Draft Final
Remedial Investigation/Feasibility Study and Proposed Plan
Colorado School of Mines Research Institute Site
Flood Plain Area
Golden, Colorado

November 2011

Prepared for:
Colorado School of Mines
Golden, CO 80401

Prepared by:
S.M. Stoller Corporation
105 Technology Drive, Suite 190
Broomfield, Colorado 80021

Table of Contents

Executive Summary 1

1. Introduction **1-1**
1.1 Regulatory Initiative 1-2
1.2 Purpose of Report 1-2
1.3 Site Description 1-2
1.4 Site History 1-3
1.5 Clay Pits Area History 1-8
1.6 Previous Investigations 1-9
1.7 Report Organization 1-10
1.8 Schedule 1-10

2. Physical Characteristics of Study Area **2-1**
2.1 Surface Features and Utilities 2-1
2.2 Meteorology 2-1
2.2.1 Precipitation 2-1
2.2.2 Temperature 2-2
2.2.3 Wind Direction and Speed 2-2
2.3 Surface-Water Hydrology/Quality 2-3
2.4 Geology 2-3
2.4.1 Bedrock Structure 2-4
2.4.2 Bedrock Stratigraphy 2-5
2.4.3 Geologic Characteristics of the Surficial Deposits / Soils 2-6
2.4.4 Water-Bearing Units 2-8
2.5 Groundwater Hydrology 2-9
2.6 Demography, Land Use, and Water Use 2-11
2.6.1 Demography 2-11
2.6.2 Land Use 2-11
2.6.3 Surface-Water Uses 2-11
2.6.4 Groundwater Uses 2-12
2.6.5 National Historic Preservation Act Considerations 2-12
2.7 Ecology 2-13

3. Study Area Investigations **3-1**
3.1 EPA Removal Action 3-1
3.2 Investigation and Cleanup, Stoller 2007 3-1
3.3 Flood Plain Test Pit Investigation, Stoller 2010 3-2
3.3.1 Extent of COCs 3-2
3.3.2 Study of Site Ambient Uranium Levels 3-3
3.3.3 Geochemical Modeling for Site-Specific Cleanup Level 3-7
3.4 Establishment of Tentative Site Cleanup Goals 3-9
3.5 Flood Plain Soil Investigation 3-11
3.5.1 Site Preparation 3-14
3.5.2 Instrument Bias/Correlation 3-14

3.5.3 Iterative Lateral and Vertical Extent Determination and Excavation 3-15
3.5.4 Confirmation Sampling 3-16
3.6 Air Monitoring 3-17
3.7 Groundwater Investigation 3-18

4. Nature and Extent of Affected Materials 4-1
4.1 Summary of Previous Flood Plain Soil Characterization 4-1
4.2 Applicable Regulatory Classification 4-1
4.3 Flood Plain Site Soil (OU1) Characterization Results 4-1
4.3.1 Structures Encountered during Characterization 4-2
4.3.2 Nature and Extent of Impacted Soil 4-4
4.3.2.1 Metals 4-4
4.3.2.2 Radionuclides 4-8
4.3.2.3 Exceptions to Nature and Extent 4-9
4.3.2.4 Nature and Extent Conclusions 4-10
4.3.2.5 Stockpile Sampling Results 4-10
4.4 Groundwater (OU2) Characterization 4-12

5. Contaminant Fate and Transport 5-1
5.1 Potential Routes of Migration 5-1
5.2 Contaminant Persistence 5-1
5.3 Contaminant Migration 5-1
5.3.1 Material Migration to Groundwater 5-2
5.3.2 Factors Affecting Migration 5-2
5.3.3 Geochemical Modeling of Uranium 5-2

6. Risk Assessment 6-1
6.1 Human Health Evaluation 6-2
6.2 Exposure Assessment 6-2
6.3 Soil Radionuclide Risk Characterization 6-3
6.3.1 RESRAD Model Description 6-4
6.3.2 Microshield Model Description 6-4
6.3.3 Drinking Water Pathway 6-5
6.3.4 Receptor Dose/Risk Assessment 6-6
6.3.5 Results of Radionuclide Assessment 6-7
6.4 Soil Metals Risk and Toxicity Assessment 6-9
6.4.1 Arsenic Assessment 6-10
6.4.2 Lead 6-14
6.4.3 Molybdenum 6-15
6.4.4 Mercury 6-15
6.4.5 Vanadium 6-15
6.5 Risk Assessment Summary 6-16

