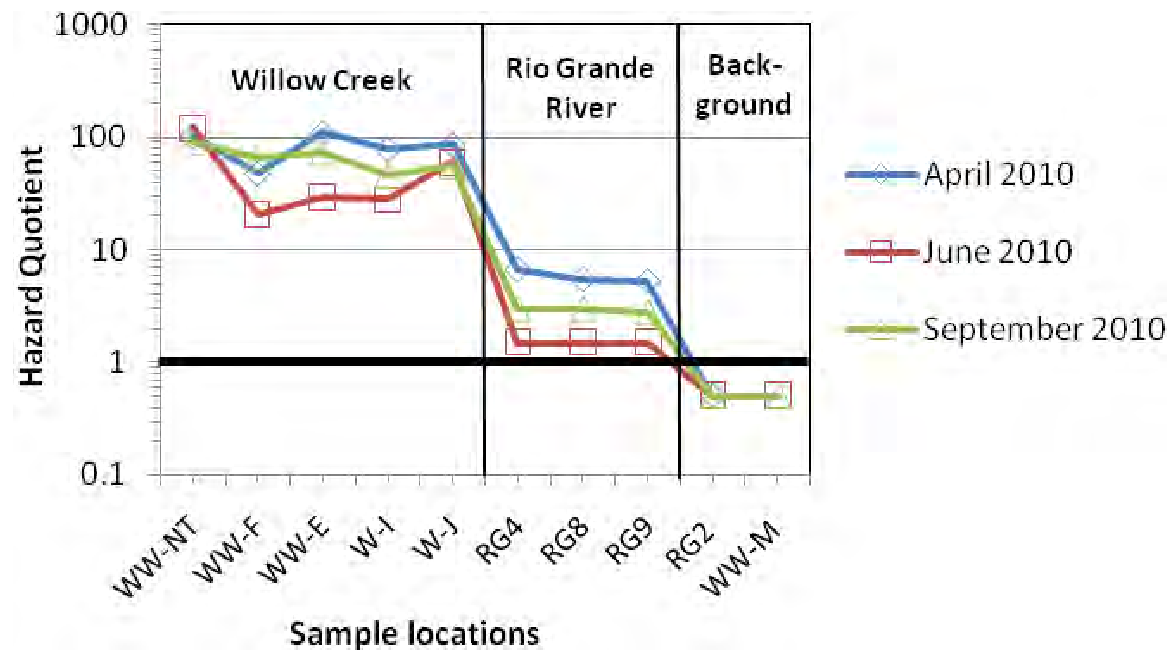
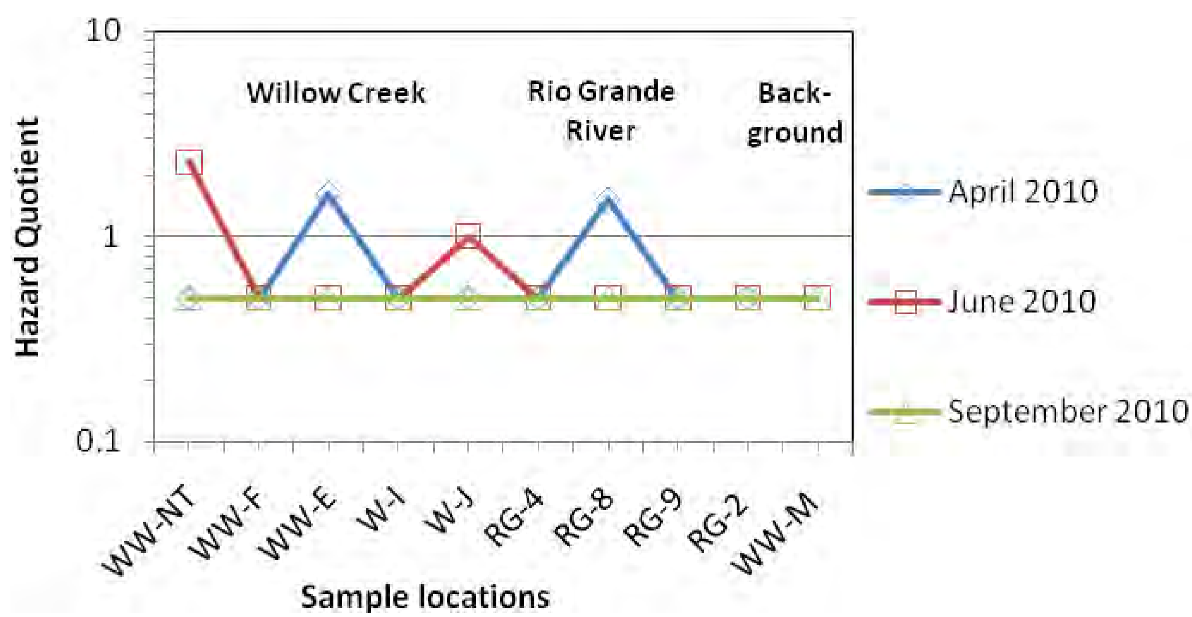


Figure 4-5: Cu chronic-based HQs for water column invertebrates (maximum exposure scenario)



From TechLaw, 2011c

Figure 4-6: Zn effect-based HQs for aquatic insectivorous birds (maximum exposure scenario)

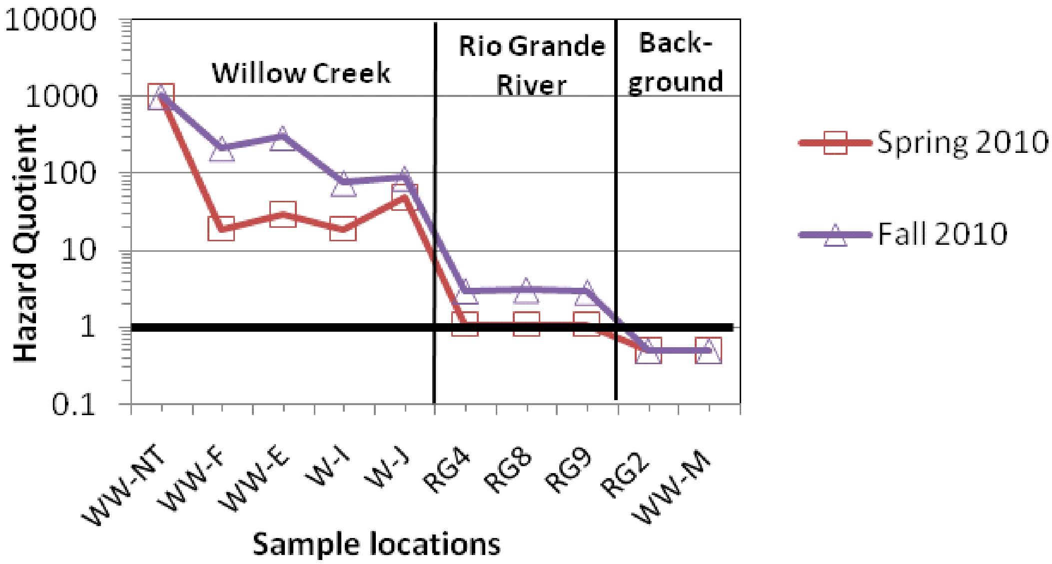
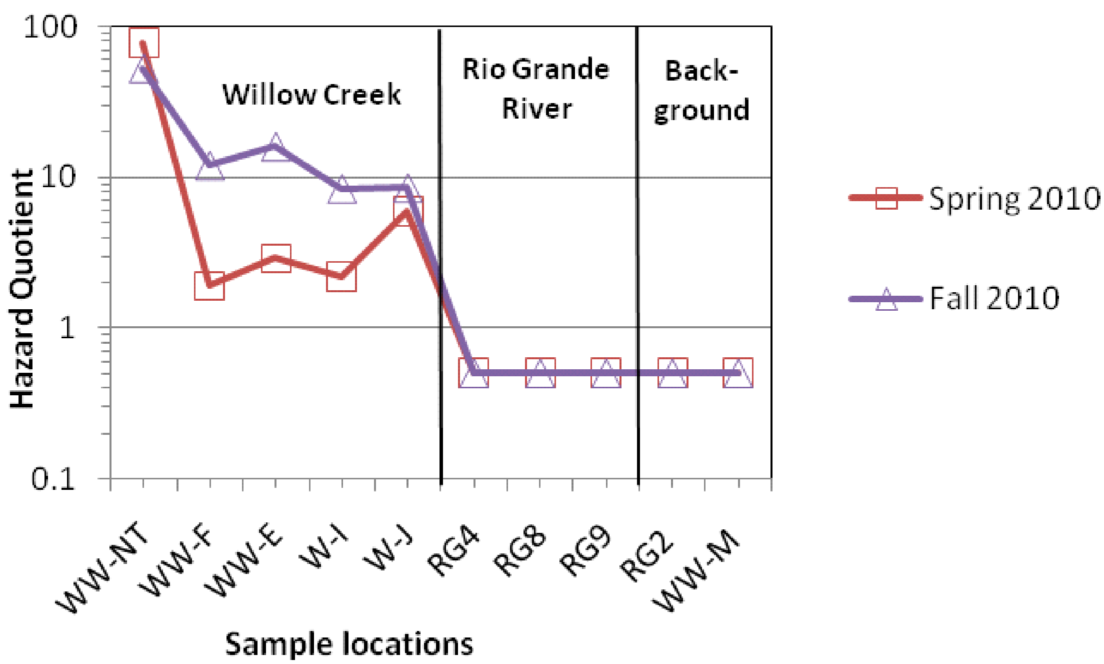


Figure 4-7: Cd effect-based HQs for aquatic insectivorous birds (maximum exposure scenario)



From TechLaw, 2011c

Figure 4-8: Pb effect-based HQs for aquatic insectivorous birds (maximum exposure scenario)

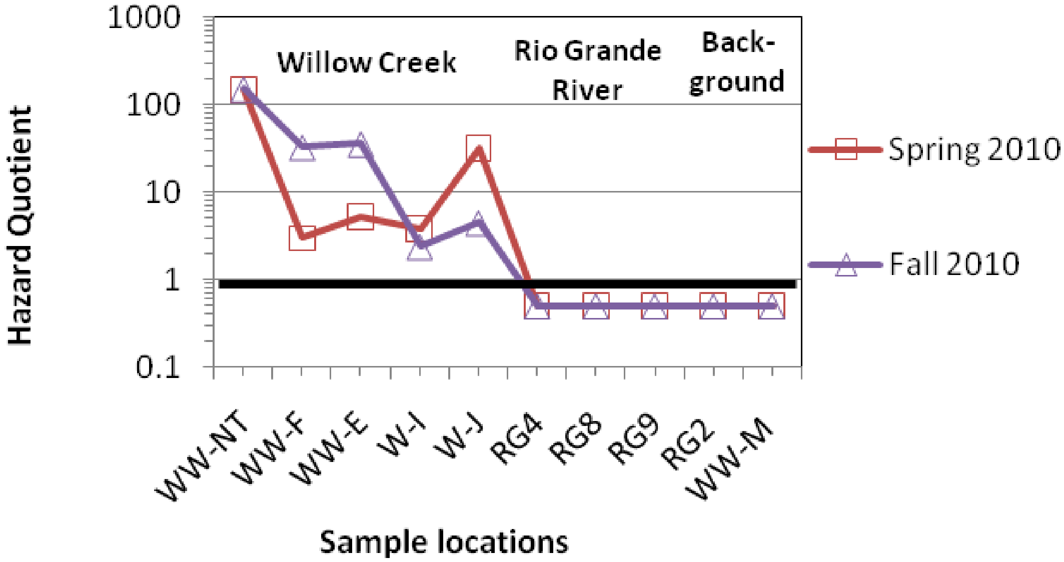
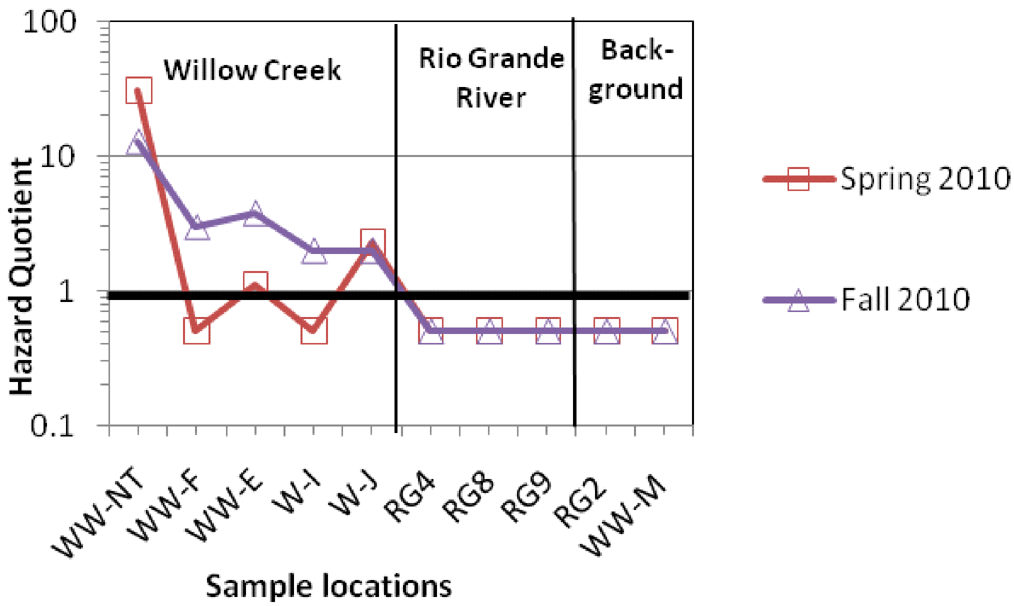


Figure 4-9: Cd effect-based HQs for omnivorous birds (maximum exposure scenario)



From TechLaw, 2011c

Figure 4-10: Pb effect-based HQs for omnivorous birds (maximum exposure scenario)

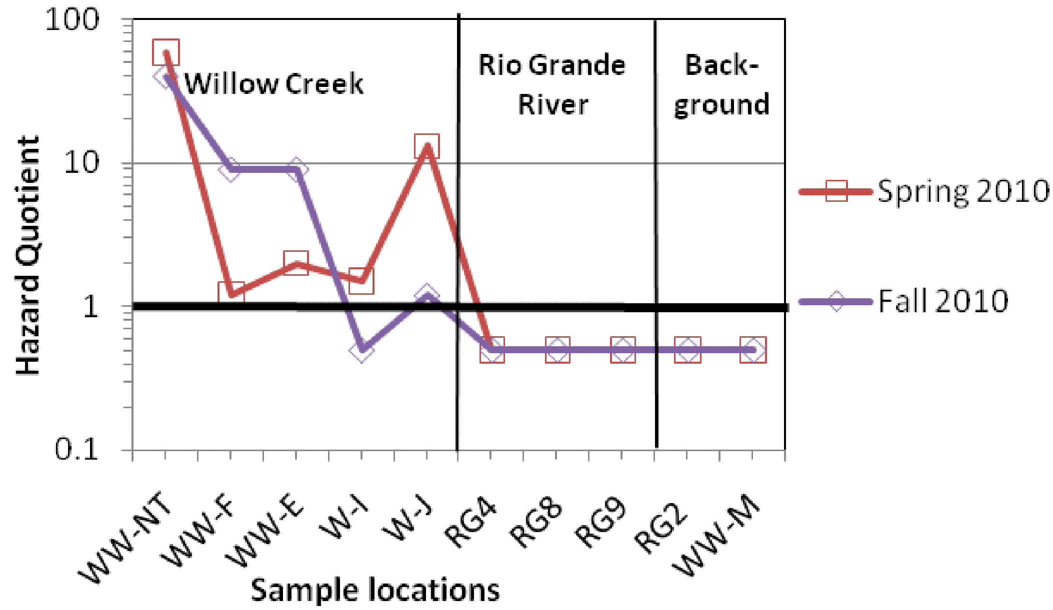
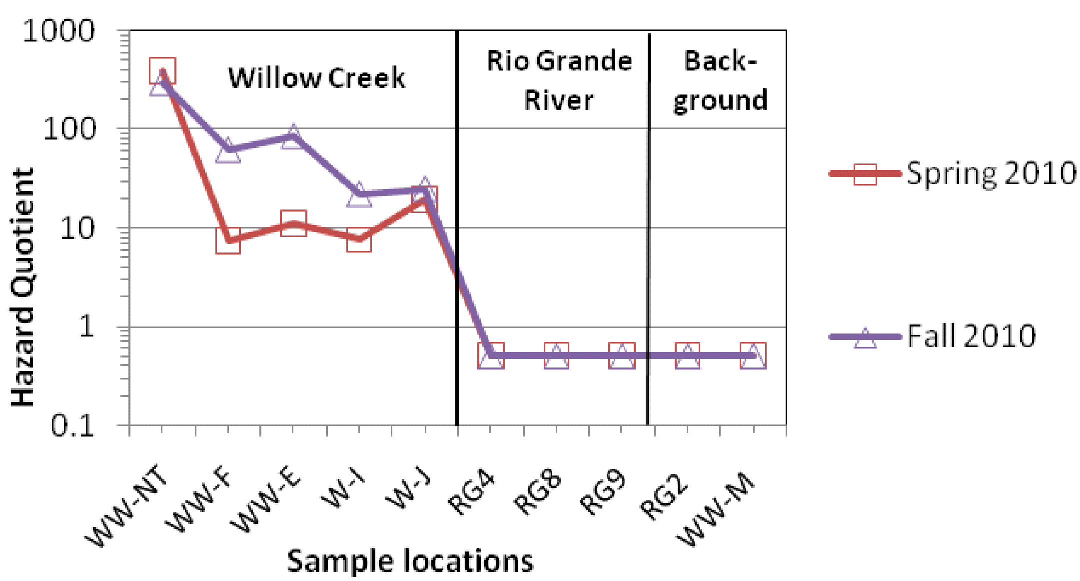


Figure 4-11: Zn effect-based HQs for omnivorous birds (maximum exposure scenario)



From TechLaw, 2011c

Figure 4-12: Cu effect-based HQs for omnivorous birds (maximum exposure scenario)

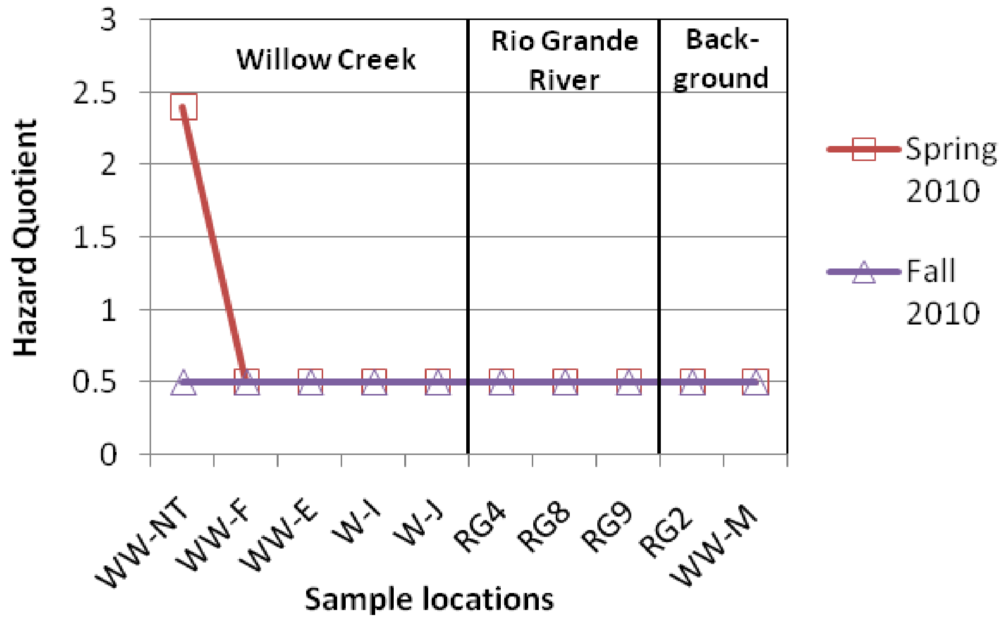
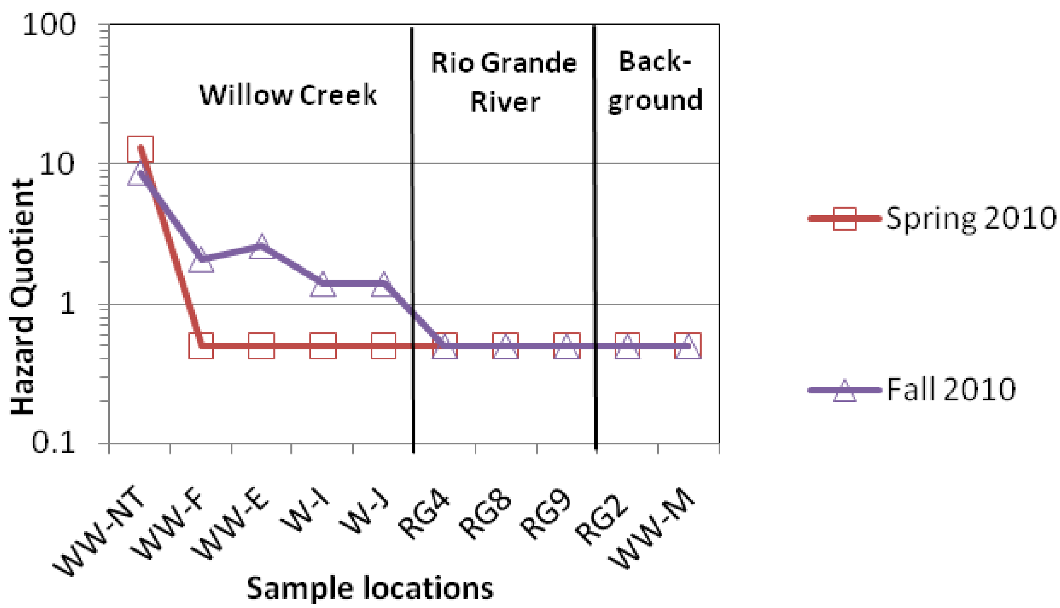


Figure 4-13: Cd effect-based HQs for piscivorous birds (maximum exposure scenario)



From TechLaw, 2011c

Figure 4-14: Zn effect-based HQs for piscivorous birds (maximum exposure scenario)

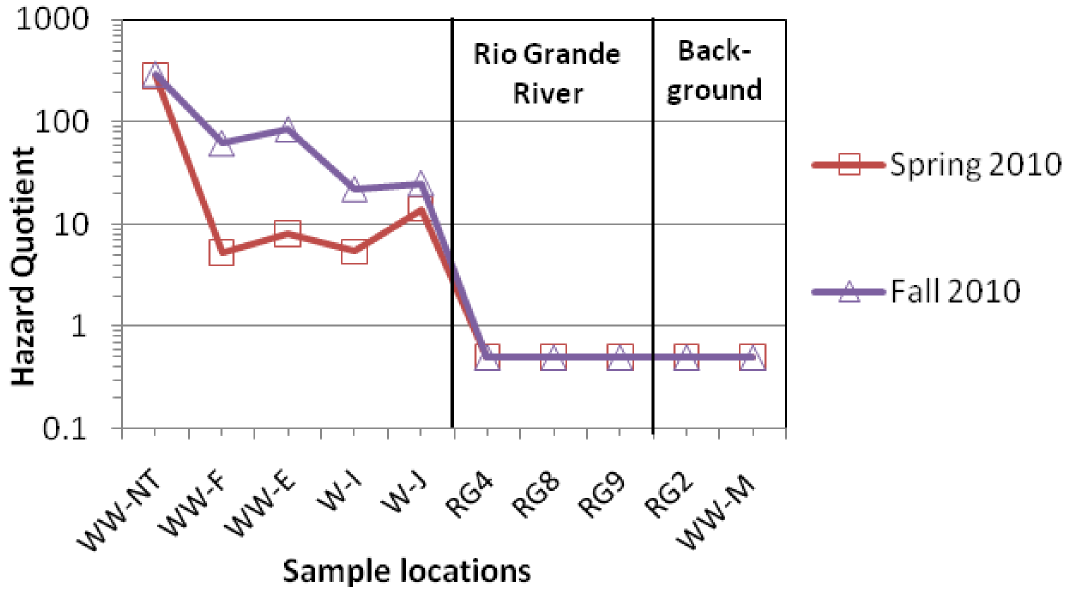
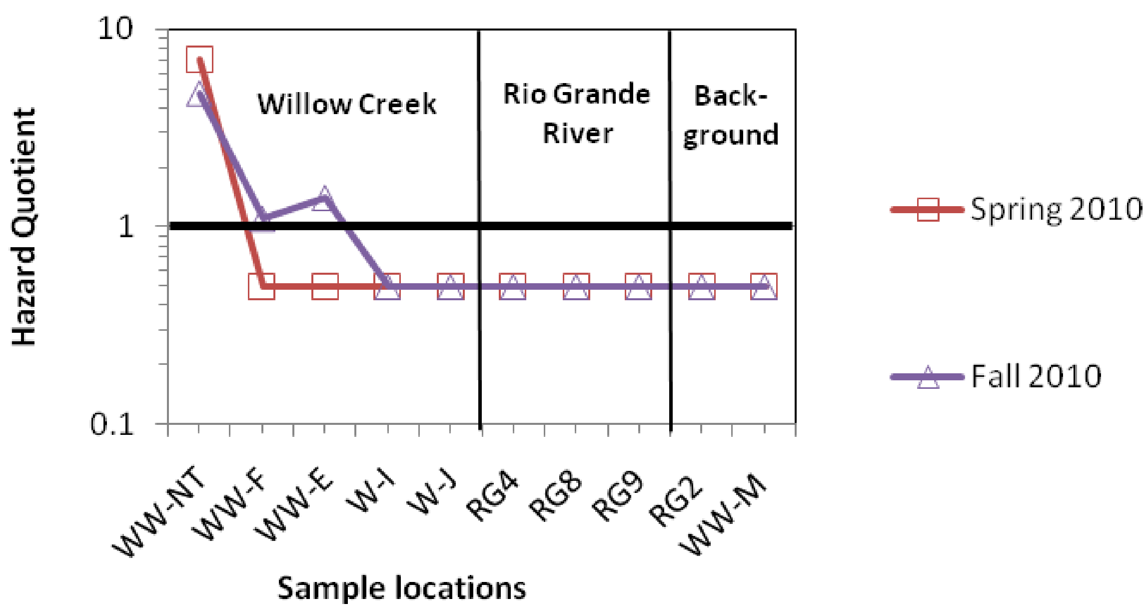


Figure 4-15: Cd effect-based HQs for herbivorous mammals (maximum exposure scenario)



From TechLaw, 2011c

Figure 4-16: Zn effect-based HQs for herbivorous mammals (maximum exposure scenario)

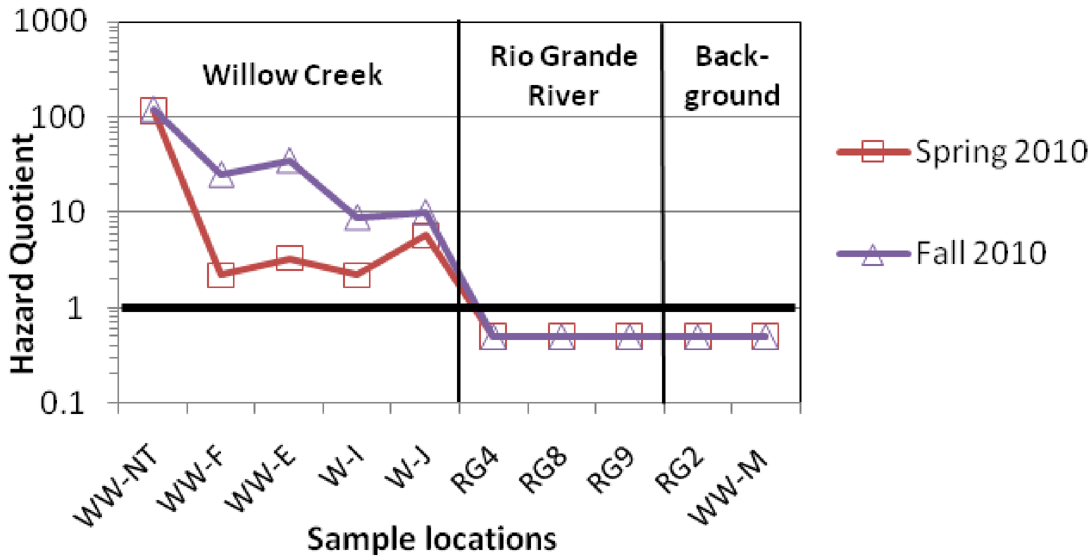
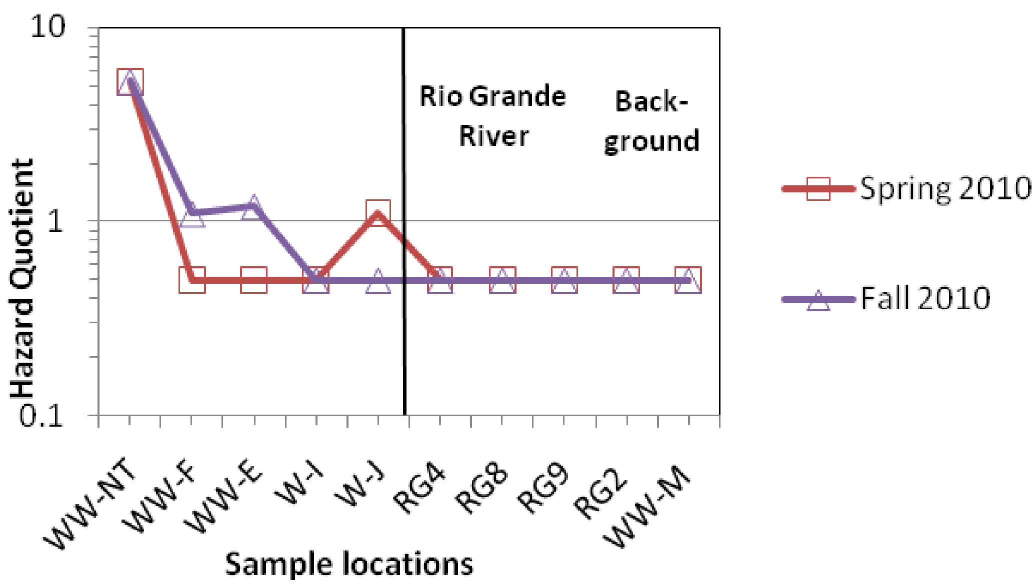
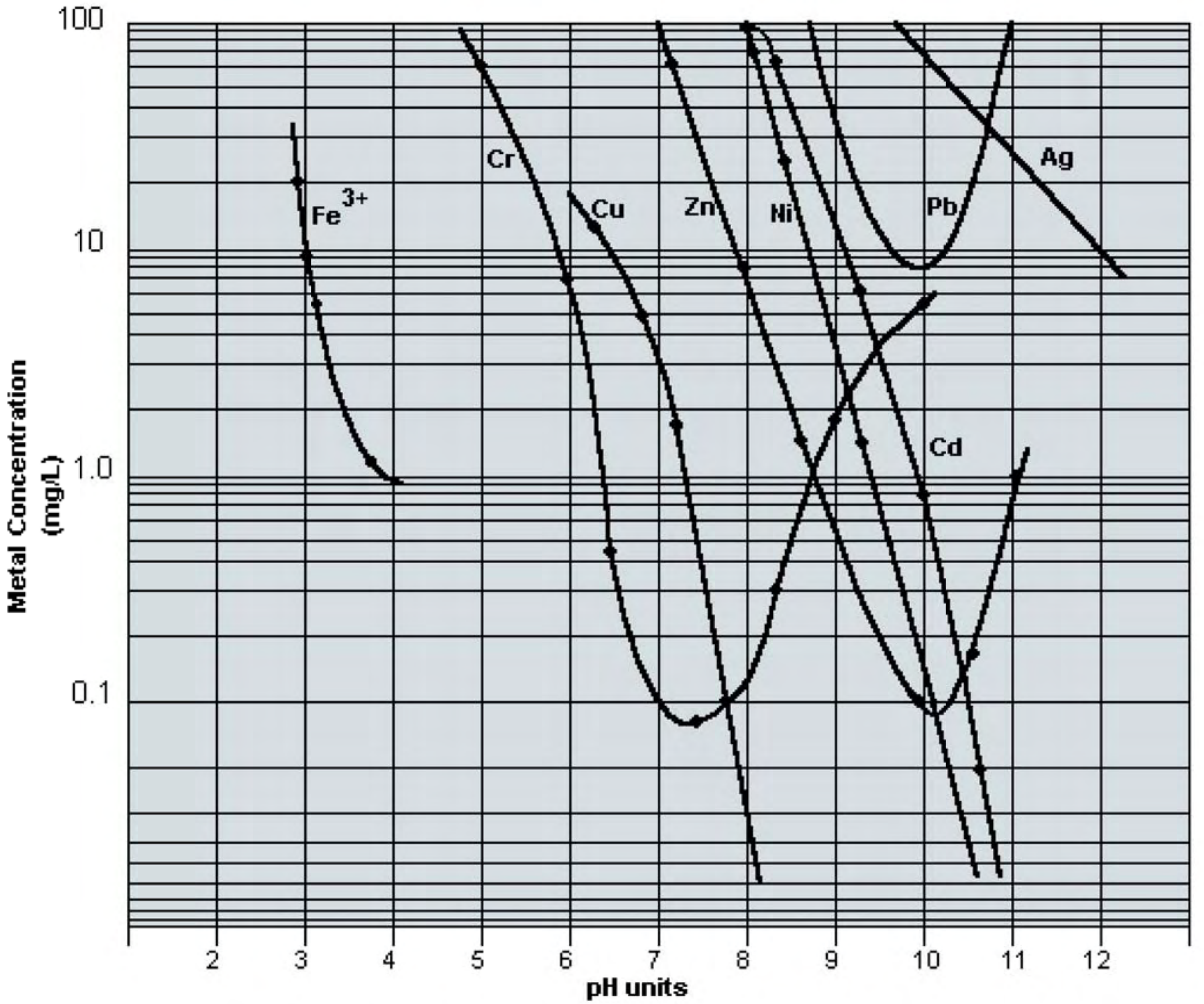


Figure 4-17: Pb effect-based HQs for herbivorous mammals (maximum exposure scenario)



From TechLaw, 2011c



SOURCE: http://www.hoffland.net/src/tks/3.xml

HDR Engineering, Inc.

Metals Solubility Curves
Nelson Tunnel/Commodore Waste Rock Pile Site
Remedial Investigation Report

DATE: April, 2010	Figure 5-1

APPENDICES

Appendix A

Report from Dr. Williams

Anton Krupicka and Mark Williams
INSTAAR
University of Colorado-Boulder
August 23, 2011

Hydrologic System of the Nelson Tunnel/Commodore Mine, Creede, CO

Isotope Sampling
Acid mine drainage (AMD) discharging from the portal of the Nelson Tunnel near Creede, CO is currently impacting water quality in West Willow Creek and, 1.5 miles further downstream, the Rio Grande River. From 2007-2010 a series of water samples were collected from sites within the Nelson Tunnel and from surface waters, springs, domestic wells and precipitation collectors in the West Willow Creek watershed. These samples were analyzed for stable isotope content of $\delta^{18}O$ and deuterium and the radiogenic isotope tritium. A subset of five of these samples was analyzed for the $\delta^{14}C$ of dissolved inorganic carbon (DIC). The purpose of this analysis was to help delineate source waters for the water in the mine tunnel through a combination of dating and stable isotope mixing.

Stable isotope results show water in the Nelson Tunnel to be largely well-mixed with source waters being either a mixture of snow and rain recharge or just snow that has undergone some fractionation. Figure 1 shows how deuterium and $\delta^{18}O$ mine water samples plot as a mixture of the snow and rain end-members and along the Global Meteoric Water Line (GMWL), indicating no evaporation in the samples. Two sites in the tunnel—the Del Monte Raise and the Corkscrew Raise—have noticeably more-enriched isotope values, which suggests that these sites could be independently receiving contributions of more recent rain water and/or are sites of an eddy in the mine pool (see Figure 2).

Similarly, tritium values along the length of the tunnel are primarily "tritium-dead" (<1.5 TU) except for higher values at both the Del Monte and the Corkscrew (see Figure 3). Tritium-dead results indicate water that is at least older than the "bomb-spike" waters of nuclear weapons testing in the 1960s. The higher values at the Del Monte and the Corkscrew again suggest a mixing with small amounts of more recent water or a poorly-mixed eddy that still retains a few TUs of the original bomb-spike signature.

DIC $\delta^{14}C$ testing of sites along the mine tunnel all indicate water on the order of hundreds to thousands of years of age (see Figure 4). This long residence time indicates a long flowpath from infiltration at the surface—likely higher in the watershed—to the upwelling/inflowing into the mine tunnel. However, these ages could be affected by other sources of carbon—namely chemical weathering—that have not been corrected for in the calculated age.

Stable isotope values of samples taken from surface waters, springs, and domestic wells all indicate a well-mixed source just as was found in the majority of the mine tunnel waters (see Figure 5). However, all of these sites have higher tritium values that suggest either much more recent post-bomb spike water or a mixture of more recent water with a small contribution of the older bomb spike water from the 1950s. The flowpaths that recharge these sample sites are likely much shorter than the flowpath discharging into the Nelson Tunnel.

Mine Water Temperature

Water temperature data from several sites within the mine were gathered between 2002 and 2007 (see Figure 6). While groundwater would typically be expected to be in the 5-10° C range, temperatures of water in the Nelson Tunnel were between 14 and 21° C, likely as a result of latent volcanic heat at depth in the area. Water temperature generally cooled the closer the site was to the tunnel portal with the hottest temperatures being recorded farthest back in the tunnel at the Park Regent, Decline and Berkshire Shafts.

This data is consistent with the isotope data that suggests a source of water somewhere between the Decline and Berkshire shafts that has followed a long flowpath. The majority of water coming into the tunnel is likely from this region and has been heated as a result of a deep flowpath before it upwells into the tunnel. The Del Monte site exhibited cooler water in the tunnel which is also consistent with its slightly anomalous $\delta^{18}O$ and tritium data, all suggesting that it is the site of an eddy in the tunnel waters.

2010 Slug Injection Tracer Test

In addition to the isotopic analysis, in 2010 a slug injection tracer test using three inorganic salts was conducted along the length of the Nelson Tunnel. The purpose of this test was to characterize the flow regimes of the two major mine pools in the tunnel and to help determine where water is entering the tunnel and whether it might be leaving the tunnel before it reaches the portal.

Results from this test suggest that the upper mine pool—located between the Decline Shaft and No Name Winze—is very slow moving. Flow velocities of roughly 10m/hr were calculated along the length of the upper mine pool, indicating a quasi-stagnant body of water with significant lateral exchange due to eddies, tunnel blockages, and dispersion and diffusion with less dominant down-tunnel advection.

In contrast to this, the lower mine pool—located between No Name Winze and the tunnel Portal—had flow velocities of approximately 25m/hr and a well-defined tracer breakthrough curve that indicated advection-dominant channelized flow with likely no additional inflows of water. Flow in the lower mine pool seems to be especially advection-dominant below the Bachelor Shaft with flow between No Name Winze and Bachelor Shaft being affected by some dispersion as characterized by a possible slow leakage of tracer in the tunnel hydrograph after the initial breakthrough tracer curve.

While this 2010 tracer test indicates inflows occurring in the upper mine pool, results from a previous tracer test (Davies, G., 2001) with a slug injection in the Berkshire Shaft (located in the upper mine pool) showed a very strong tracer breakthrough curve, suggesting similar conditions between the Berkshire and the Portal as was observed in the fall 2010 tracer test for just the lower mine pool. If this is indeed the case now, 10 years later, it would show that the hypothesized upwelling tunnel inflows are likely occurring somewhere between the Decline Shaft and the Berkshire Shaft—reducing the tunnel distance for significant inflows to only 270 meters versus the current spatial resolution for inflows of 1050 meters, i.e. the length of the entire upper mine pool.

Conclusion

These isotopic and tracer test results allow us to develop a picture of the hydrologic workings of the Nelson Tunnel/Commodore Mine system. The isotopic results show that the waters in the mine are largely not directly connected to surface waters or to the shallow groundwater (springs, seeps). Instead, this water in the tunnel appears to have a residence time on the order of hundreds to thousands of years and tracer results suggest that this water is entering the tunnel in the slow-moving, quasi-stagnant upper mine pool, likely resulting from the intersection of the tunnel with a system of watershed-wide faults. The water discharged from this upper mine pool is well-mixed and especially after the Bachelor Shaft enjoys a much quicker passage through the lower mine pool before it discharges at the Nelson Tunnel Portal. It appears there may be some small surface connection to the tunnel waters at both the Del Monte and Corkscrew Raises—or that these are the sites of more poorly-mixed eddies—but these possible connections' overall contribution to the quantity of water in the tunnel is fairly insignificant.

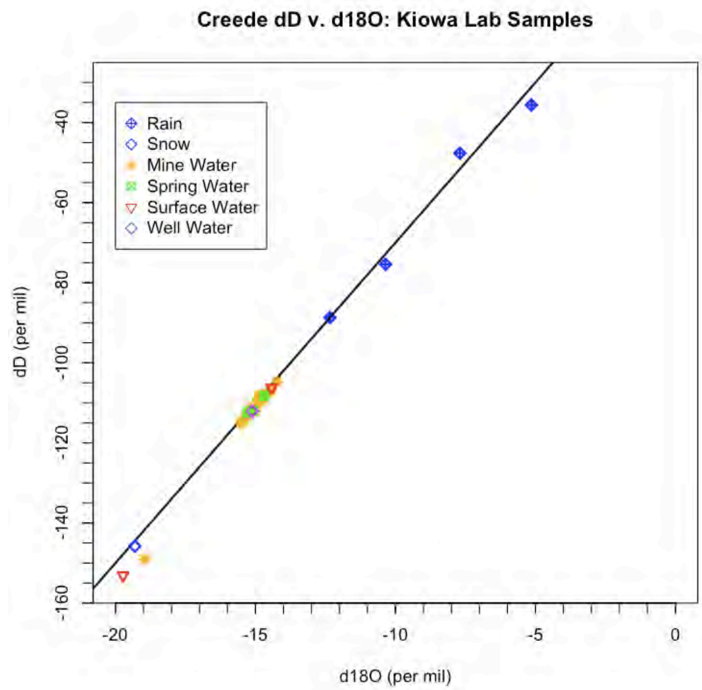


Figure 1. Mine water samples plot between rain samples on the right and the snow sample on the left, suggesting the source to be either a mixture of rain and snow or snow that has undergone fractionation.

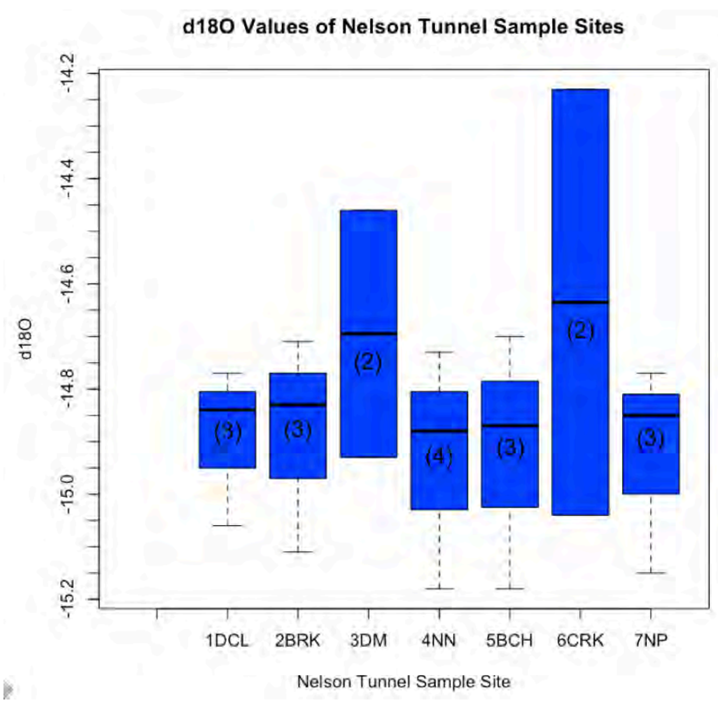


Figure 2. Sample sites in the Nelson Tunnel starting from the farthest back and going to the portal (Decline, Berkshire, Del Monte, No Name, Bachelor, Corkscrew, Portal). Sample sizes are in parentheses.