7. Development and Screening of Alternatives 7-1
7.1 Identification of Remedial Action Objectives (RAOs) 7-3
7.2 Identification of Treatment, Recovery, or Containment Options 7-5

7.2.1 Baseline Risk Assessment Impact on Available Options 7-5
7.2.2 Available Options 7-7
7.2.3 Remaining Action Groups 7-7
7.3 Evaluation of Technologies 7-8
7.4 Generation of Alternatives 7-10
7.4.1 Remedial Action Alternative Screening 7-11
7.4.2 Common Alternative Elements 7-12
7.4.3 Alternatives 1a, 1b and 1c – No Action 7-14
7.4.4 Alternative 2 – Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility 7-15
7.4.5 Alternative 3 – Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository 7-15
7.4.6 Alternative 4 – Onsite Solidification and Placement into an Above-Grade Repository 7-16
7.4.7 Disposal Facility Options 7-17

8. Detailed Analysis of Alternatives 8-1
8.1 Site Disposition ARARs 8-3
8.2 Analysis of Alternatives 8-5
8.2.1 Alternative 1: No Action 8-5
8.2.2 Alternative 2: Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility 8-7
8.2.3 Alternative 3: Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository 8-11
8.2.4 Alternative 4: Onsite Solidification and Placement into an Above-Grade Repository 8-13
8.3 Comparative Analysis of Alternatives 8-16
8.3.1 Protection of Human Health and the Environment 8-17
8.3.2 Compliance with ARARs 8-18
8.3.3 Long-Term Effectiveness and Permanence 8-19
8.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment 8-19
8.3.5 Short-Term Effectiveness 8-20
8.3.6 Implementability 8-21
8.3.7 Cost 8-23
8.3.8 State Acceptance 8-25
8.3.9 Community Acceptance 8-25
8.4 Summary 8-25

9. Remedy Selection 9-1
9.1 Criteria Review 9-1
9.2 Remedy Selection Process 9-1
9.3 Proposed Plan 9-1
9.4 Incorporation of RI/FS and Proposed Plan Comments 9-1
9.5 Final Remedy Selection 9-2
9.6 Record of Decision 9-2

10. References 10-1

List of Tables

Table 3-1 Soil Analytical Results from Flood Plain Test Pits: (Tentative Cleanup Goal Exceedances in Red) 3-4
Table 3-2 Summary of Ambient Soil Sample Results for Alluvium 3-5
Table 3-3 Comparison of Normal and Log Normal Statistics 3-5
Table 3-4 Ambient Alluvial Uranium Normal Descriptive Statistics (mg/kg) 3-6
Table 3-5 Flood Plain Bedrock and Background Bedrock Analytical Results 3-7
Table 3-6 Tentative Site Cleanup Goals and Established Background Levels 3-9
Table 3-7 Effluent Concentration Standards1 3-17
Table 3-8 Air Monitoring Summary CSMRI Creekside Site Characterization October – November 2010 3-18

Table 4-1 Laboratory Metals and Ra-226 Results (mg/kg) of Soil Sample Collected in Concrete Tunnel 4-3
Table 4-2 Laboratory Metals Results Excavated Material 4-5
Table 4-3 Final Metals Confirmatory Sample Results and Summary Statistics 4-7
Table 4-4 Final Radionuclide Confirmatory Sample Results and Summary Statistics 4-9
Table 4-6 Exceptions to Confirmatory Data Set for Extent 4-10
Table 4-7 Stockpile Laboratory Metals Results 4-11
Table 4-8 Stockpile Laboratory TCLP Results 4-11
Table 4-9 Stockpile Laboratory Radionuclide Results 4-12

Table 6-1 Radionuclide Exposure Scenarios 6-3
Table 6-2 Uranium Concentrations in Surface Water Samples Collected on Clear Creek 6-5
Table 6-3 Effective Diffusion Coefficient (De) for Radon in Concrete 6-6
Table 6-4 Stockpile Dimensions 6-7
Table 6-5 Doses and Risks Associated with Radionuclides 6-8
Table 6-6 Summary of Metal Results (mg/kg) Above Action Levels and Background 6-9
Table 6-7 Final Metals Confirmatory Sample Results and Summary Statistics 6-9
Table 6-8 Soil Consumption Arsenic Risk: Gardener/Groundskeeper 6-12
Table 6-9 Soil Consumption Arsenic Risk: Residential 6-13
Table 6-10 Lead Risk Urban Residential (Child) 6-14
Table 6-11 Cumulative Total Lifetime Risk from Radionuclides and Arsenic 6-16