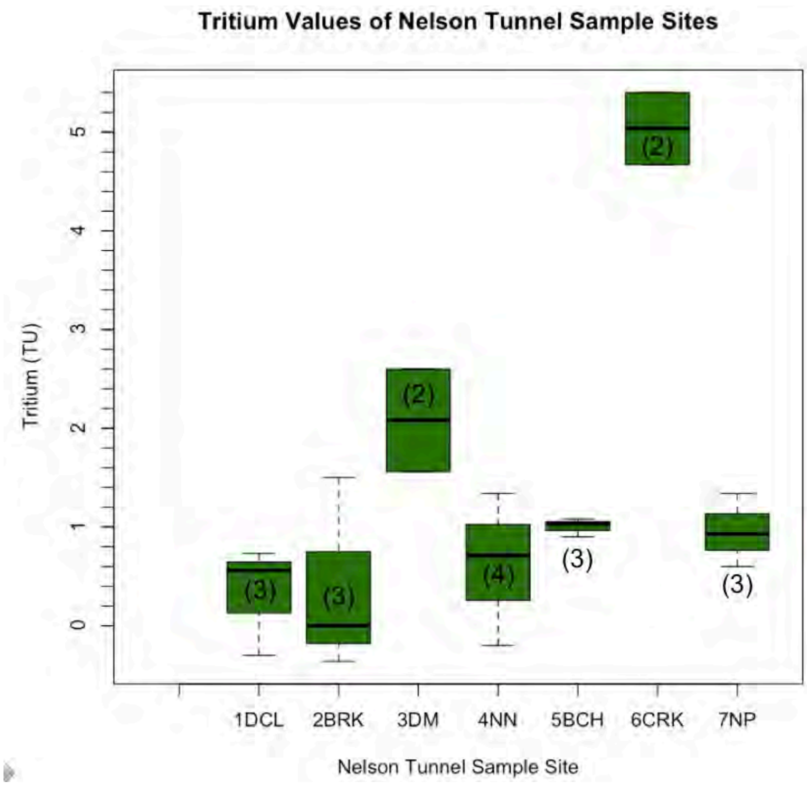


Figure 3. Tritium values at the same sample sites as in Figure 2. Sample sizes in parentheses.

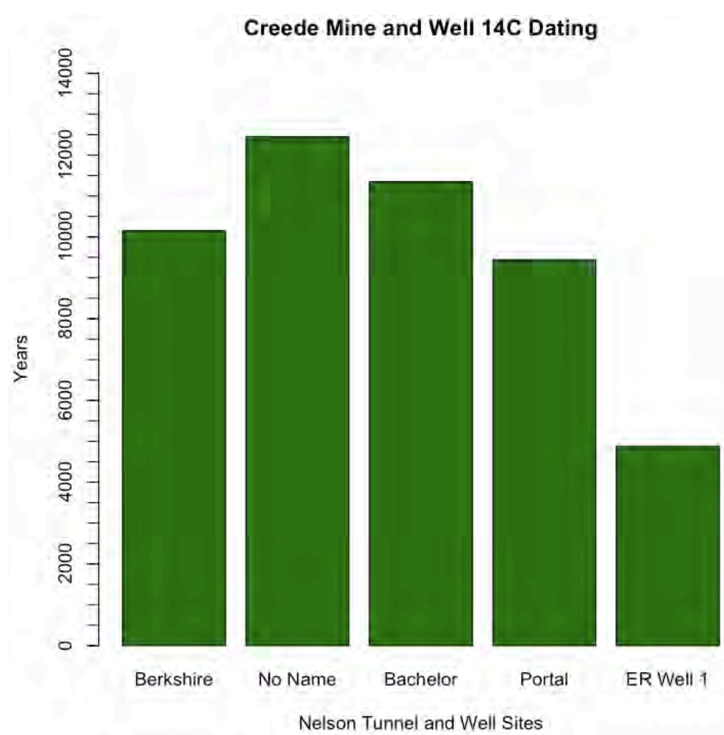


Figure 4. 14C dating of inorganic carbon at four selected mine tunnel sites and one domestic well. Water in the mine is roughly twice as old as the well water, suggesting a long, deep flowpath for water to get into the tunnel.

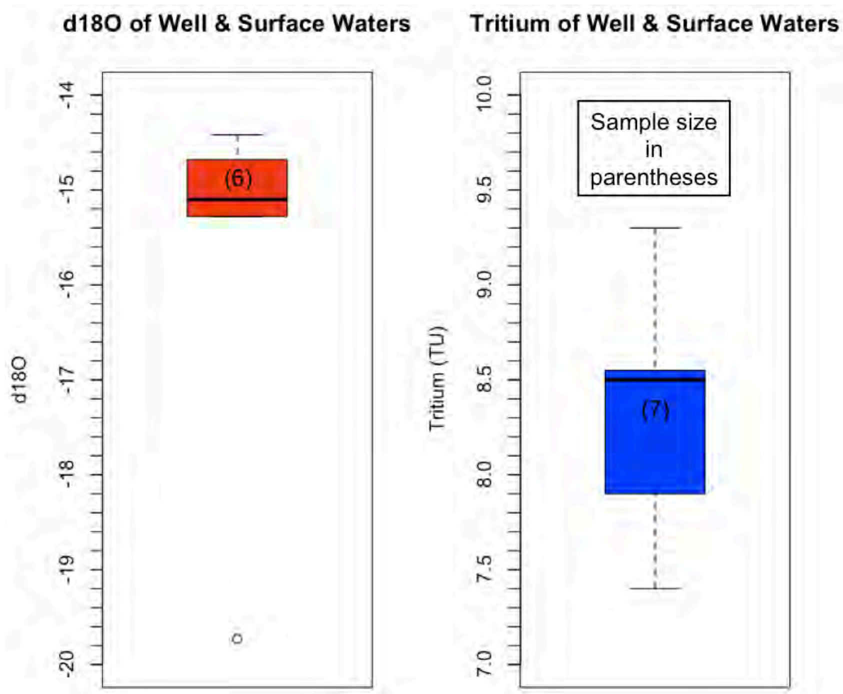


Figure 5. The depleted d18O outlier is a creek sample taken during June when flow would be snowmelt-dominated.

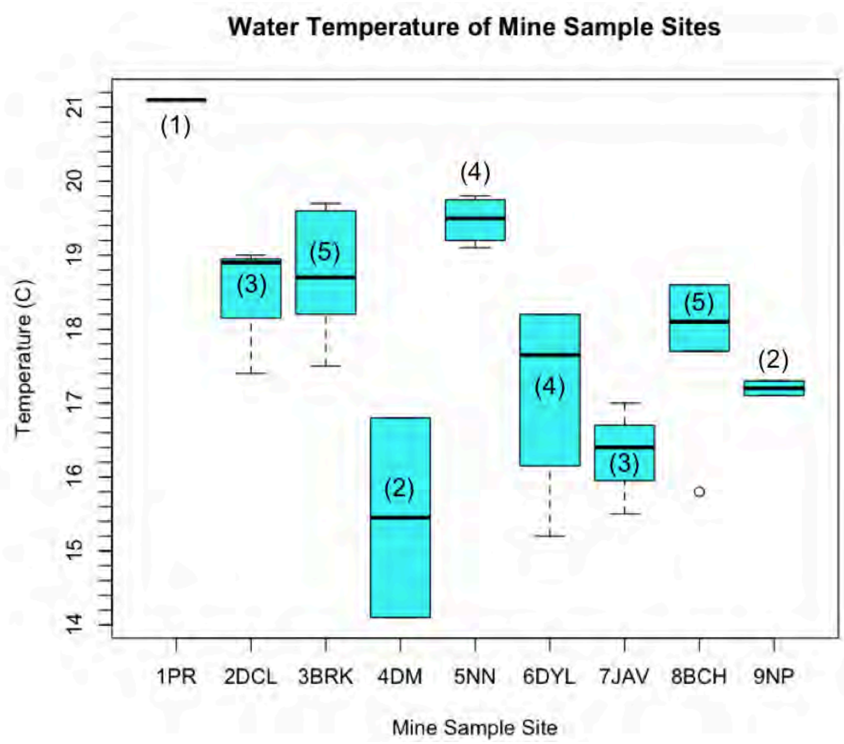


Figure 6. Water temperature for mine sites Park Regent, Decline, Berkshire, Del Monte, No Name, Daylight, Javelin, Bachelor, and Portal, with Park Regent being the farthest back in the tunnel.

Appendix B

Draft Final TMDL Assessment

FINAL DRAFT
TOTAL MAXIMUM DAILY LOAD ASSESSMENT

Rio Grande
Segment CORGRG04
Mineral and Rio Grande Counties, Colorado

TMDL SUMMARY	
Waterbody Name/Segment Number	Mainstem of the Rio Grande from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line, CORGRG04.
Pollutant/Condition Addressed	Cd, Zn
Affected Portion of Segment	Cadmium: Willow Creek to Wagon Wheel Gap, Zinc: Willow Creek to Del Norte
Use Classification/Waterbody Designation	Agriculture Aquatic Life Cold 1 Recreation E Water Supply
Waterbody Antidegradation Designation	reviewable
Water Quality Goal and Target	Attainment of water quality standards in the Rio Grande below the mixing zone with Willow Creek.

EXECUTIVE SUMMARY

The Rio Grande, segment CORGRG04, has been identified as water-quality limited for dissolved cadmium and zinc on the 1998 and subsequent 303(d) Lists, as approved by the Colorado Water Quality Control Commission. There are apparent point source discharges of pollutants, permitted and unpermitted, to Willow Creek which discharges to the Rio Grande, segment CORGRG04. This TMDL derives load allocations for dissolved cadmium and zinc to demonstrate the load reduction necessary to attain the currently adopted standards. The sources of pollutants in this watershed are predominately related to historic mining, mineral milling and smelting, mineral prospecting, and natural mineralization. Because there is a local watershed initiative and proposed Superfund listing to address the historic mining problems, this TMDL does not contain an implementation plan to attain standards. The focus of this TMDL is pollutant sources and reductions in the Willow Creek drainage. Since Willow Creek is the primary pollutant source to the Rio Grande, and it has no aquatic life standards, it needs to be remediated in order for the Rio Grande below Willow Creek to attain water-quality standards.

I. INTRODUCTION

Section 303(d) of the federal Clean Water Act ("CWA") requires States to periodically submit to the U. S. Environmental Protection Agency ("EPA") a list of water bodies that are water quality impaired. Water quality limited segments are those water bodies that, for one or more assigned use classifications or standards, the classification or standard is not fully achieved. This list of water bodies is referred to as the "303(d) List". In Colorado, the agency responsible for developing the 303(d) List is the Water Quality Control Division ("WQCD"). The 303(d) List is adopted by the Water Quality Control Commission ("WQCC") as Regulation Number 93. The WQCC adopted the current 303(d) List in March of 2006.

For water bodies and streams on the 303(d) list, a Total Maximum Daily Load (TMDL) is used to determine the maximum amount of a pollutant that a water body may receive and still maintain water quality standards. The TMDL is the sum of the Waste Load Allocation (WLA), which is the load from point source discharge (permitted and non-permitted), Load Allocation (LA), which is the load attributed to natural background and/or non-point sources, and a Margin of Safety (MOS) (Equation 1).

(Equation 1) $$TMDL = WLA + LA + MOS$$

Alternatively, a segment or pollutant may be removed from the list if the applicable standard is attained, if implementation of clean up activities via an alternate means will result in attainment of standards, if the original listing decision is shown to be in error, or if the standards have been changed as the result of a Use Attainability Analysis (UAA) or other EPA approved method.

II. GEOGRAPHICAL EXTENT

2.1 Segment Description

Rio Grande Segment 4 is located in Mineral and Rio Grande Counties, Colorado. This 83.3 mile segment is defined as the mainstem of the Rio Grande from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line. The upper thirty miles of the segment are impaired and are listed on the 2008 303(d) List for dissolved cadmium and dissolved zinc.

The sources of dissolved cadmium and zinc are predominately from historic mining features in the Willow Creek drainage, and a lesser source from groundwater springs above Wagon Wheel Gap. The Willow Creek Watershed is located in Mineral County, Colorado in the eastern part of the San Juan Mountains in southwestern Colorado. Willow Creek and its tributaries, East Willow Creek and West Willow Creek, drain the Willow Creek Watershed, an area of 39.8 mi^2 (103.1 km^2). The primary community in the watershed is the town of Creede, which is the county seat for Mineral County. Creede's elevation is 8,852 ft (2,685 m.) above mean sea level. Currently, the stream segment that defines the Willow Creek drainage, Rio Grande segment 7 (CORGRG07), has been assigned "ambient conditions" as the applicable water quality standards. However, in order to attain standards in the mainstem of the Rio Grande below Willow Creek, metal loading via the Willow Creek drainage must be addressed.

Therefore, the scope of this TMDL includes the Willow Creek drainage and Rio Grande Segment 4.

The Willow Creek watershed is roughly triangular, narrowing to the south to the point where Willow Creek enters the Rio Grande. The watershed is approximately 7 mi. (11.5 km.) wide at its widest point. The highest point in the watershed is La Garita Peak, northeast of Creede, at an elevation of 13,894 ft. (4,235 m.). Much of the Upper Section exceeds 11,000 ft. (3,353 m.) in elevation. The lowest point is the confluence of Willow Creek with the Rio Grande at 8,602 ft. (2,622 m.). Thus, the vertical relief of the watershed is 5,292 ft. (1,613 m.). This relief is the basis for the significant variation in precipitation, temperature, and vegetation throughout the watershed (USEPA, 2005).

The watershed has been divided into sections based on natural differences in landscape characteristics. Aggregations of sub-watersheds served as the basis for creating the sections, which have been named Upper, Middle, Creede, and Lower. The relatively pristine Upper Section of the watershed contrasts sharply with the Middle, Creede and Lower Sections, which have been profoundly impacted by historic mining. The Middle Section has steep terrain and stream gradient and narrow canyons and is the heart of the Creede Mining District. The Creede Section contains the City of Creede at the mouth of the Willow Creek Canyon. The Lower Section contains the relatively flat alluvial floodplain of Willow Creek before its confluence with the Rio Grande (USEPA, 2005).

2.2 Discharge Permits and Property Ownership

Permit Holder	Permit Number	Design Capacity (gallons per day)	Location of Discharge	Notes
Creede, City of	CO0040533	**560,000**	Tributary of Willow Creek (Ditch)	
Homestake Bulldog Mountain Operation	CO0000710	452,000	Windy Gulch (Tributary to Willow Creek)	DMR data shows source of zinc is insignificant. Cadmium is not monitored.

Table 1. Discharge permits for Willow Creek watershed.

III. WATER QUALITY STANDARDS

Standards Framework

Waterbodies in Colorado are divided into discrete units or “segments”. The Colorado *Basic Standards and Methodologies for Surface Water*, Regulation 31(WQCC 2006b), discusses segmentation of waterbodies in terms of several broad considerations:

> *31.6(4)(b)…Segments may constitute a specified stretch of a river mainstem, a specific tributary, a specific lake or reservoir, or a generally defined grouping of waters within the basin (e.g., a specific mainstem segment and all tributaries flowing into that mainstem segment.*

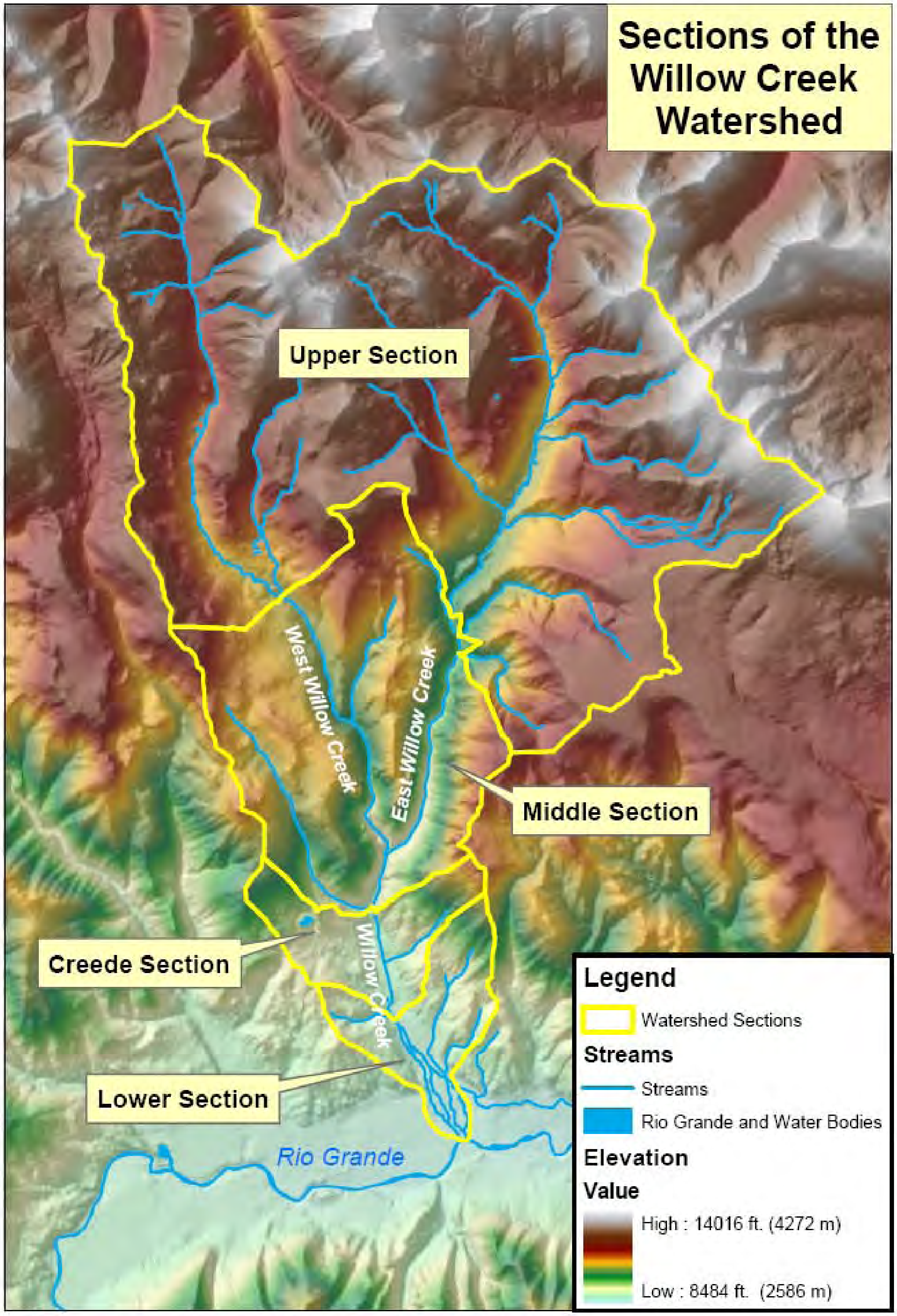


Figure 1. Sections of the Willow Creek watershed based on natural differences in landscape characteristics (Taken from: Hermann, K.A. and M. Wireman (editors). *Aquatic Resources Assessment of the Willow Creek Watershed*. Internal Report, U.S. Environmental Protection Agency, Region 8 Denver, Colorado, 2005).

(c) Segments shall generally be delineated according to the points at which the use, physical characteristics or water quality characteristics of a watercourse are determined to change significantly enough to require a change in use classifications and/or water quality standards

As noted in paragraph 31.6(4)(c), the use or uses of surface waters are an important consideration with respect to segmentation. In Colorado there are four categories of beneficial use which are recognized. These include Aquatic Life Use, Recreational Use, Agricultural Use and Water Supply Use. A segment may be designated for any or all of these "Use Classifications":

31.6 Waters shall be classified for the present beneficial uses of the water or the beneficial uses that may be reasonably expected in the future for which the water is suitable in its present condition or the beneficial uses for which it is to become suitable as a goal.

Each assigned use is associated with a series of pollutant specific numeric standards. These pollutants may vary and are relevant to a given Classified Use. Numeric pollutant criteria are identified in sections 31.11 and 31.16 of the *Basic Standards and Methodologies for Surface Water*.

Uses and Standards Addressed in this TMDL

The Colorado Basic Standards and Methodologies for Surface Water, Regulation 31 identifies standards applicable to all surface waters statewide (WQCC 2006b). The pollutants of concern for this assessment are dissolved cadmium and zinc in Rio Grande Segment 4 (Table 3). The specific numeric standards assigned to the listed stream segments are contained in Regulation 36, the Classifications and Numeric Standards for the Rio Grande Basin (WQCC, 2006c) (Table 3.1). In the case of the Rio Grande, cadmium and zinc concentrations exceed Aquatic Life Use-based standards intended to protect against short-term, acutely toxic conditions (acute) and longer-term, sub-lethal (chronic) effects. Aquatic Life Use-based standards for other parameters are attained as are all assigned numeric standards associated with Recreational, Water Supply and Agricultural Use Classifications.

Date (Cycle Year) of Current Approved 303(d) list: 2008		
WBID	**Segment Description**	**Designated Uses & Impairment Status**
CORGRG04	Mainstem of the Rio Grande from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Water Supply: Not Impaired Agriculture: Not Impaired

Table 2. Designated uses and impairment status for Rio Grande Segment 4.

The relevant standards for Rio Grande Segment 4 addressed in this document are the Aquatic Life Use-based table value standards, which vary based on hardness. The highest hardness values and therefore more lenient standards occur during low flow, which helps to offset the lack of dilution available at these times.

The stream segment addressed here is use classified as Aquatic Life Cold 1, Recreation E, Water Supply, and Agriculture. The elevated levels of listed heavy metals exceed the Aquatic Life Use standards, while other uses are supported (Table 2).

Water Quality Criteria for Impaired Designated Uses		
WBID	**Impaired Designated Use**	**Applicable Water Quality Criteria and Status**
CORGRG04	Aquatic Life Cold 1	Dissolved Phase Cd (1) / Not Attained Dissolved Phase Zn (1) / Not Attained
Applicable State or Federal Regulations: (1) Classifications and Numeric Standards for Rio Grande Basin (Reg 36)		

Table 3. Ambient water quality criteria and status for Rio Grande Segment 4, mainstem of the Rio Grande from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line.

The USGS report titled "*Evaluation of Metal Loading to Streams near Creede, Colorado*" estimates a net gain in the Rio Grande from Willow Creek in August and September of 2000, of 89.7 kg/day (197.8 lbs/day) of zinc and 0.5 kg/day (1.1 lbs/day) of cadmium. The contribution of the Nelson Tunnel is estimated to be approximately158 kg/day (347.6 lbs/day) of zinc to Willow Creek (Kimball et al., 2004). As demonstrated in the USGS tracer study, some attenuation of metals in Willow Creek occurred after the inflow of Nelson Tunnel discharge. There was measured attenuation of metals loads in Willow Creek ranging from a high of 45% for lead, to 15% for zinc (Kimball et al., 2004). Since it is an iron-rich system where there is abundant formation of iron colloids, it is common to see substantial metal attenuation (Kimball et al., 1994).

Two clear patterns emerged from the study of these loadings. First, the Nelson Tunnel contributed the greatest loads of Cd, Mn, Pb, Sr, Zn, and SO_4. Generally, this was greater than 50 percent of the load along the study reach. For some of these solutes, the Nelson Tunnel contributed about 10 times the load contributed by any other stream segment. Not only did the Nelson Tunnel contribute the majority of load for most solutes, but there were also substantial loads contributed for Cd, Mn, Pb, Zn, and SO_4 in the two segments downstream from the Nelson Tunnel. These loads could result from leakage of Nelson Tunnel discharge into the large waste-rock pile at the Commodore Mine and then discharge of this leakage to the stream (Kimball et al., 2004).

3.1 Water Quality Goals and Targets

The water quality target and goal for this TMDL is attainment of the current dissolved cadmium and zinc water quality standards in the Rio Grande below the mixing zone with Willow Creek. New zinc standards and new, more stringent cadmium standards were adopted at the 2007 Arkansas/Rio Grande Basin hearings, and therefore greater load reductions are required to attain the standards.

The following table lists the water quality standards for Rio Grande Segment 4 from the Water Quality Control Commission's Regulation No. 36.

Water quality standards for Rio Grande Segment 4 (CORGRG04)					
Stream Segment Description	Classification	Physical and Biological	INORGANICS mg/l	METALS ug/l	
4. Mainstem of the Rio Grande from a point immediately above the confluence with Willow Creek to the Rio Grande/Alamosa County line.	Aquatic Life Cold 1 Recreation E Water Supply Agriculture	E.Coli=126/100ml D.O.=6.0mg/l D.O.(sp)=7.0mg/l pH=6.5-9.0	NH_3(ac)/(ch)=TVS Cl_2(ac)=0.019 Cl_2(ch)=0.011 CN=0.005 S=0.002 B=0.75 NO_2=0.05 NO_3=10 Cl=250 SO_4=WS	As(ac)=340 As(ch)=0.02 (Trec) Cd(ac)=TVS(tr) Cd(ch)=TVS CrIII(ac)=50(Trec) CrVI(ac/ch)=TVS Cu(ac/ch)=TVS Fe(ch)=1000(Trec) Pb(ac/ch)=TVS	Mn(ac/ch)=TVS Hg(ch)=0.01(Trec) Ni(ac/ch)=TVS Se(ac/ch)=TVS Ag(ac)=TVS Ag(ch)=TVS(tr) Zn(ac/ch)=TVS

Table 3.1. Water quality standards for Rio Grande Segment 4 (CORGRG04).

3.2 Hydrology

Data from the weather station at Creede, Colorado shows that the watershed is arid to semi-arid. At the higher elevations, most of the moisture is from winter snowfall. The southerly exposure of the watershed and its steep slopes result in rapid snowmelt and runoff. Climate data for the Creede Weather Station, the only weather station in the watershed, for the period of June 1978 through March 2004 is summarized as follows:

Average annual precipitation: 13.2 in. (335 mm.)
Month of highest precipitation: August (2.6 in. (65 mm.))
Month of lowest precipitation: December (0.5 in. (13 mm.))
Average annual snowfall: 47.9 in. (122 cm.)
Average annual temperature: 40.9º F (14.3º C)
Month of highest average temperature: July (60.8º F (16.0º C))
Month of lowest average temperature: January (21.9º F (-5.6º C))
(Source: http://www.wrcc.dri.edu/summary/climsmco.html)

The drainage area at the USGS gage on the Rio Grande at Wagon Wheel Gap is 780 square miles, and the gage is at 8,430 feet above sea level. The hydrograph of the Rio Grande at Wagon Wheel Gap is typical of mountain streams, with low flows occurring in the late fall to early spring followed by a large increase in flow, usually in May or June, due to snowmelt that tails off through the summer (Table 3.20, Figure 2). Median monthly flows were approximately between 100 and 1,870 cubic feet per second, based on USGS gage #08217500 flows from 1952 through 2007 (Table 3.20). Gage flow for the Rio Grande below Wagon Wheel Gap, USGS gage #08217500 was available for the period of record 1952-2000. Gage flow for the Rio Grande at Del Norte, USGS gage #08220000 was available for the period of record 1952-2007 (Table 3.21, Figure 3). The drainage area at the USGS gage on the Rio Grande near Del Norte is 1,320 square miles, and the gage is at 7,980 feet above sea level. Flows from the downstream gage were then

Hydrologic characteristics of Rio Grande at Wagon Wheel Gap, CO (USGS gage #08127500), POR: 1952-2000, Estimated: 2001-2007							
Month	25th%	5th%	95th%	75th%	Median	1E3 Acute Flow, cfs	30E3 Chronic Flow, cfs
Jan	86	65	154	118	100	60	71
Feb	86	70	160	122	105	60	71
Mar	100	84	291	151	120	61	71
Apr	196	114	936	473	309	91	87
May	810	365	2870	2010	1370	216	148
Jun	1290	426	3384	2440	1870	115	115
Jul	373	193	2160	1510	782	98	103
Aug	264	146	1290	680	390	87	99
Sep	212	135	746	405	280	92	99
Oct	177	124	592	365	241	97	74
Nov	112	89	312	174	132	60	71
Dec	90	65	173	130	110	60	71

Table 3.20. Hydrologic characteristics of Rio Grande Segment 4 (CORGRG04), Rio Grande below Wagon Wheel Gap, USGS #08127500. POR: 1952-2007

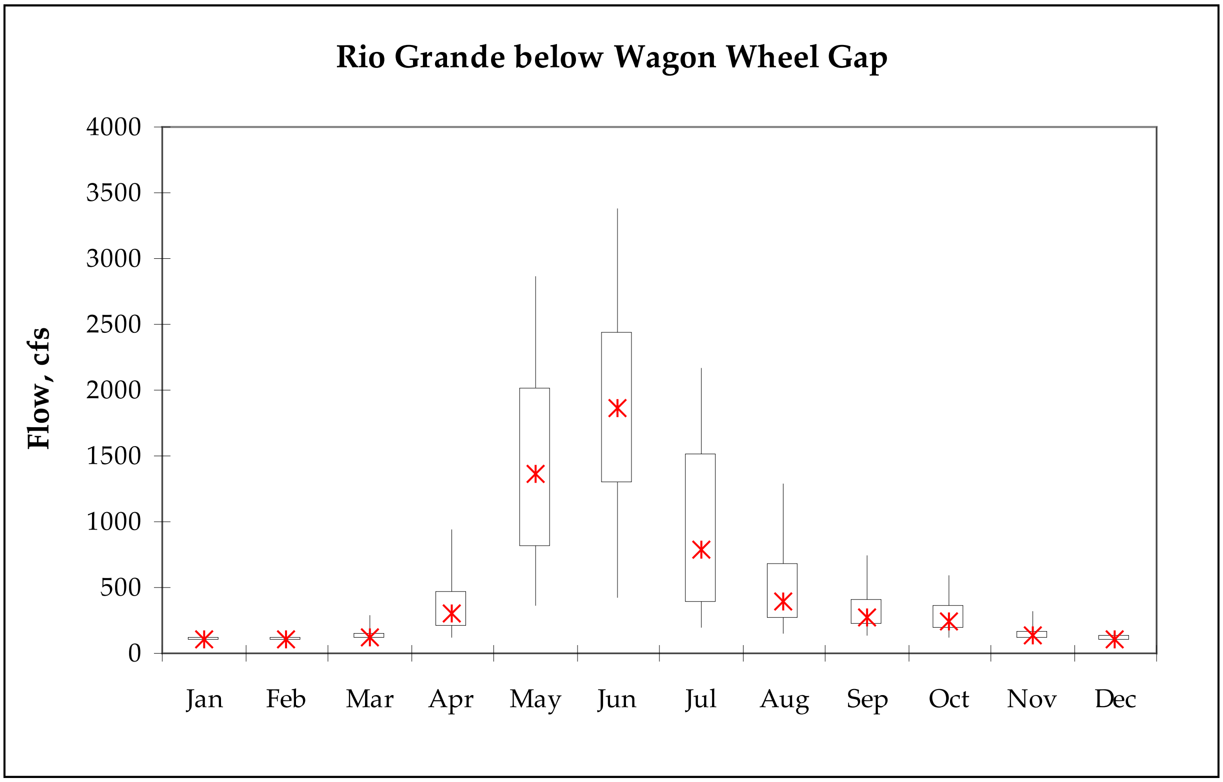


Figure 2. Box and whisker plots for Rio Grande below Wagon Wheel Gap (USGS gage # 08217500). Boxes represent upper and lower quartiles (25th and 75th percentiles) while whiskers represent 5th and 95th percentile monthly flow values. Red stars indicate median monthly flows.

Hydrologic characteristics of Rio Grande near Del Norte, CO (USGS gage #08220000), POR: 1952-2007							
Month	25th%	5th%	95th%	75th%	Median	1E3 Acute Flow, cfs	30E3 Chronic Flow, cfs
Jan	130	105	246	190	165	87.9	111.5
Feb	150	120	245	201	171	91.0	111.5
Mar	180	145	516	280	219	111.0	111.5
Apr	365	221	1590	839	544	137.0	151.0
May	1320	611	4940	3320	2190	316.0	198.0
Jun	1770	602	5790	4010	2790	135.0	136.0
Jul	520	240	3195	1890	976	108.0	114.0
Aug	348	185	1620	919	540	89.0	111.5
Sep	268	182	1110	554	384	97.0	111.5
Oct	257	177	869	540	353	120.0	111.5
Nov	176	130	500	303	221	87.9	111.5
Dec	150	110	280	216	180	87.9	111.5

Table 3.21. Hydrologic characteristics of the Rio Grande near Del Norte, CO (USGS #08220000). POR: 1952-2007.

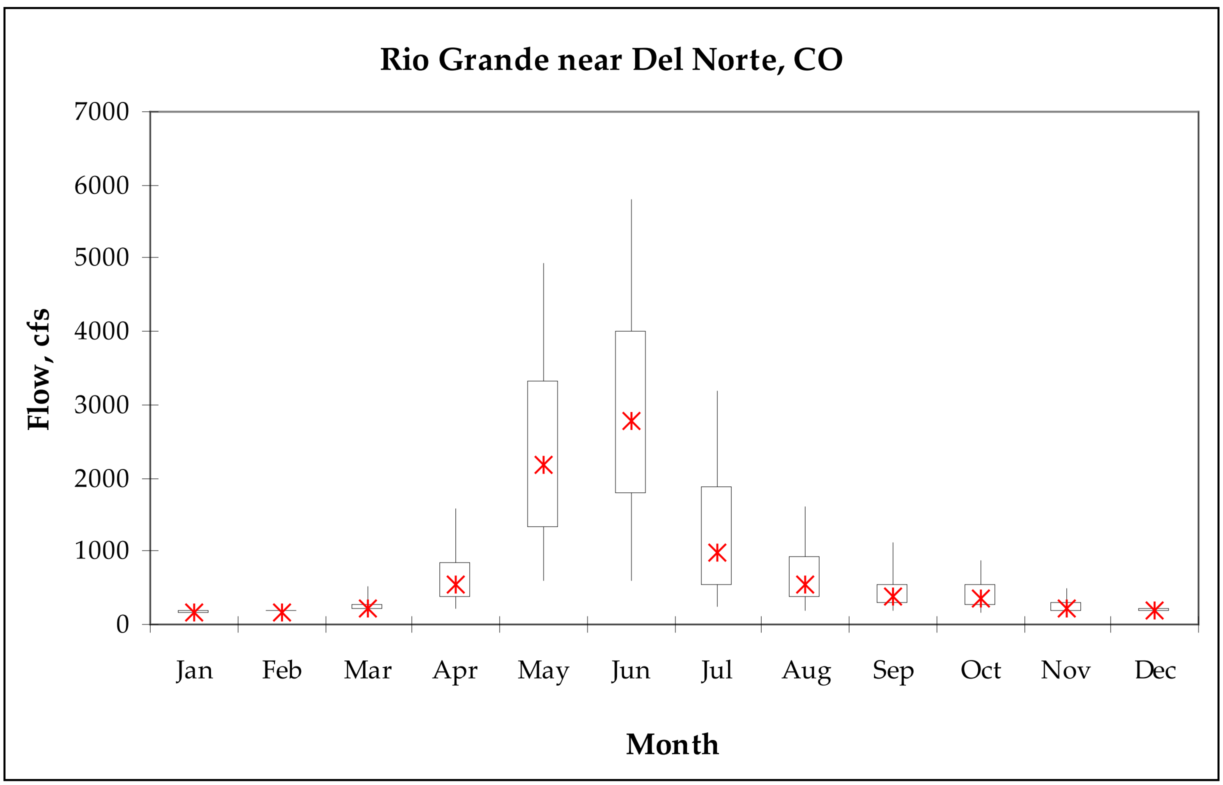


Figure 3. Box and whisker plots for Rio Grande near Del Norte (USGS gage # 08220000). Boxes represent upper and lower quartiles (25th and 75th percentiles) while whiskers represent 5th and 95th percentile monthly flow values. Red stars indicate median monthly flows.

Hydrologic characteristics of Willow Creek at Creede, CO (Estimated from USGS gage #08127500), POR: 1952-2007							
Month	25th%	5th%	95th%	75th%	Median	1E3 Acute Flow, cfs	30E3 Chronic Flow, cfs
Jan	4.0	3.1	6.9	5.4	4.7	2.9	3.4
Feb	4.1	3.4	7.2	5.6	4.9	2.9	3.4
Mar	4.7	4.0	12.4	6.8	5.5	3.0	3.4
Apr	8.6	5.3	36.4	19.5	13.1	4.3	4.1
May	31.9	15.3	102.2	73.6	51.7	9.4	6.7
Jun	49.0	17.7	118.9	88.0	68.9	5.4	5.3
Jul	15.6	8.5	78.7	56.6	30.9	4.6	4.8
Aug	11.4	6.6	49.0	27.1	16.3	4.1	4.6
Sep	9.3	6.1	29.6	16.9	12.0	4.4	4.6
Oct	7.9	5.7	23.9	15.3	10.4	4.6	3.6
Nov	5.2	4.2	13.3	7.8	6.0	2.9	3.4
Dec	4.2	3.1	7.7	5.9	5.1	2.9	3.4

Table 3.22. Hydrologic characteristics of Willow Creek at Creede, CO (CORGRG07) as estimated from Rio Grande below Wagon Wheel Gap (USGS #08217500). POR: 1952-2007.

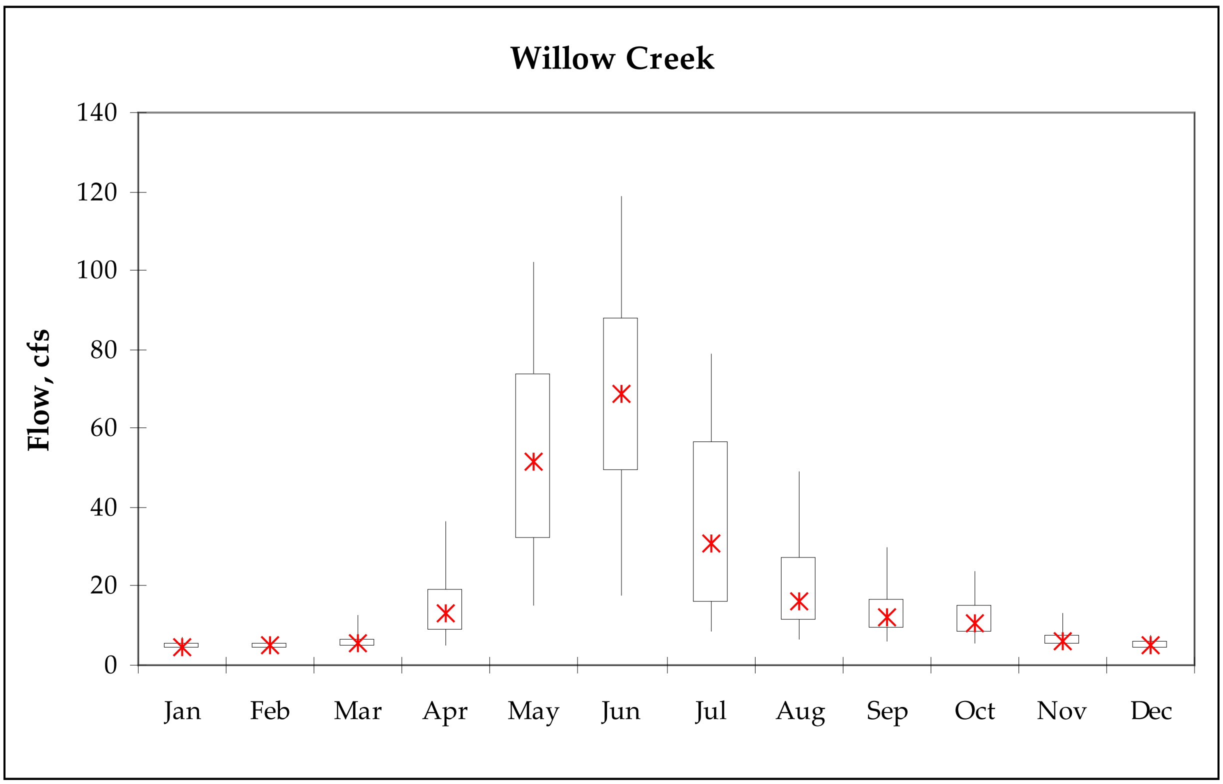


Figure 4. Box and whisker plots for Willow Creek at Creede, CO. Boxes represent upper and lower quartiles (25th and 75th percentiles) while whiskers represent 5th and 95th percentile monthly flow values. Red stars indicate median monthly flows.

	Median Willow Creek Flow, cfs	Median Rio Grande Flow, cfs	% Flow
January	4.7	100	4.7%
February	4.9	105	4.6%
March	5.5	120	4.6%
April	13.1	309	4.3%
May	51.7	1370	3.8%
June	68.9	1870	3.7%
July	30.9	782	3.9%
August	16.3	390	4.2%
September	12.0	280	4.3%
October	10.4	241	4.3%
November	6.0	132	4.6%
December	5.1	110	4.6%

Table 3.23. Median flow (cfs) of Willow Creek and Rio Grande (Segments RGRG04 and RGRG07) and percent contribution from Willow Creek.

used to predict flows from the most recent period of record (2001-2007) for the Rio Grande below Wagon Wheel Gap using Equation 1 (R^2 = 0.96). Acute and chronic low flows were calculated using USEPA DFLOW software. Figures 2 and 3 and Tables 3.20 and 3.21 illustrate the hydrologic characteristics of the Rio Grande.

A large source of heavy metals to the Rio Grande is from Willow Creek, although it is only responsible for approximately 4% of the flow annually (Table 3.23). Gage flow for the Rio Grande at Del Norte, USGS gage #08220000 was available for the period of record 1952-2007. Gaged Willow Creek flows for the period of record 1952-1981 were regressed with flows on the Rio Grande below Wagon Wheel Gap (R^2 = 0.89). Willow Creek flows for the more recent period of record were predicted from flows at the Rio Grande below Wagon Wheel Gap for the period of record 1952-2007 from Equation 2. Estimated median monthly flows for the Willow Creek gage (#08126500) were approximately between 4.7 and 68.9 cubic feet per second. Figure 4 and Table 3.22 illustrate the hydrologic characteristics of Willow Creek. The percent contribution of Willow Creek to the Rio Grande is demonstrated in Table 3.23. On average, Willow Creek contributes approximately 4.3% of the flow to the Rio Grande below Wagon Wheel Gap.

(Eq. 1) Rio Grande blw WWG = (0.6128*USGS #08220000) + 31.834

(Eq. 2) Willow Creek = 0.0673 * USGS #08127500 $^{0.92}$

Flows were summarized for both the Rio Grande below Wagon Wheel Gap (USGS gage #08127500), and Willow Creek at Creede, CO (USGS gage#08126500). Acute and chronic low flows were calculated using USEPA DFLOW software (Tables 3.20 through 3.22). Acute (1E3) and chronic (30E3) flows are biologically based low flows. Biologically-based design flows are intended to measure the actual occurrence of low flow events with respect to both the duration and frequency (i.e., the number of days aquatic life is subjected to flows below a certain level within a period of several years). Although the extreme value analytical techniques used to calculate hydrologically-based design flows have been used extensively in the field of hydrology and in state water quality standards, these methods do not capture the cumulative nature of effects of low flow events because they only consider the most extreme low flow in any given year. By considering all low flow events with a year, the biologically-based design flow method accounts for the cumulative nature of the biological effects related to low flow events. Acute low flows (1E3) refer to single low flow events that occur once in a three year period. Chronic low flows (30E3) refer to 30-day low flow periods which occur once in three year. The use of low flows to calculate load reductions tends to overestimate loading reductions needed to protect desired uses.

East and West Willow Creek contribute to the flow in Willow Creek. Loading from other dispersed, subsurface inflows along West Willow Creek add substantial loads, but these are small in comparison to the loads from the Nelson Tunnel. No significant contribution of metals load from potential sources occurs along East Willow Creek. The lack of measurable loading on East Willow may be a result of previous remedial actions along that stream. The lower Willow Creek section has a relatively small contribution of the load compared to what has been contributed upstream (Kimball et al., 2004).

Studies were undertaken by the USGS during low-flow conditions in late summer for two reasons. First, the mass-loading pattern expressed at low flow reflects the importance of metal sources that enter the stream on a continuous basis. Remedial actions that address the sources identified at low flow will therefore improve water quality during the entire year. These sources can include mine waste sources such as waste rock piles, tailings piles, and mine workings and also drainage from adits, tunnels, or ground-water pathways to the stream. Some of these sources contribute water and solutes to the stream as distinct surface inflows, but some contribute water through dispersed, subsurface inflows to the stream. Second, the pattern of metal loading at low flow indicates which sources contribute to high concentrations during the winter months, when the most toxic conditions likely occur (Besser and Leib, 1999). During the low-flow winter months, mine drainage is less diluted by other sources of water, and limits of toxicity are more likely to be exceeded (Besser and others, 2001). Although dissolved metal loads are greater during snowmelt runoff, truly dissolved metal concentrations generally are lower, and the risk to aquatic life is not as great.

3.3 Ambient Water Quality

To identify exceedances of the assigned water–quality standards, the eighty-fifth percentile concentrations of metals were calculated using the most current available data from the Colorado Department of Public Health and Environment (CDPHE), Colorado Division of Wildlife (CDOW) River Watch, and U.S. Geological Survey (USGS). Sampling sites were located above Wagon Wheel Gap, below Wagon Wheel Gap, and on the Rio Grande near Del Norte (Table 3.3).

Sample Location	Period of Record	N hardness samples	No. Cd-D samples	No. Zn-D samples	Source
Rio Grande above Wagon Wheel Gap	2002-2006	9	9	9	WQCD, RW, USGS
Rio Grande below Wagon Wheel Gap	1992-2005	71	70	63	WQCD
Rio Grande near Del Norte	2001-2005	68	61	54	WQCD, RW

Table 3.3 Sources of water-quality data for 303(d) listed stream segment on the Rio Grande.