Table 7-1 Site DCGLs and Cleanup Levels 7-4
Table 7-2 Remedial Action Alternatives 7-11
Table 7-3 Remedial Action Objectives 7-12
Table 7-4 CSMRI Site Disposal Options Summary 7-17

Table 8-1 ARARs for Soils, Groundwater, and Surface Water 8-4
Table 8-2 Dose Predictions under Alternative 2 with Failure of Institutional Controls 8-8

Table 8-3 RESRAD-Predicted Worker Doses for Excavation Activities under Alternative 2 8-9
Table 8-4 Evaluation of Alternatives 8-16
Table 8-5 Factors Associated with Protection of Human Health and the Environment Criteria and ARARs Criteria.. 8-18
Table 8-6 Estimated Schedules 8-21
Table 8-7 Availability of Disposal Facilities 8-23
Table 8-8 Cost Information for Each Alternative 8-23
Table 8-9 Cost Information for Each Alternative including Stigma Value (in millions of dollars) 8-24

List of Figures

Figure 1-1 CSMRI Site Location Map Flood Plain Area
Figure 1-2 CSMRI Site Map showing the Flood Plain Area

Figure 2-1 CSMRI Flood Plain Site Map with Topography
Figure 2-2 Meteorological Monitoring Location in Clear Creek Canyon
Figure 2-3 Bedrock Geologic Map of Site
Figure 2-4 Surficial Geologic Map of Site
Figure 2-5 Soil Profile
Figure 2-6 Weimer's Cross Section
Figure 2-7 Groundwater Potentiometric Surface Map –Sept 2010

Figure 3-1 Test Pit Locations and Total Uranium Concentration in Soil (mg/kg)

Figure 4-1 Location of Entrance to Concrete Water Tunnel
Figure 4-2 Final Uranium Confirmatory Sample Results
Figure 4-3 Final Lead Confirmatory Sample Results
Figure 4-4 Final Arsenic Confirmatory Sample Results

Figure 6-1 Flood Plain Characterization Area Showing Locations of Test Pits and Characterization Area Confirmatory Samples.
Figure 6-2 Areas Evaluated in the Current Risk Assessment

List of Appendices

Appendix A Photographs
Appendix B Air Sampling Results
Appendix C Offsite Analytical Laboratory Sample and Data Validation Summary Reports for the Laboratory Data Packages
Appendix D VSP Reports
Appendix E Risk Calculations
Appendix F ARARs
Appendix G Detailed Cost Estimates
Appendix H Property Values
Appendix I Proposed Plan

List of Acronyms/Definitions

ALARA	As Low As Reasonably Achievable
ANS	American Nuclear Society
ARAR	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
BFI	Browning-Ferris Industries
bgs	Below Ground Surface
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CEDE	Committed Effective Dose Equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	U.S. Code of Federal Regulations
COC	contaminant of concern
cpm	Counts Per Minute
CSMRI	Colorado School Mines Research Institute (the Site)
CSWP	Characterization Survey Work Plan (URS Corporation)
cy	cubic yard
DCGL	Derived Concentration Guideline Level
DCGLemc	Decision Control Guide Limit, Elevated Measurement Comparison
DCGLw	Wilcox rank-sum
DOE	U.S. Department of Energy
dpm	disintegrations per minute
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
FGS	field gamma scintillator
GPERS-II	Global Positioning Environmental Radiological Surveyor
GPS	Global Positioning System
HEAST	Health Effects Assessment Summary Tables
ICRP	International Commission on Radiological Protection
ISOCS	In-Situ Object Counting System
LOD	level of detection
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	Maximum Contaminant Levels (EPA Drinking Water)
MCLG	Maximum Contaminant Level Goal
mg/kg	milligram per kilogram
mg/L	milligram per liter
MLEP	mass-limit equation procedure
mrem	Millirem – small unit of radiation dose (one thousandth of a rem)
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priority List
NRC	U.S. Nuclear Regulatory Commission
NUREG	U.S. Nuclear Regulatory Commission publication
OU	Operable Unit