Rio Grande above Wagon Wheel Gap					
	Mean Hardness	Cd-D, TVS (ch)	Cd-D	Zn-D, TVS (ch)	Zn-D
Annual	25	0.15	***1.2***	38.1	***180***
Low Flow	34	0.19	***2.1***	49.6	***406***
High Flow	21	0.13	***0.3***	32.9	***106***

Table 3.31. Ambient water quality data for CORGRG04, the Rio Grande above Wagon Wheel Gap (concentrations are given as 85th percentiles per Section 303(d) Listing Methodology for chronic standards). Exceedances are italicized and highlighted in bold.

Ambient concentrations and table-value standards of dissolved cadmium and zinc for the Rio Grande above Wagon Wheel Gap are expressed in Table 3.31. Because there was not enough data to develop monthly ambient concentrations, data were divided into seasons of high flow (e.g. May through July) and low flow (e.g. September through January). No samples were available for the month of August. Table value standards were exceeded for both cadmium and zinc during both flow regimes. The ambient cadmium concentrations were approximately 2.25 times the standard during periods of runoff, while concentrations were roughly 11 times the table value standard during low flow periods. The same pattern is true for zinc, with exceedances during high flow periods of about 3.2 times the standard and over 8 times the standard during low flow periods.

Since Rio Grande Segment 4 is an Aquatic Life Cold 1 stream, it has been assigned an acute cadmium trout standard to protect sensitive trout species. Acute dissolved cadmium standards were exceeded in three of the nine samples (33%) in the Rio Grande above Wagon Wheel Gap. Acute zinc standards were exceeded in six of the nine samples (67%).

Ambient eighty-fifth percentile stream concentrations and table-value standards of cadmium and zinc for the Rio Grande below Wagon Wheel Gap are expressed in Table 3.32. The segment of the Rio Grande below Wagon Wheel Gap is in attainment of the dissolved cadmium standard in the month of June. This is primarily due to the dilution effect from peak runoff flows (Tables 3.20 and 3.32). The dissolved zinc standard is exceeded for the entire year. Similar to below Wagon Wheel Gap, the Rio Grande near Del Norte is in attainment of the chronic cadmium standard for one month of the year in May (Table 3.32). Additionally, it is in attainment of the chronic zinc standard in May as well (Table 3.32).

Acute dissolved cadmium standards were exceeded in thirty-six of the seventy samples (51%) in the Rio Grande below Wagon Wheel Gap. Acute zinc standards were exceeded in fifty-two of the sixty-three samples (83%). Acute dissolved cadmium standards were exceeded in four of the sixty-one samples (7%) in the Rio Grande near Del Norte. Acute zinc standards were not exceeded in any of the fifty-four samples (0%).

	Rio Grande below Wagon Wheel Gap					Rio Grande near Del Norte				
	Hardness	Cd-D, TVS (ch)	Cd-D, ug/L	Zn-D, TVS (ch)	Zn-D, ug/L	Hardness	Cd-D, TVS (ch)	Cd-D, ug/L	Zn-D, TVS (ch)	Zn-D, ug/L
Jan	42	0.22	***2.3***	59.3	***593***	59	0.28	***0.8***	79.3	***258***
Feb	44	0.23	***2.3***	61.7	***600***	60	0.29	***1.0***	80.4	***245***
Mar	38	0.20	***2.1***	54.5	***720***	58	0.28	***0.8***	78.1	***292***
Apr	34	0.19	***0.6***	49.6	***103***	46	0.24	***0.3***	64.1	***142***
May	26	0.15	***0.4***	39.4	***81***	33	0.18	0.0	48.3	35
Jun	24	0.14	0.0	36.8	***57***	30	0.17	***0.3***	44.5	***61***
Jul	29	0.17	***0.8***	43.3	***101***	47	0.24	***0.4***	65.3	***80***
Aug	33	0.18	***0.9***	48.3	***232***	55	0.27	***0.4***	74.7	***82***
Sep	35	0.19	***0.9***	50.8	***211***	39	0.21	***0.5***	55.7	***72***
Oct	37	0.20	***0.9***	53.3	***200***	69	0.32	***0.6***	90.6	***200***
Nov	39	0.21	***1.6***	55.7	***421***	89	0.39	***0.7***	112.6	***204***
Dec	46	0.24	***2.0***	64.1	***502***	66	0.31	***0.6***	87.2	***192***

Table 3.32. Ambient water quality data for CORGRG04 (concentrations are given as 85th percentiles per Section 303(d) Listing Methodology for chronic standards). Exceedances are italicized and highlighted in bold.

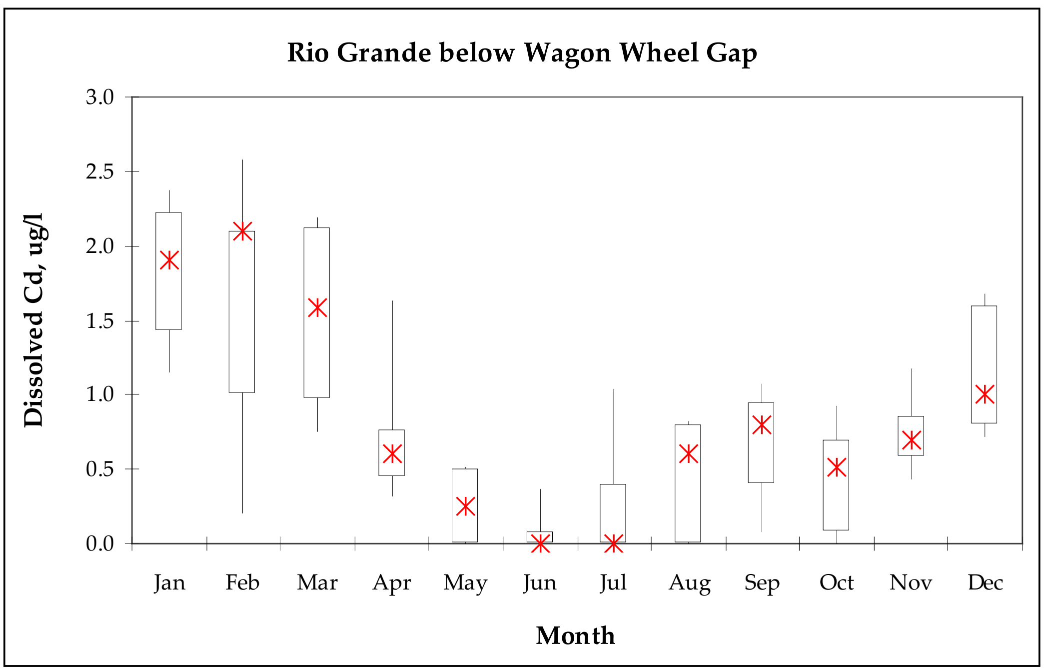


Figure 5. Box and whisker plot for dissolved cadmium on the Rio Grande below Wagon Wheel Gap. Boxes represent upper and lower quartiles (25th% and 75th%); while whiskers represent 5th% and 95th% values. Stars represent median values.

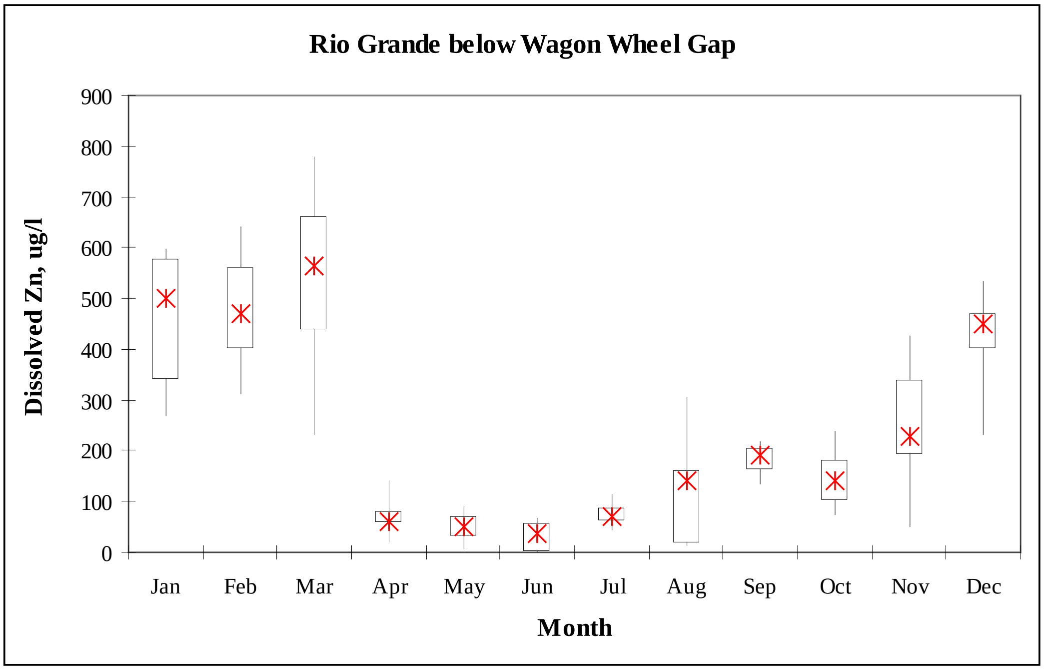


Figure 6. Box and whisker plot for dissolved zinc on the Rio Grande below Wagon Wheel Gap. Boxes represent upper and lower quartiles (25^{th}% and 75^{th}%); while whiskers represent 5^{th}% and 95^{th}% values. Stars represent median values.

As demonstrated by the box and whisker plots of dissolved cadmium and zinc in the Rio Grande below Wagon Wheel Gap, concentrations in the Rio Grande increase during periods of low flow. Variability in sample range decreases during runoff and dilutes metals concentrations. As the flows drop off in August and September, metals concentrations begin a slow increase. January, February, and March represent the highest observed concentrations in the Rio Grande below Wagon Wheel Gap (Figures 5 and 6)

PROBLEM IDENTIFICATION

4.1 Background

Past mining activities resulting in hydrologic modifications and past and ongoing metals loading from mine drainage and mine waste piles are the most significant influences on the current state of the aquatic resources in the Willow Creek Watershed (Figures 7 and 8). The history of mining in the Creede Mining District can be traced back indirectly to 1865 when a party of prospectors, led by Charles Baker, explored the upper Animas River drainage in search of placer gold. While Baker's exploration did not locate economically viable quantities of gold or silver, it did open the door for subsequent prospecting parties to explore the San Juan Mountains for hard-rock gold and silver. The success of these efforts led to mining camps such as Ouray, Silverton, Telluride, Lake City, and Rico. Mining in these districts developed slowly until 1873, when the U.S. Government and the Ute Indians signed the Brunot Treaty. The terms of the treaty required the U.S. Government to pay the Ute Tribe $25,000 for four million acres of mineral-rich land while the Ute Tribe retained the right to hunt on the ceded land. After the treaty was signed, access into the San Juan Mountains increased significantly through the construction of wagon roads and rail lines. The Denver & Rio Grande Railroad constructed a line to South Fork, just 20 miles south of present-day Creede. This greatly increased prospecting activities along the upper Rio Grande and its tributaries.

In 1876 a group of prospectors, including J. C. McKenzie and H. M. Bennett, explored the Willow Creek Watershed. They discovered silver ore west of the present day City of Creede and staked the Alpha Claim. In 1878, McKenzie discovered another ore body and staked the Bachelor Claim. McKenzie failed to find investors to mine these claims and, in 1885, sold the Alpha Claim to Richard and J. N. H Irwin. McKenzie retained the title to the Bachelor, but soon gave up attempts to mine and process its ore. Thirteen years would pass before the next significant discovery occurred in the Willow Creek Watershed. In May of 1889, a party of prospectors, including Nicholas C. Creede, E. R. Taylor and G. L. Smith, located the Holy Moses Vein on Campbell Mountain, which was extremely rich in silver. The discovery began nearly 100 years of mining in the Creede district.

The discovery of the Holy Moses Vein greatly increased prospecting in the King Solomon District, as the area was known in 1890. In 1890, Richard Irwin discovered more silver ore near the Old Alpha Claim. In 1891, a party of miners prospected along West Willow Creek. They encountered samples of floating metals and followed the lead upstream along West Willow Creek. An examination of the samples revealed the high-grade nature of the ore and led to the establishment of the Last Chance Claim. With a developing understanding of the orientation of the ore body, Creede staked the Amethyst Claim a short distance north of the Last Chance Claim. The Last Chance and Amethyst Mines, located along the Amethyst Vein, would become the richest, most profitable mines in the Creede Mining District.

Figure 7. Historic mining in the Willow Creek watershed (Taken from Hermann, K.A. and M. Wireman (editors). *Aquatic Resources Assessment of the Willow Creek Watershed*. Internal Report, U.S. Environmental Protection Agency, Region 8 Denver, Colorado, 2005).

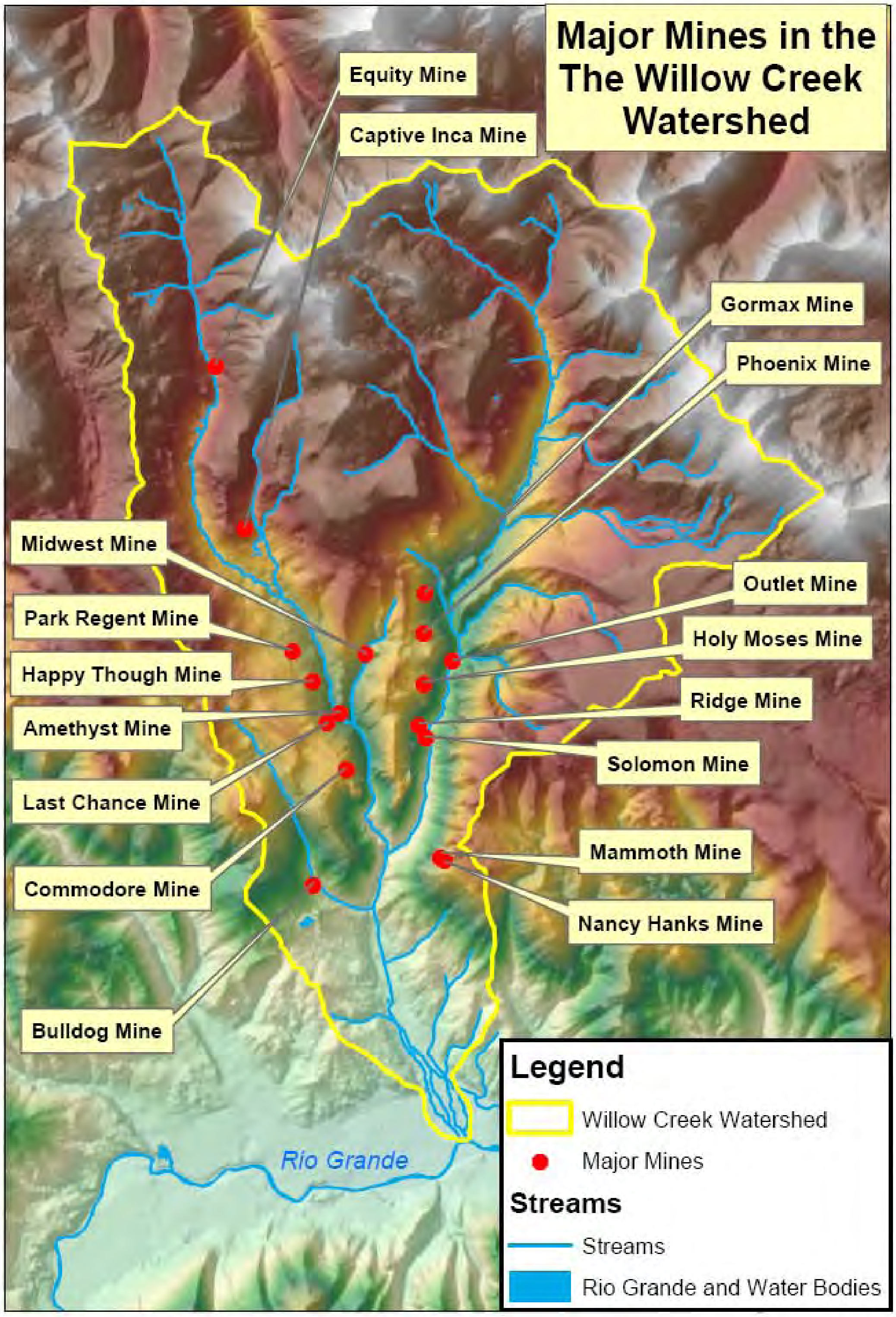


Figure 8. Primary mine sites in the Willow Creek Watershed (Taken from Hermann, K.A. and M. Wireman (editors). *Aquatic Resources Assessment of the Willow Creek Watershed*. Internal Report, U.S. Environmental Protection Agency, Region 8 Denver, Colorado, 2005)

From 1890 through the 1980s, mining activity, economic vibrancy, and population in the watershed fluctuated interdependently. Many factors influenced the boom-bust cyclical nature of mining in the watershed. These included prospector discoveries of high-grade silver ore veins at different mine claims, the Brunot Treaty of 1873, development of a rail line from South Fork to North Creede, the Bland-Allison Act of 1878, the Pittman Act of 1922, the Silver Purchase Act of 1934, technological advances in mine ore processing, and multiple mine claim ownership. By the 1980s, all mining had ended in the Creede District. After 100 years of silver production, the District is now undergoing environmental cleanup and its residents continue to treasure its mining past.

In 1998, the USEPA and the Colorado Department of Public Health and Environment (CDPHE) began to look at options for characterizing and remediating water quality impacts to Willow Creek and the Rio Grande from historic mining activities within the Creede Mining District. After some preliminary assessment work, the district was considered for listing on the National Priorities List and subsequent assessment and remediation pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), often referred to as Superfund. The citizens of Creede and Mineral County were determined to avoid this listing primarily because they perceived that by designating the mining district as a Superfund site, it would have negative impacts on the local economy and community.

As an alternative, the WCRC was established in 1999 to develop, guide, and implement a stakeholder-based watershed approach to remediating and restoring water quality and riparian conditions along Willow Creek. The WCRC set goals with regard to the community's vision for the Willow Creek Watershed. These are:

(1) *Protect the Rio Grande from future fish kills associated with non-point source releases during unusual hydrologic events*
(2) *Improve the visual and aesthetic aspects of the Willow Creek Watershed and its historical mining district*
(3) *Implement appropriate and cost-effective flood control and stabilization measures for non-point sources*
(4) *Protect and preserve historic structures*
(5) *Reclaim the Willow Creek Floodplain below Creede to improve the physical, chemical, biological, and aesthetic qualities of the creek as an integral part of the local community*
(6) *Continue to improve water quality and physical habitat in the Willow Creek Watershed as part of a long-term watershed management program*

These goals have guided the assessment and restoration efforts during the past six years. The WCRC, with financial and technical support from local citizens, the Rio Grande Water Conservation District, the U.S. Department of Agriculture (USDA), USEPA, CDPHE, and the Colorado Division of Minerals and Geology (CDMG), has made significant progress in assessing water quality impacts from historic mining activities and in remediating non-point sources of contamination related to those activities.

Stressors on physical habitat condition include watershed disturbances and hydrologic modifications. The in-stream habitat in the Middle Section is significantly impaired by mine waste rock and mill tailings in steep topographic settings. This is especially noticeable on West Willow Creek. The flood control flume through Creede is also a serious impairment to physical habitat condition. The flume is a case where the same feature has opposite values depending on the value endpoint of physical habitat or hydrologic conditions. The EPA assessment weights the flood control value of the flume as relatively more important than the physical habitat value of removing it. Grazing and forest clear-cutting are not current stressor issues in the watershed (EPA, 2005).

No recent aquatic life information has been collected for CORGRG04. Prior to 2001, the DOW collected brown trout, cutthroat trout, longnose dace, rainbow trout, and white sucker from this section of the Rio Grande River between 1997 and 2001. The trout biomass was dominated by brown trout with biomass ranging from 30 to 54 lbs/acre.

Aquatic life data collected by the U.S. Fish and Wildlife Service (USFWS) on Willow Creek, Segment 7, shows a decreasing abundance and diversity of both fish and macro-invertebrates in East and West Willow Creek as one travels downstream to the confluence with Willow Creek. Only two fish were captured in the mainstem of Willow Creek, and metals tolerant invertebrate taxa dominated the macro-invertebrate assemblage. Similar to East and West Willow Creek, species diversity and abundance decreased as one traveled downstream.

The waters of the Rio Grande River between Creede and South Fork (Below the Willow Creek confluence) are designated as "Gold Medal" waters. These are catch-and-release fishing areas and offer the greatest potential for trophy trout fishing. The South Fork area has several stretches of the Rio Grande River that are designated as Gold Medal waters, and one can find brown and rainbow trout fishing from Rio Grande Reservoir downstream to Del Norte. The section of water between South Fork and Del Norte provides the best location for catching trophy brown trout (www.southfork.org/activities/southfork/fishing.php). These waters represent important aquatic resources that might potentially be impacted by pollutant loading originating in the Willow Creek drainage.

4.2 Source Analysis

Point Sources

Site Name	Drainage	Zn ug/l	Cd ug/l	Median Flow, cfs	Zn Load lbs/day	Cd Load lbs/day
Solomon Complex	East Willow Creek	31219	156.5	0.079*	13.28	0.067
Payne’s Culvert	East Willow Creek	420	2.1	0.060	0.136	0.0007
Diversion Box SWI	East Willow Creek	1059	4.7	0.201*	1.149	0.005
Nelson Tunnel	West Willow Creek	68375	226.1	0.528	195.0	0.640
Commodore Mine	West Willow Creek	2887	21.2	0.025	0.390	0.003
Amethyst Mine	West Willow Creek	198**	1.6**	0.030	0.032	0.0003
West Willow Seep	West Willow Creek	154000	862.7	0.030	24.9	0.140
Nelson Tunnel at Bachelor Shaft	West Willow Creek	64840	178.4	0.634	222.0	0.611
Midwest Mine	Nelson Creek	288**	2.6**	0.020	0.031	0.0003
Bulldog Mine	Windy Gulch	1064	7.6	0.335	1.92	0.014

*Taken from USGS Report, 2005.
**Dissolved metals calculated as 90% of total recoverable values

Table 4.20. Point source contributions of cadmium and zinc to the Willow Creek watershed.

Combined Point, Non-Point, and Natural Sources by Drainage

Drainage	Zn Load lbs/day	Cd Load lbs/day
East Willow	14.565	0.0727
West Willow	442.322	1.3943
Nelson Creek	0.031	0.0003
Windy Gulch	1.92	0.014
Willow Creek combined braids at the Rio Grande	149.64	0.60

Table 4.21. Combined source contributions of cadmium and zinc to the Willow Creek watershed.