pCi/g	pico-Curies per gram
pCi/L	pico-Curies per liter
ppm	part per million
PRP	Potentially Responsible Party
QA/QC	quality assurance/quality control
RA	Remedial Action
RAIS	Risk Assessment Information System
RAO	Remedial Action Objectives
RAOA	Removal Action Options Analysis
RCRA	Resource Conservation and Recovery Act
RESRAD	Pathway analysis computer code developed for implementing U.S. Department of Energy Residual Radioactive Material Guidelines.
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPD	relative percent difference
RSICC	Radiation Safety Information Computational Center
SSL	soil screening level
SWPE	soil/water partition equation
TCLP	Toxicity Characteristic Leaching Procedure
TEDE	Total Effective Dose Equivalent
UAO	Unilateral Administrative Order (from EPA)
UCL	Upper Confidence Limit
µg/L	microgram per liter
US	United States
USACE	U.S. Army Corps of Engineers
VSP	Visual Sampling Plan
WL	Working Level: Any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3 x 105 MeV of potential alpha energy.
XRF	x-ray fluorescence
yr	year

Table of Contents for Section 1

Executive Summary 1
1. Introduction 1-1
  1.1 Regulatory Initiative 1-2
  1.2 Purpose of Report 1-2
  1.3 Site Description 1-2
  1.4 Site History 1-3
  1.5 Clay Pits Area History 1-8
  1.6 Previous Investigations 1-9
  1.7 Report Organization 1-10
  1.8 Schedule 1-10

List of Figures

Figure 1-1 CSMRI Site Location Map Flood Plain Area

Figure 1-2 CSMRI Site Map showing the Flood Plain Area

Executive Summary

This Remedial Investigation and Feasibility Study (RI/FS) addresses soil in the former pond area at the Colorado School of Mines Research Institute (CSMRI) Site. The Site has recently been separated into two operable units (one for soil and one for groundwater) for the following reasons: (1) contaminated soil has been excavated from the pond area and temporarily stockpiled on the upper terrace for final disposition, (2) the soil stockpile is ready for final disposition, and (3) contaminated groundwater needs to be monitored for two years before further decisions about the groundwater may be made. Operable Unit 1 (OU1) is the soil in the former pond area, including the soil stockpiled on the upper terrace, and Operable Unit 2 (OU2) is the contaminated groundwater beneath the Site. OU2 will be addressed in a separate RI/FS at a later date. Separation into two operable units allows for the soil to be disposed of now without waiting for the completion of the two-year monitoring period.

To date, buildings, foundations, and infrastructure have been demolished and taken offsite, and the upper terrace soil along with some flood plain soil have been remediated at the Site. Additionally, the Clay Pits Area, the former U.S. Environmental Protection Agency (EPA) stockpile location, and the upper terrace have been investigated and cleaned up if necessary.

After the upper terrace soil was remediated in 2007, groundwater was monitored for two years. Groundwater monitoring results showed an isolated dissolved uranium groundwater plume located beneath the lower terrace where the former pond was located. This pond area had been the subject of an EPA removal action between 1992 and 1997. The EPA cleanup of the former pond was based on Ra-226 in soils, not uranium; and the cleanup standard for Ra-226 was higher in 1992 than the cleanup standard for Ra-226 used for the upper terrace area in 2007. The eastern pond area had been subject to ongoing groundwater monitoring. New wells installed in the western pond area showed the uranium contamination was significantly more extensive then previously demonstrated by the eastern wells.

The Colorado Department of Public Health and Environment (CDPHE) radiation control unit requested an investigation and cleanup plan to address the groundwater contamination. Stoller, on behalf of Colorado School of Mines (School), prepared a work plan to characterize, in two phases, the contaminants located on the flood plain acting as source material for the groundwater plume. The first phase, which was a preliminary characterization effort, yielded the following information:

- Uranium concentrations in soil were pervasive across the flood plain. The majority of test pits in the flood plain area had uranium concentrations at less than twice ambient levels with the exception of the west end where concentrations were higher.
- Dissolved uranium in groundwater at concentrations above State groundwater standards was present across the Site in decreasing concentrations toward the east. Coupled with other Site data, this indicated the likely contaminant source for groundwater existed in the vicinity of western well CSMRI-8 where the higher uranium soil concentrations were identified and artificial fill was observed in test pits. Essentially all dissolved uranium

occurs as highly soluble U^{+6} in the form of a carbonate complex, and the Site-specific partitioning coefficient for uranium was very low (less than 0.2 L/kg).