Drainage from the Nelson Tunnel can be measured at two separate points: the Nelson Tunnel and the Nelson Tunnel at the Bachelor Shaft. When loads are measured from the Nelson Tunnel at the Bachelor Shaft, loads may surpass the Nelson Tunnel measurement alone. The tunnel is the lowest of a vast network of tunnels and associated mine workings throughout the Middle Section of the watershed (Figure 1). The Nelson Tunnel, which is properly called the Nelson/ Wooster /Humphries Tunnel, is approximately 11,000 feet long and was constructed in 1899 to facilitate the hauling of ore from mines located along the Amethyst Vein complex. The Nelson Tunnel is the lowest tunnel constructed along the Amethyst Vein system and functions as a drain for the underground workings that are connected via winzes and raises (EPA, 2005). The Nelson Tunnel discharges to West Willow Creek approximately 1.5 miles above the town of Creede and above the confluence of East and West Willow Creeks.

The significant load from West Willow Creek is an accumulation of the discharges from five non-permitted point sources, the Nelson Tunnel, Commodore Mine, Amethyst Mine, West Willow Seep, and the Bachelor Shaft (Table 4.20 and 4.21). Since median flows typically range from 4.7 to 68.9 on Willow Creek, and flows on West Willow are only a portion of this, significant dilution of metals does not occur in West Willow Creek.

Two significant alluvial fan deposits occur along the northeast side of Willow Creek. The first extends from an area across the road from the Emperious Tailings Pile southeastward to where the Willow Creek Valley joins the Rio Grande Valley (Figure 9). A second alluvial fan deposit occurs at the mouth of Dry Creek, a tributary to Willow Creek on the east side. Alluvial fans consist of poorly sorted sediments that occur where smaller streams deposit sediment loads as they reach the valleys of larger streams. It is likely that ground water in these deposits would discharge into the terrace deposits. This is potentially significant, because the alluvial fan sediments may be mineralized (currently unknown) and ground water that discharges from the upper alluvial fan deposition may influence the chemistry of the ground water down gradient of the Emperious Tailings Pile (USEPA, 2005).

Ground water that occurs within the unconsolidated deposits that underlie the floodplain below Creede does not discharge to Willow Creek, but flows southward towards the Rio Grande River and discharges to the valley-fill deposits that underlie the Rio Grande Valley. Ground water that occurs in these deposits may be important for maintaining a healthy riparian ecosystem. Prior to mining activities in the Creede Mining District, a willow-dominated riparian community was well developed in the floodplain. This type of riparian community is highly dependent on a seasonally consistent shallow ground-water table and a hyporheic zone undisturbed by human activities. The hyporheic zone is the subsurface zone where stream water flows through short segments of its adjacent bed and

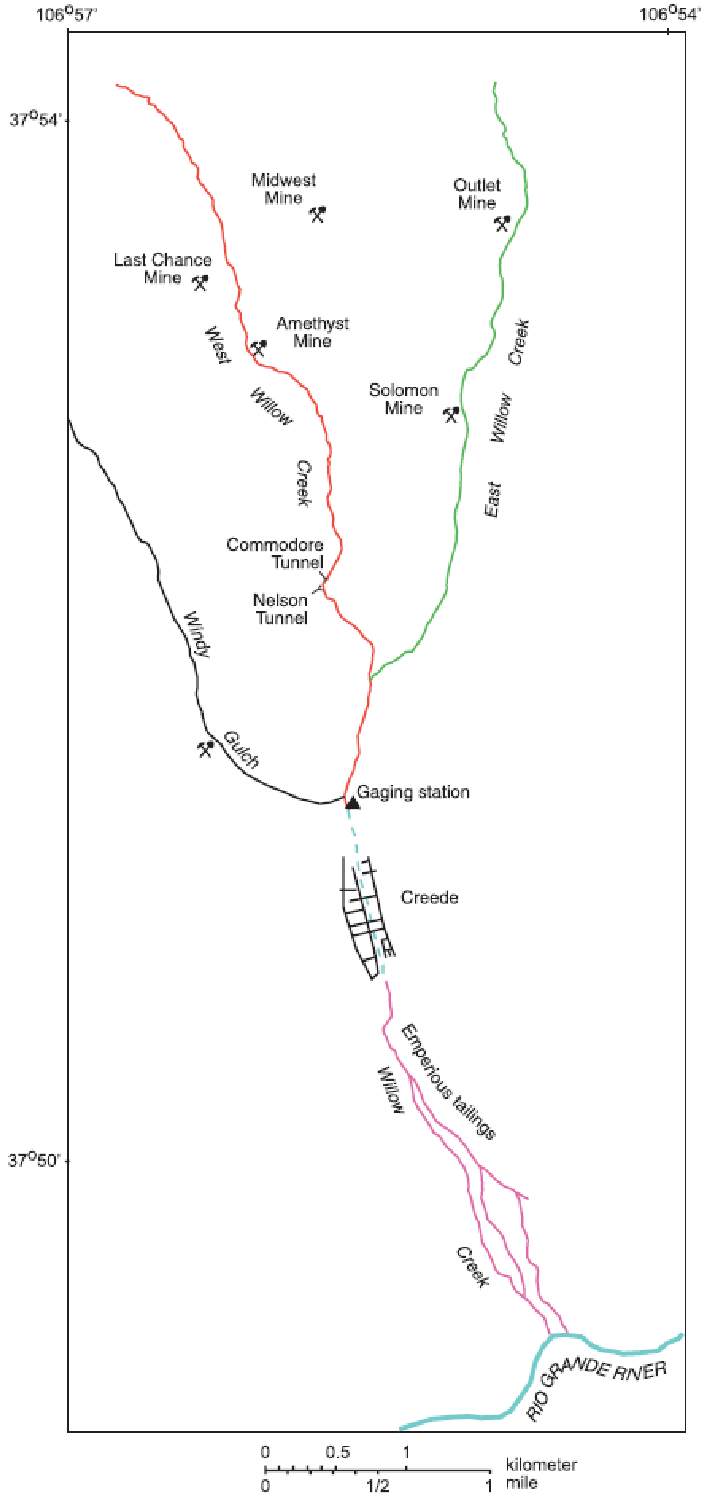


Figure 9. Location of principal mines and alluvial fan deposits in the Willow Creek watershed (Taken from B.A. Kimball, R.L. Runkel, K. Walton-Day, and B.K. Stover. *Evaluation of Metal Loading to Streams near Creede, Colorado, August and September 2000*. U.S. Geological Survey, Scientific Investigations Report 2004-5143).

banks. Historic depths to ground water are not known. However, recent water level data from monitoring wells in the floodplain clearly indicate that ground water in the alluvial deposits along Willow Creek does not discharge to Willow Creek. (USEPA, 2005). There is also a possibility that ground water discharges to the Willow Creek valley fill sediments from the fan and debris deposits to the east of the road. This ground water may contain significant concentrations of heavy metals. At this time the importance of this inflow is unknown (USEPA, 2005).

6.0 TMDL ALLOCATION

Total Maximum Daily Loads ("TMDL")

A TMDL is comprised of the Load Allocation ("LA"), which is that portion of the pollutant load attributed to natural background or the nonpoint sources, the Waste Load Allocation ("WLA"), which is that portion of the pollutant load associated with point source discharges, and a Margin of Safety ("MOS"). The TMDL may also include an allocation reserved to accommodate future growth. The TMDL may be expressed as the sum of the LA, WLA and MOS.

$$TMDL = WLA + LA + MOS$$

TMDL = Sum of Waste Load Allocations + Sum of Load Allocations + Margin of Safety

Waste Load Allocations "(WLA")

There are two permitted dischargers to Segment 7 on Willow Creek; the City of Creede and the Homestake Bulldog Mountain Operation. There are also non-permitted point sources to Willow Creek that will require a waste load reduction. However, since the TMDL reflects the overall reduction necessary to attain standards in CORGRG04 downstream of the mixing zone with Willow Creek, no WLAs are included in Tables 6.1 and 6.2. Willow Creek does not contain assigned aquatic life standards and in this document it is treated as the point source and is therefore given the waste load allocation. If reductions are made in non-permitted point sources to Willow Creek, the Rio Grande will be closer to attainment of its water quality standards. There are no permitted discharges in the listed portion of Rio Grande, Segment 4; therefore the TMDL does not contain specific discharger WLAs for CORGRG04. Willow Creek is assigned the entire waste load allocation.

Load Allocations ("LA")

All other sources that were examined are considered non-point sources and are therefore accountable to load allocations.

Margin of Safety ("MOS")

According to the Federal Clean Water Act, TMDLs require a margin of safety (MOS) component that accounts for the uncertainty about the relationship between the pollutant loads and the receiving waterbody. The margin of safety may be explicit (a separate value in the TMDL) or implicit (included in factors determining the TMDL). In the case of the Rio Grande TMDL, the margin of safety lies in the calculation of the allowable TMDL based on 30-day chronic low flows. Ambient stream loads were calculated using median stream flows. As a result, proposed reductions also address exceedances of the acute cadmium (trout) standard as well as all other acute standards assigned to these listed segments. The proposed reductions are conservative over-estimates of the reductions needed in order to attain chronic standards; however, they also take into account the stringent acute standards for cadmium.

The TMDL was calculated using a monthly chronic low flow estimated from USGS gage #08127500 multiplied by the existing stream standard and a conversion factor (0.0054) to approximate a load in pounds/day. Eighty-fifth percentile stream concentrations were calculated from sampled values on a monthly basis and multiplied by monthly median flows and a conversion factor (0.0054) to estimate a daily load in pounds/day.

Acute and chronic low flows were calculated using USEPA DFLOW software. Acute (1E3) and chronic (30E3) flows are biologically based low flows. Biologically-based design flows are intended to measure the actual occurrence of low flow events with respect to both the duration and frequency (i.e., the number of days aquatic life is subjected to flows below a certain level within a period of several years). Although the extreme value analytical techniques used to calculate hydrologically-based design flows have been used extensively in the field of hydrology and in state water quality standards, these methods do not capture the cumulative nature of effects of low flow events because they only consider the most extreme low flow in any given year. By considering all low flow events with a year, the biologically-based design flow method accounts for the cumulative nature of the biological effects related to low flow events. Acute low flows (1E3) refer to single low flow events that occur once in a three year period. Chronic low flows (30E3) refer to 30-day low flow periods which occur once in three years. A conservative element is included with the use of chronic low flows and median monthly stream flows which more closely approximates the critical condition in the Rio Grande. By incorporating the critical condition into the calculation of the TMDL, load reductions tend to be overestimated.

The TMDL equation becomes the following:

TMDL = Sum of Load Allocations (LA)

LA (lbs/day) = Water Quality Standard, TVS (ug/l) x Flow (cfs) x 0.0054

6.1 TMDL FOR DISSOLVED CADMIUM AND ZINC

TMDL for dissolved cadmium for RGRG04								
Month	30E3 Chronic Flow (cfs)	Hardness, $CaCO_3$, mg/L	Cd-D TVS, ug/L	Cd TMDL lbs/day	Current Cd, ug/L	Current Cd Load lbs/day	Load Reduction	Percent Load reduction
January	71	42	0.22	0.08	2.3	1.3	1.2	93%
February	71	44	0.23	0.09	2.3	1.3	1.2	93%
March	71	38	0.20	0.08	2.1	1.4	1.3	94%
April	87	34	0.19	0.09	0.6	1.0	0.9	91%
May	148	26	0.15	0.12	0.4	3.3	3.2	96%

TMDL for dissolved cadmium for RGRG04								
June	115	24	0.14	0.09	0.0	0.0	-0.1	0%
July	103	29	0.17	0.09	0.8	3.2	3.1	97%
August	99	33	0.18	0.10	0.9	1.9	1.8	95%
Septembe r	99	35	0.19	0.10	0.9	1.3	1.2	92%
October	74	37	0.20	0.08	0.9	1.2	1.1	93%
Novembe r	71	39	0.21	0.08	1.6	1.1	1.0	93%
December	71	46	0.24	0.09	2.0	1.2	1.1	92%

Table 6.10. TMDL for dissolved cadmium for Rio Grande Segment 4.

Attainment of the TMDL is based on the end of the mixing zone below Willow Creek. The average annual cadmium load reduction for Rio Grande Segment 4 (CORGRG04) would be approximately 86%. Load reductions are high throughout the year (> 90%), with reductions ranging between 91% and 97%. During the month of peak runoff (i.e. June), however, load reductions drop to zero.

TMDL for dissolved zinc for RGRG04 below Wagon Wheel Gap								
Month	30E3 Chronic Flow (cfs)	Hardness, $CaCO_3$, mg/L	Zn-D TVS, ug/L	Zn TMDL lbs/day	Current Zn, ug/L	Current Zn Load. Lbs/day	Load Reductio n	Percent Load reductio n
January	71	42	59.3	22.7	592.5	320.0	297.2	93%
February	71	44	61.7	23.7	600.0	340.2	316.5	93%
March	71	38	54.5	20.9	720.0	466.6	445.7	96%
April	87	34	49.6	23.3	103.0	171.9	148.6	86%
May	148	26	39.4	31.5	80.8	597.8	566.3	95%
June	115	24	36.8	22.9	57.0	575.1	552.2	96%
July	103	29	43.3	24.1	100.8	425.7	401.6	94%
August	99	33	48.3	25.8	232.0	488.6	462.8	95%
Septembe r	99	35	50.8	27.2	211.0	319.0	291.9	91%
October	74	37	53.3	21.3	200.0	260.3	239.0	92%
Novembe r	71	39	55.7	21.4	421.0	300.1	278.7	93%
Decembe r	71	46	64.1	24.6	502.0	298.2	273.6	92%

Table 6.11. TMDL for dissolved zinc for Rio Grande Segment 4.

The average zinc load reduction for Rio Grande Segment 4 (CORGRG04) would be approximately 93%. Load reductions range between 86% in April to 96% in March and June. Load reductions rarely drop below 90% except in April, and remain above 90% for the remainder of the year.

Although the Willow Creek watershed accounts for approximately 4% of the flow in the Rio Grande, it is primarily responsible for the contribution of heavy metals to the Rio Grande, predominately cadmium and zinc. Table 6.3 illustrates the monthly cadmium load of Willow Creek and the approximate contribution to the load in the mainstem of Willow Creek. The metals load from Willow Creek is diluted once it reaches the Rio Grande while another portion may have some loss to groundwater. The contribution of metals load to the Rio Grande from Willow Creek appears to be magnified during periods of high flow. Willow Creek accounts for over 100% of the cadmium load to the Rio Grande for four months out of the year, April-May and August-September. For the remaining months it is responsible for between 58% and 90% of the cadmium load. The zinc load from Willow Creek is greater than the load in the Rio Grande during the months of April through August and October. Willow Creek accounts for between 106% of the zinc load in August to as much as 217% of the load in April (Table 6.4). The lowest contribution occurs in months of low flow with contributions ranging from 50% in March to 76% in September (Table 6.4).

Willow Creek contribution to TMDL for dissolved cadmium for RGRG04						
Month	Rio Grande Cd-D TVS, ug/L in	Rio Grande Cd TMDL lbs/day	Rio Grande, Current Cd, ug/L	Rio Grande, Current Cd Load lbs/day	Willow Creek Load, lbs/day	Willow Creek Load as % of Load in Rio Grande
January	0.22	0.08	2.3	1.3	0.9	70%
February	0.23	0.09	2.3	1.3	0.8	64%
March	0.20	0.08	2.1	1.4	0.8	58%
April	0.19	0.09	0.6	1.0	1.7	161%
May	0.15	0.12	0.4	3.3	5.6	168%
June	0.14	0.09	0.0	0.0	3.7	--
July	0.17	0.09	0.8	3.2	2.9	90%
August	0.18	0.10	0.9	1.9	2.6	139%
September	0.19	0.10	0.9	1.3	1.6	123%
October	0.20	0.08	0.9	1.2	1.1	87%
November	0.21	0.08	1.6	1.1	0.8	75%
December	0.24	0.09	2.0	1.2	0.8	70%

Table 6.3. Percent contribution of Willow Creek (CORGRG07) to TMDL for dissolved cadmium for Rio Grande Segment 4.

Willow Creek contribution to TMDL for dissolved zinc for RGRG04						
Month	Rio Grande Zn-D TVS, ug/L in	Rio Grande Zn TMDL lbs/day	Rio Grande, Current Zn, ug/L	Rio Grande, Current Zn Load lbs/day	Willow Creek Zn Load, lbs/day	Willow Creek Load as % of Load in Rio Grande

Willow Creek contribution to TMDL for dissolved zinc for RGRG04							
Month	Rio Grande Zn-D TVS, ug/L in	Rio Grande Zn TMDL lbs/day	Rio Grande, Current Zn, ug/L	Rio Grande, Current Zn Load lbs/day	Willow Creek Zn Load, lbs/day	Willow Creek Load as % of Load in Rio Grande
January	59.3	22.7	592.5	320.0	221.9	69%
February	61.7	23.7	600.0	340.2	206.8	61%
March	54.5	20.9	720.0	466.6	214.1	46%
April	49.6	23.3	103.0	171.9	388.5	226%
May	39.4	31.5	80.8	597.8	1504.1	252%
June	36.8	22.9	57.0	575.1	847.6	147%
July	43.3	24.1	100.8	425.7	547.1	129%
August	48.3	25.8	232.0	488.6	686.9	141%
September	50.8	27.2	211.0	319.0	301.3	94%
October	53.3	21.3	200.0	260.3	267.1	103%
November	55.7	21.4	421.0	300.1	204.4	68%
December	64.1	24.6	502.0	298.2	211.2	71%

Table 6.4. Percent contribution of Willow Creek (CORGRG07) to TMDL for dissolved zinc for Rio Grande Segment 4.

Unlike contaminant concentrations in Willow Creek waters, where concentrations decrease by dilution upon entering the Rio Grande, the load contribution from Willow Creek to the Rio Grande essentially increases during high flow conditions. The data indicate that Willow Creek significantly contributes to water quality exceeding standards for zinc and cadmium in the Rio Grande, and the load contribution from Willow Creek to the Rio Grande significantly increases levels of aluminum, cadmium, copper, lead, and zinc (EPA, 2005).

Since Willow Creek is an accumulation of discharges from various mine workings on both East and West Willow Creek, they were given a single Waste Load Allocation in the Rio Grande TMDL (Tables 6.5 and 6.6). The Waste Load Allocation was calculated by multiplying the median monthly flow from Willow Creek by the monthly table value standard and a conversion factor (0.0054) to obtain a load in pounds/day. Low flow periods represent the critical condition for the Rio Grande, however, since loads from Willow Creek are more significant during periods of higher flow, median flows were used to calculate the Waste Load allocation for Willow Creek.

Load reductions were then calculated for the Rio Grande to meet the TMDL Load Allocation. Loading reductions average between 91% in September to 97% in May for cadmium with the highest load reductions occurring in months of both high and low flow (Table 6.5). No cadmium load reductions are required in the Rio Grande for the month of June. In the remaining months, all of the load reductions remain above 90%. If flows are low in the Rio Grande during months of runoff, but not in Willow Creek, the metals contribution to Willow Creek is exacerbated. Similar to cadmium, load reductions for zinc are high during both high and low flow months with monthly load reductions averaging over 90%. Load reductions range from 90% in April to 99% in June (Table 6.6).

TMDL for dissolved cadmium for RGRG04 below Wagon Wheel Gap									
Month	30E3 Chronic Flow (cfs)	Rio Grande Hardness, $CaCO_3$, mg/L	Rio Grande Cd-D TVS, ug/L	Rio Grande Cd TMDL lbs/day	Willow Creek WLA, lbs/day	Load Allocation in Rio Grande, lbs/day	Current Cd Load in Rio Grande, lbs/day	Load Reduction in Rio Grande	Percent Load reduction in Rio Grande
January	74	42	0.22	0.08	0.010	0.069	1.3	1.2	94%
February	74	44	0.23	0.08	0.011	0.072	1.3	1.2	94%
March	74	38	0.20	0.07	0.012	0.060	1.4	1.3	95%
April	87	34	0.19	0.08	0.021	0.059	1.0	1.0	92%
May	148	26	0.15	0.11	0.056	0.052	3.3	3.2	97%
June	170	24	0.14	0.12	0.074	0.041	0.0	-0.1	0%
July	162	29	0.17	0.13	0.045	0.089	3.2	3.0	96%
August	131	33	0.18	0.11	0.025	0.090	1.9	1.8	94%
September	125	35	0.19	0.12	0.017	0.099	1.3	1.2	91%
October	95	37	0.20	0.09	0.017	0.075	1.2	1.1	92%
November	74	39	0.21	0.08	0.010	0.066	1.1	1.1	93%
December	74	46	0.24	0.09	0.010	0.076	1.2	1.1	93%

Table 6.5. TMDL for dissolved cadmium for Rio Grande Segment 4 with Willow Creek as a Waste Load Allocation.

TMDL for dissolved zinc for RGRG04 below Wagon Wheel Gap									
Month	30E3 Chronic Flow (cfs)	Rio Grande Hardness, $CaCO_3$, mg/L	Rio Grande Zn-D TVS, ug/L	Rio Grande Zn TMDL lbs/day	Willow Creek WLA, lbs/day	Load Allocation in Rio Grande, lbs/day	Current Zn Load in Rio Grande, lbs/day	Load Reduction in Rio Grande	Percent Load reduction in Rio Grande
January	74	42	59.3	22.7	2.77	20.0	320.0	300.0	94%
February	74	44	61.7	23.7	3.26	20.4	340.2	319.8	94%
March	74	38	54.5	20.9	3.41	17.5	466.6	449.1	96%
April	87	34	49.6	23.3	5.85	17.4	171.9	154.4	90%
May	148	26	39.4	31.5	15.21	16.3	597.8	581.5	97%
June	170	24	36.8	22.9	19.36	3.5	575.1	571.6	99%
July	162	29	43.3	24.1	12.27	11.8	425.7	413.9	97%
August	131	33	48.3	25.8	6.98	18.8	488.6	469.7	96%
September	125	35	50.8	27.2	4.61	22.5	319.0	296.5	93%

October	95	37	53.3	21.3	4.90	16.4	260.3	243.9	94%
November	74	39	55.7	21.4	2.75	18.6	300.1	281.5	94%
December	74	46	64.1	24.6	2.80	21.8	298.2	276.4	93%

Table 6.6. TMDL for dissolved zinc for Rio Grande Segment 4 with Willow Creek as a Waste Load Allocation.

TMDL for dissolved cadmium for RGRG04 near Del Norte								
Month	30E3 Chronic Flow (cfs)	Hardness, $CaCO_3$, mg/L	Zn-D TVS, ug/L	Zn TMDL lbs/day	Current Zn, ug/L	Current Zn Load lbs/day	Load Reduction, lbs/day	Percent Load reduction
January	111.5	59	79.3	47.73	257.5	229.4	181.7	79%
February	111.5	60	80.4	48.42	245.0	226.2	177.8	79%
March	111.5	58	78.1	47.04	291.6	344.8	297.8	86%
April	151.0	46	64.1	52.28	141.8	416.1	363.9	87%
May	198.0	33	48.3	51.65	34.7	410.1	358.4	87%
June	136.0	30	44.5	32.71	61.1	920.1	887.4	96%
July	114.0	47	65.3	40.20	80.2	422.5	382.3	90%
August	111.5	55	74.7	44.96	82.4	240.3	195.4	81%
September	111.5	39	55.7	33.54	71.8	149.0	115.4	77%
October	111.5	73	90.6	54.54	198.5	378.3	323.8	86%
November	111.5	89	112.6	67.77	203.7	243.1	175.3	72%
December	111.5	66	87.2	52.52	191.9	186.5	134.0	72%

Table 6.7. TMDL for dissolved zinc for Rio Grande Segment 4 near Del Norte, CO.

Load reductions were also calculated for the Rio Grande near Del Norte in order to attain the TMDL. Zinc loading reductions average between 72% in November and December to 96% in June. Unlike upstream reductions on the Rio Grande below Wagon Wheel Gap, the highest load reductions occur in months of higher flow (Table 6.7).

Exceedances of the acute standards were addressed by multiplying the sample data by monthly chronic load reductions. In the case of both the Rio Grande below Wagon Wheel Gap and near Del Norte, chronic monthly load reductions will bring the Rio Grande into attainment of its acute cadmium and zinc standards.

7.0 RESTORATION PLANNING AND IMPLEMENTATION PROCESS

The segment of the Rio Grande River, CORGRG04, first appeared on the list of impaired water bodies (Clean Water Act (CWA) 303(d) list) in 1998. In order to avoid Superfund (NPL) listing, the residents of Creede and the surrounding portion of Mineral County, have developed a community-based effort to identify and address the most pressing environmental concerns in the Willow Creek watershed. The Willow Creek Reclamation Committee (WCRC) is directing efforts to improve water quality and physical habitat in the watershed as part of a long-term watershed revitalization program.

Historic mining activities related to underground mining of silver and base metals resulted in water quality impairment and overburden dumping in the 39 square mile Willow

Creek watershed. From 1999 through 2003, the WCRC, with technical and financial assistance from EPA, the USFS, the NRCS, the Colorado Division of Minerals and Geology and the Colorado Department of Public Health and Environment, directed a variety of watershed characterization efforts. These included: (1) identifying sources of heavy metals, (2) characterizing transport of heavy metals to surface waters, (3) quantifying heavy metals loading to Willow Creek and the Rio Grande River, (4) characterizing mine waste materials, (5) bio-assessment of aquatic resources, (6) characterizing hydrological conditions in underground mines, and (7) identifying watershed land revitalization opportunities (USEPA Fact Sheet).

- Colorado completed a major stabilization of the Commodore dump, which West Willow Creek runs through. Engineering completed preliminary flood control analyses and conceptual design for the area. The work continues to be refined based on discussions with stakeholders, and they are also considering an analysis at East Willow Creek.
- There are about 11 mine waste dumps in the Creede district, some quite large. The State of Colorado and EPA wrote a Sampling and Analyses Plan for all dumps. The SAP was approved by the State of Colorado and EPA's 319 program for implementation. The SAP called for sampling at each mine waste dump of paste pH, and laboratory analyses of metals. Contractors hired by the WCRC and Creede volunteers collected mine waste samples. Based on the results it is known that a couple of the piles are contaminated. Samples were collected from contaminated piles for hazardous waste TCLP analyses in 2002. The data confirmed the presence of a few contaminated areas in some piles (USEPA Fact Sheet).
- The WCRC, Colorado Division of Mining Reclamation and Safety (CDRMS), and the USFS, with a 319 grant, re-contoured portions of the Last Chance waste pile to reduce snow accumulation and subsequent leaching during spring melting. Additionally, a concrete catchment barrier was installed at the toe of the waste pile to prevent sloughing of eroded waste material into the creek. They also worked on the Amethyst waste pile. Waste was pulled back from the creek, the toe of the waste piles was armored against high flow events, the creek channel was deepened, and a new grizzly was constructed at the portal crossing on the creek above the waste pile. Work was completed in fall of 2007 (CDRMS 2007).
- USEPA Region 8 is in the process of approving a CERCLA removal action on Willow Creek (USEPA Fact Sheet).

The next stage of cleanup in Willow Creek has prompted EPA to consider placing the Nelson Tunnel/Commodore Waste Rock site on the NPL list. Putting the Nelson Tunnel/Commodore Waste Rock site on a national priorities list would make it eligible to receive federal cleanup funds while the EPA seeks to recover funds from parties responsible for contamination. If no parties are found or if the parties cannot pay, Superfund dollars would be used for cleanup.

Monitoring

In order to insure that the TMDL is adequately protective of the segment, monitoring of Willow Creek and its tributaries, in addition to the Rio Grande above and below the confluence of Willow Creek, is required. A more in-depth characterization of the groundwater sources would also be beneficial to the remediation of the Willow Creek watershed. Additional remediation of Willow Creek is required in order for the Rio Grande to attain Aquatic Life Use based standards below the Willow Creek mixing zone.

Conclusion

The goal of this TMDL is the attainment of the Aquatic Life Use based standard for cadmium and zinc within Segment 4 of the mainstem of the Rio Grande downstream of the mixing zone with Willow Creek to Del Norte. Loading reductions are required in order to attain the TMDLs for both cadmium and zinc.

8.0 PUBLIC INVOLVEMENT

There has been a strong public participation in protecting and enhancing the water quality of Willow Creek and the Rio Grande River. The Willow Creek Reclamation Committee, U.S. Environmental Protection Agency (Region 8), U.S. Forest Service (USFS), Natural Resource Conservation Service (NRCS), the Colorado Division of Minerals and Geology, and the Colorado Department of Public Health and Environment (CDPHE) have been actively involved in better understanding the water quality issues of Willow Creek in order to better deal with the legacy of historical mining.

The public has had an opportunity to be involved in the Water Quality Control Commission (WQCC) hearings, and throughout the years, the WQCC has adopted ambient based standards for Willow Creek, Segment CORGRG07. Opportunities have also been available through the 303(d) listing process, which also has a public notice period for public involvement.

The TMDL itself is subject to an independent public process. The TMDL was made available for public review and comment during a 30 day public notice period in January 2008. Notice is provided in the Colorado Water Quality Information Bulletin.

Public participation will continue to promote future restoration of the watershed, as new remediation possibilities are explored.

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Appendix C

Derivation of Risk Based Concentrations for Selection of Soil COPCs

Appendix C
Derivation of Risk-Based Concentrations for Selection of Soil COPCs

C.1 Non-Lead RBCs

Risk-based concentrations presented in Table 4-6 were derived from equations combining Site-specific exposure assumptions with EPA toxicity data. The method for computing an RBC is to reverse the basic risk equation and solve for the concentration that corresponds to the specified risk. Noncarcinogenic and carcinogenic RBCs were calculated as follows:

$$RBC_{(Noncarcinogenic)} = HQ/[(HIF_{NC\ Soil\ Ingest} * RBA)/RfD_{oral} + (TWF_{NC\ Inh}*PEF)/RfC_{inh})]$$

$$RBC_{(carcinogenic)} = TR/[(HIF_{C\text{-}Soil\ Ingest} * RBA)*SF_{oral} + (TWF_{C\ -\ Inh}*IUR*1{,}000\ \mu g/mg*PEF)]$$

Parameter	Unit	Value
HQ = Hazard Quotient	Unitless	1E-01
TR = Target Risk	Unitless	1E-06
HIF = Human Intake Factor	kg/kg-day	HIF values are summarized in Tables 4-11 and 4-13.
TWF = Time Weighting Factor	Unitless	TWF values are summarized in Tables 4-11 and 4-13
RBA = Relative Bioavailability	Percent	100% for all analytes except arsenic; RBA for arsenic = 50%
PEF = Particulate Emission Factor	kg/m^3	Particulate Emission Factor characterizing soil to air transfer. PEF = 7.35E-10 kg/m^3 for Rock Hunter RBC calculations (EPA recommended default value based on wind erosion (EPA, 1989)) PEF = 1.18E-06 kg/m^3 for ATV rider RBC calculations (estimated PEF from ATV riding at Quincy Smelter as referenced in *Baseline HHRA for the Standard Mine Site Gunnison County, CO* (SRC, 2008))
RfD_{oral} = Reference Dose for non-cancer effects	mg/kg-day	Sources for values used in the RBC calculations are included in Table 4-15.
RfC_{inh} = Reference Concentration for non-cancer effects	mg/m^3	Sources for values used in the RBC calculations are included in Table 4-15.
SF_{oral} = Slope Factor for cancer effects (ingestion)	kg-day/mg	Sources for values used in the RBC calculations are included in Table 4-15.
IUR = Inhalation Unit Risk for cancer effects (inhalation)	$(\mu g/m^3)^{-1}$	Sources for values used in the RBC calculations are included in Table 4-15.

The selected RBC is the lower of the non-cancer and cancer RBCs for any receptor. Tables C-1 and C-2 summarize the RBC calculations for the rock hunter and ATV rider scenarios.

C.2 Lead RBCs

In the EPA document, *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil*, the following equation is recommended for computation of risk from lead to women of child-bearing age:

$$GM = PbB0 + BKSF * AD$$

where:
GM = geometric mean blood lead value in an exposed individual (ug/dL)
PbB0 = baseline blood lead value (ug/dL)
BKSF = biokinetic slope factor (ug/dL in blood per ug/day absorbed)
AD = absorbed dose (ug/day)

The absorbed dose is computed as follows:

$$AD = \Sigma (C_i * IR_i \cdot * AF_i)$$

where:
C_i = Concentration of lead in medium i (ug/g in soil, ug/m^3 in air, ug/L in water)
IR_i = Average daily intake rate of medium i (g/day of soil, m^3/day of air, L/day of water)
AF_i = Absorption fraction from medium i

If exposure is not continuous, the value of IR is calculated as follows:

$$IR_i = IR_i(\text{per day}) * (\text{days per year}) / 365$$

Assuming a lognormal distribution, the 95th percentile blood lead value in a group of women is given by:

$$95^{th} = GM \cdot GSD^{1.645}$$

where:
GSD = geometric standard deviation

Because the blood lead value in a fetus in slightly lower than in the blood of the mother, the 95th percentile concentration in the fetus is given by:

$$95^{th}(\text{fetus}) = 95^{th}(\text{mother}) \cdot \text{Ratio}$$

where
Ratio = the ratio of the concentration of blood lead in the fetus to that of the mother.

Table C-3 summarizes inputs used to calculate soil RBCs for the ATV Rider On Site, ATV Rider Off Site, and Rock Hunter scenarios. The RBCs were calculated based on CTE intake rates for these receptors. The detailed calculations are provided in Table E-4. As seen in the table, a soil RBC for lead cannot be calculated for the ATV rider on site scenario. The Site-specific air concentration included in the calculation (which is the maximum detected lead concentration from air sampling conducted at the site while ATV riding) overpowers the equation and there is not possible to estimate an acceptable soil lead concentration in combination with this amount of inhalation exposure.

Table C-1
Soil RBC Calculations Rock Hunter Scenario

	Target HQ Noncancer	Target Risk Cancer	Soil RBA	Ingestion Toxicity Factors		Inhalation Toxicity Factors		Soil to Air PEF (kg/m^3)	Noncancer RBC (mg/kg)	Cancer RBC (mg/kg)
				RfD (mg/kg-d)	SF $(mg/kg\text{-}d)^{-1}$	RfC (mg/m^3)	IUR$(\mu g/m^3)^{-1}$			
Aluminum	1.00E-01	1.00E-06	1.0	1.0E+00	--	5.00E-03	--	7.35E-10	2,503,774	
Antimony	1.00E-01	1.00E-06	1.0	4.0E-04	--	--	--	7.35E-10	1,023	
Arsenic	1.00E-01	1.00E-06	0.5	3.0E-04	1.5	1.50E-05	4.30E-03	7.35E-10	1,528	79
Beryllium	1.00E-01	1.00E-06	1.0	2.0E-03	--	2.00E-05	2.40E-03	7.35E-10	5,061	231,293
Cadmium	1.00E-01	1.00E-06	1.0	1.0E-03	--	1.00E-05	1.80E-03	7.35E-10	2,530	308,390
Calcium	1.00E-01	1.00E-06	1.0	1.4E+01	--	--	--	7.35E-10	36,536,354	
ChromiumVI	1.00E-01	1.00E-06	1.0	3.0E-03	--	1.00E-04	8.40E-02	7.35E-10	7,648	6,608
Copper	1.00E-01	1.00E-06	1.0	4.0E-02	--	--	--	7.35E-10	102,302	
Iron	1.00E-01	1.00E-06	1.0	7.0E-01	--	--	--	7.35E-10	1,790,281	
Magnesium	1.00E-01	1.00E-06	1.0	5.7E+00	--	--	--	7.35E-10	14,614,541	
Manganese	1.00E-01	1.00E-06	1.0	1.4E-01	--	5.00E-05	--	7.35E-10	275,288	
Mercury	1.00E-01	1.00E-06	1.0	3.0E-04	--	--	--	7.35E-10	767	
Nickel	1.00E-01	1.00E-06	1.0	2.0E-02	--	9.00E-05	2.60E-04	7.35E-10	49,959	2,135,008
Potassium	1.00E-01	1.00E-06	1.0	5.0E+01	--	--	--	7.35E-10	127,877,238	
Selenium	1.00E-01	1.00E-06	1.0	5.0E-03	--	2.00E-02	--	7.35E-10	12,787	
Silica(SiO2)	1.00E-01	1.00E-06	1.0	--	--	3.00E-03	--	7.35E-10	71,453,590	
Silver	1.00E-01	1.00E-06	1.0	5.0E-03	--	--	--	7.35E-10	12,788	
Sodium	1.00E-01	1.00E-06	1.0	3.4E+01	--	--	--	7.35E-10	87,687,249	
Strontium	1.00E-01	1.00E-06	1.0	6.0E-01	--	--	--	7.35E-10	1,534,527	
Thallium	1.00E-01	1.00E-06	1.0	--	--	--	--	7.35E-10		
Vanadium	1.00E-01	1.00E-06	1.0	5.0E-03	--	--	--	7.35E-10	12,788	
Zinc	1.00E-01	1.00E-06	1.0	3.0E-01	--	--	--	7.35E-10	767,263	

Human Intake Factors for soil ingestion used in RBC calculations (see Table 4-13): ($HIF_{NC\ Soil\ Ingest}$ = 3.91E-08 kg/kg-day; $HIF_{C\text{-}Soil\ Ingest}$ = 1.68E-08 kg/kg-day)
Time Weighted Factors for inhalation used in RBC calculations (see Table 4-13): ($TWF_{NC\ Inhal}$ = 5.71E-03; $TWF_{C\ -\ Inh}$ = 2.45E-03)

Table C-2
Soil RBC Calculations ATV Rider Scenario

	Target HQ Noncancer	Target Risk Cancer	Soil RBA	Ingestion Toxicity Factors RfD (mg/kg-d)	Ingestion Toxicity Factors SF $(mg/kg\text{-}d)^{-1}$	Inhalation Toxicity Factors RfC (mg/m^3)	Inhalation Toxicity Factors IUR $(\mu g/m^3)^{-1}$	Soil to Air PEF (kg/m^3)	Noncancer RBC (mg/kg)	Cancer RBC (mg/kg)	FINAL RBC (mg/kg)
Aluminum	1.00E-01	1.00E-06	1.0	1.0E+00	--	1.40E-03	--	1.18E-06	20,454		20,454
Antimony	1.00E-01	1.00E-06	1.0	4.0E-04	--	--	--	1.18E-06	511		511
Arsenic	1.00E-01	1.00E-06	0.5	3.0E-04	1.5	1.50E-05	4.30E-03	1.18E-06	173	27	27
Beryllium	1.00E-01	1.00E-06	1.0	2.0E-03	--	2.00E-05	2.40E-03	1.18E-06	266	144	144
Cadmium	1.00E-01	1.00E-06	1.0	1.0E-03	--	1.00E-05	1.80E-03	1.18E-06	70	192	70
Calcium	1.00E-01	1.00E-06	1.0	1.4E+01	--	--	--	1.18E-06	18,250,000		18,250,000
ChromiumVI	1.00E-01	1.00E-06	1.0	3.0E-03	--	1.00E-04	8.40E-02	1.18E-06	1,070	4	4
Copper	1.00E-01	1.00E-06	1.0	4.0E-02	--	--	--	1.18E-06	51,100		51,100
Iron	1.00E-01	1.00E-06	1.0	7.0E-01	--	--	--	1.18E-06	894,250		894,250
Magnesium	1.00E-01	1.00E-06	1.0	5.7E+00	--	--	--	1.18E-06	7,300,000		7,300,000
Manganese	1.00E-01	1.00E-06	1.0	1.4E-01	--	5.00E-05	--	1.18E-06	739		739
Mercury	1.00E-01	1.00E-06	1.0	3.0E-04	--	--	--	1.18E-06	383		383
Nickel	1.00E-01	1.00E-06	1.0	2.0E-02	--	9.00E-05	2.60E-04	1.18E-06	1,270	1,332	1,270
Potassium	1.00E-01	1.00E-06	1.0	5.0E+01	--	--	--	1.18E-06	63,875,000		63,875,000
Selenium	1.00E-01	1.00E-06	1.0	5.0E-03	--	2.00E-02	--	1.18E-06	6,253		6,253
Silica(SiO2)	1.00E-01	1.00E-06	1.0	--	--	3.00E-03	--	1.18E-06	44,542		44,542
Silver	1.00E-01	1.00E-06	1.0	5.0E-03	--	--	--	1.18E-06	6,388		6,388
Sodium	1.00E-01	1.00E-06	1.0	3.4E+01	--	--	--	1.18E-06	43,800,000		43,800,000
Strontium	1.00E-01	1.00E-06	1.0	6.0E-01	--	--	--	1.18E-06	766,500		766,500
Thallium	1.00E-01	1.00E-06	1.0	--	--	--	--	1.18E-06			
Vanadium	1.00E-01	1.00E-06	1.0	5.0E-03	--	--	--	1.18E-06	6,388		6,388
Zinc	1.00E-01	1.00E-06	1.0	3.0E-01	--	--	--	1.18E-06	383,250		383,250

Human Intake Factors for soil ingestion used in RBC calculations (see Table 4-11): ($HIF_{NC\ Soil\ Ingest}$ = 7.83E-08 kg/kg-day; $HIF_{C\text{-}Soil\ Ingest}$ = 3.35E-08 kg/kg-day)
Time Weighted Factors for inhalation used in RBC calculations (see Table 4-11): ($TWF_{NC\ Inhal}$ = 5.71E-03; $TWF_{C\ -\ Inh}$ = 2.45E-03)

Table C-3
Adult Lead Model Inputs

Parameter	Units	ATV Rider	Rock Hunter	Source
Ratio	ug/dL per ug/dL	0.9	0.9	USEPA 2003 (default)
GSD	--	1.8	1.8	USEPA 2009
PbB0	ug/dL	1.0	1.0	USEPA 2009
BKSF	ug/dL per ug/day	0.4	0.4	USEPA 2003 (default)
IRsoil	g/day	0.05	0.025	Exposure parameter (see Tables 4-11 & 4-13)
AFsoil		0.12	0.12	USEPA 2003 (default)
EF	days/yr	6	6	Exposure parameter (see Tables 4-11 & 4-13)
Cair	ug/m3	188	11	Air concentration (see Note 1)
BR	m3/hr	2.4	2.4	Exposure parameter (see Tables 4-11 & 4-13)
ET	hr/day	1.5	1.5	Exposure parameter (see Tables 4-11 & 4-13)
EF	days/yr	6	6	Exposure parameter (see Tables 4-11 & 4-13)
Csw	ug/L	--	34	Max surface water concentration for lead from June 2010 sampling
IRsw	L/day	--	0.0025	Exposure parameter (see Tables 4-11 & 4-13)
AFw		--	0.2	USEPA 2003 (default)
EF	days/yr	--	6	Exposure parameter (see Tables 4-11 & 4-13)

[1] Max air concentration for lead from June 2010 ATV riding samples (ATV On Site scenario); estimated air concentration based on CR-503 soil lead concentrations (ATV Off Site scenario); max air concentration for lead from June 2010 stationary air samples (Rock Hunter scenario).
-- = Model input not applicable to this receptor.

USEPA 2003, *Recommendations of the TRW for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil*

USEPA 2009, *Update of the Adult Lead Methodology's Default Baseline Blood Lead Concentration and Geometric Standard Deviation Parameters*. OSWER 9200.2-82.

Table C-4
RBCs for Lead

Parameter	Units	ATV Rider	Rock Hunter
PbB (GM, adult)	ug/dL	4.2	4.2
PbB(95th, fetal)	ug/dL	3.8	3.8
Ratio	ug/dL per ug/dL	0.9	0.9
GSD	--	1.8	1.8
PbB0	ug/dL	1.0	1.0
BKSF	ug/dL per ug/day	0.4	0.4
Csoil	ug/g	***	149,017
IRsoil	g/day	0.05	0.025
AFsoil	ug absorbed per ug ingested	0.12	0.12
EF	days/yr	6	6
Cair (max detected)	ug/m3	188	11
BR	m3/hr	2.4	2.4
ET	hr/day	1.5	1.5
AFa		1	1
EF	days/yr	6	6
Csw (max detected)	ug/L	--	34
IRsw	L/day	--	0.0025
AF		--	0.2
EF	days/yr	--	6
Calculated RBC		**Cannot be calculated - Cair is too great**	**149,017**

*** Lead air concentration is too excessive to allow for a contribution of lead in soil at any concentration.

Basic Equations:
PbB(fetus) target = 10.0 ug/dL; PbB(mother, 95th) = 11.11 ug/dL
PbB(fetus) = PbB(mother) * Ratio
PbB(95th) = PbB (GM)*GSD^1.645
PbB(GM) = PbB0 + BKSF * [Csoil*IRsoil*AFsoil*EF/365 + Cair*BR*ET*AFa*EF/365 + Csw*IRsw*EF/365]

Appendix D

ProUCL Results

Arsenic Waste Rock

ARSENIC (ug/kg)

General Statistics			
Number of Valid Observations	27	Number of Distinct Observations	27
Number of Missing Values	1		
Raw Statistics		Log-transformed Statistics	
Minimum	261000	Minimum of Log Data	12.47
Maximum	1350000	Maximum of Log Data	14.12
Mean	672407	Mean of log Data	13.35
Median	578000	SD of log Data	0.386
SD	265372		
Coefficient of Variation	0.395		
Skewness	1.022		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.913	Shapiro Wilk Test Statistic	0.969
Shapiro Wilk Critical Value	0.923	Shapiro Wilk Critical Value	0.923
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	759515	95% H-UCL	777945
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	896355
95% Adjusted-CLT UCL (Chen-1995)	767140	97.5% Chebyshev (MVUE) UCL	993161
95% Modified-t UCL (Johnson-1978)	761188	99% Chebyshev (MVUE) UCL	1183320
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	6.393	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	105171		
MLE of Mean	672407		
MLE of Standard Deviation	265928		
nu star	345.2		
Approximate Chi Square Value (.05)	303.2	Nonparametric Statistics	
Adjusted Level of Significance	0.0401	95% CLT UCL	756412
Adjusted Chi Square Value	300.7	95% Jackknife UCL	759515
		95% Standard Bootstrap UCL	757744
Anderson-Darling Test Statistic	0.475	95% Bootstrap-t UCL	775648
Anderson-Darling 5% Critical Value	0.746	95% Hall's Bootstrap UCL	772177
Kolmogorov-Smirnov Test Statistic	0.131	95% Percentile Bootstrap UCL	756593
Kolmogorov-Smirnov 5% Critical Value	0.168	95% BCA Bootstrap UCL	767185
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	895020
		97.5% Chebyshev(Mean, Sd) UCL	991345
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1180556
95% Approximate Gamma UCL	765677		
95% Adjusted Gamma UCL	772080		
Potential UCL to Use		**Use 95% Approximate Gamma UCL**	**765677**

Cadmium Waste Rock

CADMIUM (ug/kg)

General Statistics			
Number of Valid Observations	27	Number of Distinct Observations	27
Number of Missing Values	1		
Raw Statistics		Log-transformed Statistics	
Minimum	29300	Minimum of Log Data	10.29
Maximum	103000	Maximum of Log Data	11.54
Mean	75930	Mean of log Data	11.2
Median	79800	SD of log Data	0.297
SD	17525		
Coefficient of Variation	0.231		
Skewness	-1.247		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.887	Shapiro Wilk Test Statistic	0.761
Shapiro Wilk Critical Value	0.923	Shapiro Wilk Critical Value	0.923
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	81682	95% H-UCL	85164
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	95835
95% Adjusted-CLT UCL (Chen-1995)	80612	97.5% Chebyshev (MVUE) UCL	104216
95% Modified-t UCL (Johnson-1978)	81547	99% Chebyshev (MVUE) UCL	120679
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	12.7	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5978		
MLE of Mean	75930		
MLE of Standard Deviation	21305		
nu star	685.9		
Approximate Chi Square Value (.05)	626.1	Nonparametric Statistics	
Adjusted Level of Significance	0.0401	95% CLT UCL	81477
Adjusted Chi Square Value	622.5	95% Jackknife UCL	81682
		95% Standard Bootstrap UCL	81396
Anderson-Darling Test Statistic	1.753	95% Bootstrap-t UCL	80707
Anderson-Darling 5% Critical Value	0.744	95% Hall's Bootstrap UCL	80765
Kolmogorov-Smirnov Test Statistic	0.2	95% Percentile Bootstrap UCL	81289
Kolmogorov-Smirnov 5% Critical Value	0.168	95% BCA Bootstrap UCL	80622
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	90631
		97.5% Chebyshev(Mean, Sd) UCL	96992
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	109488
95% Approximate Gamma UCL	83177		
95% Adjusted Gamma UCL	83664		
Potential UCL to Use		**Use 95% Student's-t UCL**	**81682**
		or 95% Modified-t UCL	81547

Chromium Waste Rock

CHROMIUM (ug/kg)

General Statistics			
Number of Valid Observations	27	Number of Distinct Observations	24
Number of Missing Values	1		
Raw Statistics		Log-transformed Statistics	
Minimum	1340	Minimum of Log Data	7.2
Maximum	8400	Maximum of Log Data	9.036
Mean	3231	Mean of log Data	7.982
Median	2550	SD of log Data	0.416
SD	1759		
Coefficient of Variation	0.544		
Skewness	2.182		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.662	Shapiro Wilk Test Statistic	0.827
Shapiro Wilk Critical Value	0.923	Shapiro Wilk Critical Value	0.923
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	3809	95% H-UCL	3731
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	4328
95% Adjusted-CLT UCL (Chen-1995)	3940	97.5% Chebyshev (MVUE) UCL	4823
95% Modified-t UCL (Johnson-1978)	3833	99% Chebyshev (MVUE) UCL	5796
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	4.691	Data do not follow a Discernable Distribution (0.05)	
Theta Star	688.8		
MLE of Mean	3231		
MLE of Standard Deviation	1492		
nu star	253.3		
Approximate Chi Square Value (.05)	217.5	Nonparametric Statistics	
Adjusted Level of Significance	0.0401	95% CLT UCL	3788
Adjusted Chi Square Value	215.4	95% Jackknife UCL	3809
		95% Standard Bootstrap UCL	3783
Anderson-Darling Test Statistic	2.681	95% Bootstrap-t UCL	4047
Anderson-Darling 5% Critical Value	0.747	95% Hall's Bootstrap UCL	3828
Kolmogorov-Smirnov Test Statistic	0.26	95% Percentile Bootstrap UCL	3809
Kolmogorov-Smirnov 5% Critical Value	0.169	95% BCA Bootstrap UCL	4067
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	4707
		97.5% Chebyshev(Mean, Sd) UCL	5346
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	6600
95% Approximate Gamma UCL	3764		
95% Adjusted Gamma UCL	3801		
Potential UCL to Use		Use 95% Student's-t UCL	3809
		or 95% Modified-t UCL	**3833**

Lead Waste Rock

LEAD (mg/kg)

General Statistics			
Number of Valid Observations	27	Number of Distinct Observations	27
Number of Missing Values	1		
Raw Statistics		Log-transformed Statistics	
Minimum	8050	Minimum of Log Data	8.993
Maximum	52100	Maximum of Log Data	10.86
Mean	25416	Mean of log Data	10.04
Median	21100	SD of log Data	0.478
SD	12205		
Coefficient of Variation	0.48		
Skewness	0.935		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.848	Shapiro Wilk Test Statistic	0.91
Shapiro Wilk Critical Value	0.923	Shapiro Wilk Critical Value	0.923
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	29422	95% H-UCL	30712
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	36060
95% Adjusted-CLT UCL (Chen-1995)	29731	97.5% Chebyshev (MVUE) UCL	40645
95% Modified-t UCL (Johnson-1978)	29493	99% Chebyshev (MVUE) UCL	49651
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	4.303	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5907		
MLE of Mean	25416		
MLE of Standard Deviation	12253		
nu star	232.4		
Approximate Chi Square Value (.05)	198.1	Nonparametric Statistics	
Adjusted Level of Significance	0.0401	95% CLT UCL	29279
Adjusted Chi Square Value	196	95% Jackknife UCL	29422
		95% Standard Bootstrap UCL	29303
Anderson-Darling Test Statistic	1.314	95% Bootstrap-t UCL	30173
Anderson-Darling 5% Critical Value	0.748	95% Hall's Bootstrap UCL	29746
Kolmogorov-Smirnov Test Statistic	0.219	95% Percentile Bootstrap UCL	29444
Kolmogorov-Smirnov 5% Critical Value	0.169	95% BCA Bootstrap UCL	29591
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	35654
		97.5% Chebyshev(Mean, Sd) UCL	40085
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	48787
95% Approximate Gamma UCL	29815		
95% Adjusted Gamma UCL	30123		
Potential UCL to Use		Use 95% Student's-t UCL	29422
		or 95% Modified-t UCL	**29493**

Manganese Waste Rock

MANGANESE (mg/kg)

General Statistics			
Number of Valid Observations	27	Number of Distinct Observations	27
Number of Missing Values	1		
Raw Statistics		Log-transformed Statistics	
Minimum	852	Minimum of Log Data	6.748
Maximum	5200	Maximum of Log Data	8.556
Mean	3647	Mean of log Data	8.129
Median	4200	SD of log Data	0.424
SD	1217		
Coefficient of Variation	0.334		
Skewness	-0.553		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.906	Shapiro Wilk Test Statistic	0.838
Shapiro Wilk Critical Value	0.923	Shapiro Wilk Critical Value	0.923
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	4047	95% H-UCL	4352
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	5058
95% Adjusted-CLT UCL (Chen-1995)	4006	97.5% Chebyshev (MVUE) UCL	5646
95% Modified-t UCL (Johnson-1978)	4042	99% Chebyshev (MVUE) UCL	6800
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	6.322	Data do not follow a Discernable Distribution (0.05)	
Theta Star	576.9		
MLE of Mean	3647		
MLE of Standard Deviation	1451		
nu star	341.4		
Approximate Chi Square Value (.05)	299.6	Nonparametric Statistics	
Adjusted Level of Significance	0.0401	95% CLT UCL	4032
Adjusted Chi Square Value	297.1	95% Jackknife UCL	4047
		95% Standard Bootstrap UCL	4027
Anderson-Darling Test Statistic	1.192	95% Bootstrap-t UCL	4035
Anderson-Darling 5% Critical Value	0.746	95% Hall's Bootstrap UCL	4009
Kolmogorov-Smirnov Test Statistic	0.213	95% Percentile Bootstrap UCL	4010
Kolmogorov-Smirnov 5% Critical Value	0.168	95% BCA Bootstrap UCL	4011
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	4668
		97.5% Chebyshev(Mean, Sd) UCL	5110
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	5977
95% Approximate Gamma UCL	4156		
95% Adjusted Gamma UCL	4191		
Potential UCL to Use		**Use 95% Student's-t UCL**	**4047**
		or 95% Modified-t UCL	4042

ARSENIC (mg/kg)

General Statistics			
Number of Valid Observations	17	Number of Distinct Observations	16
Raw Statistics		Log-transformed Statistics	
Minimum	5.83	Minimum of Log Data	1.763
Maximum	166	Maximum of Log Data	5.112
Mean	52.57	Mean of log Data	3.575
Median	50.7	SD of log Data	0.996
SD	43.94		
Coefficient of Variation	0.836		
Skewness	1.321		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.869	Shapiro Wilk Test Statistic	0.936
Shapiro Wilk Critical Value	0.892	Shapiro Wilk Critical Value	0.892
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	71.17	95% H-UCL	113.9
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	121.8
95% Adjusted-CLT UCL (Chen-1995)	73.75	97.5% Chebyshev (MVUE) UCL	150.1
95% Modified-t UCL (Johnson-1978)	71.74	99% Chebyshev (MVUE) UCL	205.8
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	1.222	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	43		
MLE of Mean	52.57		
MLE of Standard Deviation	47.55		
nu star	41.56		
Approximate Chi Square Value (.05)	27.79	Nonparametric Statistics	
Adjusted Level of Significance	0.0346	95% CLT UCL	70.1
Adjusted Chi Square Value	26.61	95% Jackknife UCL	71.17
		95% Standard Bootstrap UCL	70.02
Anderson-Darling Test Statistic	0.323	95% Bootstrap-t UCL	77.61
Anderson-Darling 5% Critical Value	0.757	95% Hall's Bootstrap UCL	85.08
Kolmogorov-Smirnov Test Statistic	0.157	95% Percentile Bootstrap UCL	70.41
Kolmogorov-Smirnov 5% Critical Value	0.213	95% BCA Bootstrap UCL	73.89
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	99.02
		97.5% Chebyshev(Mean, Sd) UCL	119.1
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	158.6
95% Approximate Gamma UCL	78.63		
95% Adjusted Gamma UCL	82.11		
Potential UCL to Use		**Use 95% Approximate Gamma UCL**	**78.63**

CADMIUM (mg/kg)

General Statistics			
Number of Valid Observations	17	Number of Distinct Observations	14
Raw Statistics		Log-transformed Statistics	
Minimum	0	Log Statistics Not Avaliable	
Maximum	19.7		
Mean	2.627		
Median	1.47		
SD	4.614		
Coefficient of Variation	1.756		
Skewness	3.52		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.534	Not Available	
Shapiro Wilk Critical Value	0.892		
Data not Normal at 5% Significance Level			
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	4.581	95% H-UCL	N/A
Assuming Normal Distribution		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	4.581	95% Adjusted-CLT UCL (Chen 1995)	5.489
		95% Modified-t UCL (Johnson-1978)	4.74
Gamma Distribution Test		Data Distribution	
Gamma Statistics Not Available		Data do not follow a Discernable Distribution (0.05)	
Potential UCL to Use			
Use 95% Chebyshev (Mean, Sd) UCL	**7.505**	95% CLT UCL	4.468
		95% Jackknife UCL	4.581
		95% Standard Bootstrap UCL	4.354
		95% Bootstrap-t UCL	8.146
		95% Hall's Bootstrap UCL	11.52
		95% Percentile Bootstrap UCL	4.655
		95% BCA Bootstrap UCL	5.837
		95% Chebyshev(Mean, Sd) UCL	7.505
		97.5% Chebyshev(Mean, Sd) UCL	9.616
		99% Chebyshev(Mean, Sd) UCL	13.76

CHROMIUM (mg/kg)

General Statistics			
Number of Valid Observations	17	Number of Distinct Observations	16
Raw Statistics		Log-transformed Statistics	
Minimum	3.29	Minimum of Log Data	1.191
Maximum	27.7	Maximum of Log Data	3.321
Mean	9.194	Mean of log Data	2.089
Median	7.88	SD of log Data	0.496
SD	5.716		
Coefficient of Variation	0.622		
Skewness	2.361		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.749	Shapiro Wilk Test Statistic	0.945
Shapiro Wilk Critical Value	0.892	Shapiro Wilk Critical Value	0.892
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	11.61	95% H-UCL	11.74
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	13.96
95% Adjusted-CLT UCL (Chen-1995)	12.32	97.5% Chebyshev (MVUE) UCL	16.08
95% Modified-t UCL (Johnson-1978)	11.75	99% Chebyshev (MVUE) UCL	20.25
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	3.337	Data appear Gamma Distributed at 5% Sig Level	
Theta Star	2.756		
MLE of Mean	9.194		
MLE of Standard Deviation	5.033		
nu star	113.4		
Approximate Chi Square Value (.05)	89.86	Nonparametric Statistics	
Adjusted Level of Significance	0.0346	95% CLT UCL	11.47
Adjusted Chi Square Value	87.66	95% Jackknife UCL	11.61
		95% Standard Bootstrap UCL	11.39
Anderson-Darling Test Statistic	0.687	95% Bootstrap-t UCL	13.5
Anderson-Darling 5% Critical Value	0.743	95% Hall's Bootstrap UCL	21.48
Kolmogorov-Smirnov Test Statistic	0.174	95% Percentile Bootstrap UCL	11.56
Kolmogorov-Smirnov 5% Critical Value	0.21	95% BCA Bootstrap UCL	12.42
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	15.24
		97.5% Chebyshev(Mean, Sd) UCL	17.85
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	22.99
95% Approximate Gamma UCL	11.61		
95% Adjusted Gamma UCL	11.9		
Potential UCL to Use		**Use 95% Approximate Gamma UCL**	**11.61**

Lead CR503

LEAD (mg/kg)

General Statistics			
Number of Valid Observations	17	Number of Distinct Observations	17
Raw Statistics		Log-transformed Statistics	
Minimum	28.2	Minimum of Log Data	3.339
Maximum	2380	Maximum of Log Data	7.775
Mean	434.9	Mean of log Data	5.317
Median	216	SD of log Data	1.343
SD	582.1		
Coefficient of Variation	1.339		
Skewness	2.576		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.69	Shapiro Wilk Test Statistic	0.952
Shapiro Wilk Critical Value	0.892	Shapiro Wilk Critical Value	0.892
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	681.3	95% H-UCL	1480
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1210
95% Adjusted-CLT UCL (Chen-1995)	761.3	97.5% Chebyshev (MVUE) UCL	1535
95% Modified-t UCL (Johnson-1978)	696	99% Chebyshev (MVUE) UCL	2173
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.686	Data appear Gamma Distributed at 5% Sig Level	
Theta Star	634		
MLE of Mean	434.9		
MLE of Standard Deviation	525.1		
nu star	23.32		
Approximate Chi Square Value (.05)	13.33	Nonparametric Statistics	
Adjusted Level of Significance	0.0346	95% CLT UCL	667.1
Adjusted Chi Square Value	12.54	95% Jackknife UCL	681.3
		95% Standard Bootstrap UCL	664.9
Anderson-Darling Test Statistic	0.386	95% Bootstrap-t UCL	917.9
Anderson-Darling 5% Critical Value	0.775	95% Hall's Bootstrap UCL	1609
Kolmogorov-Smirnov Test Statistic	0.139	95% Percentile Bootstrap UCL	676
Kolmogorov-Smirnov 5% Critical Value	0.217	95% BCA Bootstrap UCL	786.9
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1050
		97.5% Chebyshev(Mean, Sd) UCL	1316
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1840
95% Approximate Gamma UCL	760.6		
95% Adjusted Gamma UCL	808.4		
Potential UCL to Use		**Use 95% Approximate Gamma UCL**	**760.6**

MANGANESE (mg/kg)

General Statistics			
Number of Valid Observations	17	Number of Distinct Observations	17
Raw Statistics		Log-transformed Statistics	
Minimum	53.5	Minimum of Log Data	3.98
Maximum	3130	Maximum of Log Data	8.049
Mean	701.6	Mean of log Data	6.223
Median	590	SD of log Data	0.908
SD	677.3		
Coefficient of Variation	0.965		
Skewness	3.146		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.614	Shapiro Wilk Test Statistic	0.842
Shapiro Wilk Critical Value	0.892	Shapiro Wilk Critical Value	0.892
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	988.4	95% H-UCL	1354
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1510
95% Adjusted-CLT UCL (Chen-1995)	1106	97.5% Chebyshev (MVUE) UCL	1844
95% Modified-t UCL (Johnson-1978)	1009	99% Chebyshev (MVUE) UCL	2500
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	1.406	Data do not follow a Discernable Distribution (0.05)	
Theta Star	499.1		
MLE of Mean	701.6		
MLE of Standard Deviation	591.7		
nu star	47.79		
Approximate Chi Square Value (.05)	32.93	Nonparametric Statistics	
Adjusted Level of Significance	0.0346	95% CLT UCL	971.8
Adjusted Chi Square Value	31.63	95% Jackknife UCL	988.4
		95% Standard Bootstrap UCL	958.7
Anderson-Darling Test Statistic	1.161	95% Bootstrap-t UCL	1365
Anderson-Darling 5% Critical Value	0.754	95% Hall's Bootstrap UCL	2302
Kolmogorov-Smirnov Test Statistic	0.252	95% Percentile Bootstrap UCL	999.8
Kolmogorov-Smirnov 5% Critical Value	0.213	95% BCA Bootstrap UCL	1174
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1418
		97.5% Chebyshev(Mean, Sd) UCL	1727
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2336
95% Approximate Gamma UCL	1018		
95% Adjusted Gamma UCL	1060		
Potential UCL to Use		**Use 95% Chebyshev (Mean, Sd) UCL**	**1418**

Appendix E

Derivation of Particulate Emission Factor for ATV Riding

Appendix E
Derivation of Particulate Emission Factor for ATV Riding

Activity based air sampling (ABS) using ATVs was conducted along segments of CR-503 near the Commodore Waste Rock Pile to determine exposure point concentrations of dust inhalation. Three air samples were analyzed for arsenic, cadmium, manganese, lead, and zinc. The area covered during the ATV riding included segments of CR-503 both within and outside of the Site boundaries.

Limitations with the air data include the following:

- Arsenic and cadmium were not detected in any of the three samples but due to unexpectedly high detection limits, the presence of these chemicals in air is uncertain.

- Chromium was identified as a chemical of potential concern (COPC) in soil at the site but was not included in the air sampling analysis.

To assess inhalation impacts of COPCs not detected and/or not included in the ABS analyses, a particulate emission factor (PEF) was estimated for ATV riding on CR-503. As discussed in Section 4.2.3.1 of the HHRA, soil sampling of CR-503 indicates the composition of metals in the road base is fairly consistent across the road segment included in the air sampling. Thus, a single PEF was estimated for use in calculating inhalation of soil particles during ATV riding on CR-503.

A particulate emission factor (PEF) relates the concentration of a contaminant in soil to the concentration of dust particles in the air. Data from the soil and air samples collected from CR-503 within the area traversed by the ATVs during the activity based air sampling are summarized in Table 1.

Table 1
Soil and Air Sampling Data from CR-503

	Soil Samples (mg/kg)			**Air Samples (ug/L)**		
	Min	Max	UCL95	93853-ATV	92721-ATV	92257-ATV
Lead	28.2	2,380	761	73	188	60.3
Manganese	53.5	3130	1418	44.7	139	67
Zinc	38.7	3290	767	55	163	55.7

With only three air samples, a reliable UCL95 cannot be calculated. As shown in Table 1, detected air concentrations from Sample 92721-ATV are between two and three times higher for each COPC than detected in Samples 93853-ATV and 92257-ATV. Many factors can contribute to this variation including speed, distance from the lead ATV, and wind conditions. In addition, soil disturbance from activities other than ATV riding may have contributed to soil particle re-suspension in air during collection of sample number 92721-ATV. It was noted in the field log that during collection of this sample, two earth graders were leveling the road which caused noticeable fine particulates to be exposed on the surface of the road. Road graders were also operating on the road at the time of the sampling and ten vehicles passed by the ATVs during the sample collection.

Due to this variation, as a reasonable estimate based on available data, the relationship between the UCL95 soil concentration and the minimum detected air concentration within the road segments sampled was used to estimate a plausible PEF.

Where:
Ca = Minimum Concentration in Air (ug/m^3)
Cs = UCL95 Concentration in Surface Soil (mg/kg)
PEF_{ATV} = Particulate emission factor for ATV riding (kg/m^3)
CF = Conversion Factor (mg/ug)

The resultant PEF from each COPC was averaged to arrive at the selected PEF for ATV riding on CR-503 (see Table 2).

Table 2
Estimated PEF for ATV Riding on CR-503

	UCL 95 Soil (mg/kg)	**Minimum Air Detection (ug/L)**	**Estimated PEF (kg/m^3)**
Lead	761	60.3	7.92E-05
Manganese	1418	44.7	3.15E-05
Zinc	767	55	7.17E-05
Average PEF			**6.08E-05**

303 East 17th Avenue
Suite 700
Denver, CO 80203
p. (303) 764 - 1520
f. (303) 860 - 7139

2060 Briargate Parkway
Suite 120
Colorado Springs, CO 80920
p. (719) 272 - 8800
f. (719) 272 - 8801

419 Canyon Blvd.
Suite 316
Fort Collins, CO 80524
p. (970) 419 - 4388
f. (970) 419 - 4389

Remedial Investigation

HDR

Nelson Tunnel/Commodore Waste Rock Pile

November 2011

United States Environmental Protection Agency

"...to protect human health and to safeguard the natural environment..."