- Geochemical modeling concluded very little soil adsorption of uranium occurs across the Site, and the shape of the uranium plume appears to be affected by upper terrace groundwater flow and water from Clear Creek.
- The ambient concentration of uranium in soils is 6.45 mg/kg (mean plus 2 standard deviations), elevated from background by historic mining activities along the entire upgradient area of the Clear Creek drainage system.
- Geochemical modeling showed that ambient uranium in soil could result in groundwater uranium concentrations as high as 400 micrograms per liter (µg/L) (parts per billion [ppb]) based on the Site-specific partitioning coefficient. However, this was determined using an EPA test method considered to be very aggressive and provides a partitioning coefficient that can be considered to be a conservative value for the Site. The actual concentration of uranium in groundwater, as caused by ambient uranium soil concentrations, is expected to be less than 400 ppb.
- One test pit (CLT-1) showed contaminants of concern other than uranium exceed tentative cleanup goals.

These data from the first phase of the investigation were used to refine the draft investigation work plan into final form for the second phase investigation. The *Final Work Plan Environmental Assessment and Characterization, Colorado School of Mines Research Institute Site, Flood Plain Area* (Stoller 2010a) presents an assessment and characterization plan for the flood plain that is similar to the approach used successfully on the main, upper terrace portion of the Site, as well as for the previous EPA removal action for the former settling pond in the flood plain area. The characterization work plan was based on interpretation and analysis of aerial photographs, existing groundwater chemical data, existing groundwater physical data, Site operational information, professional environmental engineering judgment, past assessment efforts at this Site, and historical document review. The plan proposed characterizing areas of the flood plain thought to be the most likely to contain significant sources of contamination resulting from CSMRI activities, primarily the west end of the former pond area.

The plan for the second phase of investigation was implemented at the end of September 2010. It delineated elevated uranium concentrations in soil suspected to be the sources of contamination, especially the uranium plume contamination, through excavation, sampling, and analysis. The characterization effort began near well CSMRI-8, an area known to contain CSMRI process contaminant fill material, and continued until clean areas were reached.

A total 1,400 cubic yards of excavated soil were transported and stockpiled on a lined staging area just above the lower terrace in an upper terrace area prepared for future use as a parking lot. The stockpile is periodically inspected and maintained as needed until final remedy selection and implementation. The stockpiled soil was sampled and analyzed for constituents affecting remedy selection.

Characterization work yielded the following information about the Site:

- The volume of contaminated soil excavated from the flood plain is approximately 1,400 cubic yards.
- Three contaminants of concern were detected in the excavated and stockpiled soils at mean concentrations above their tentative cleanup goals. These are Ra-226 (20.56 pCi/g), uranium (15 mg/kg), and lead (411 mg/kg).
- The contaminants identified in the flood plain soil include uranium, arsenic, lead, mercury, vanadium, radium-226, thorium-230, uranium-234, uranium-235, and uranium-238.
- The flood plain contained artificial fill.
- Sampling of soil and bedrock after soil excavation shows that the remaining soil and bedrock materials are not apparent sources of contamination of groundwater or soil.
- The nature and extent of soil contamination in the flood plain area has been characterized.
- Groundwater will need to be monitored for two years to determine if additional response action is necessary for the groundwater (five quarters remain as of the date of this publication).
- Data confirmed the action was warranted.

The findings from the site characterization were used as the basis for development of the Feasibility Study (FS). The FS develops, screens, and evaluates alternatives for remedial actions. These remedial action alternatives will be evaluated by decision makers and aid in the selection of the appropriate remedy. The primary requirement of the selected alternative is to be protective of human health and the environment by eliminating, reducing, and/or controlling risks posed through each Site pathway.

The FS screened five remedial action alternatives:

1. No action
2. Ship stockpiled soil to an offsite commercial waste disposal facility
3. Leave stockpiled material onsite and build a below-grade repository
4. Onsite solidification and placement into an above-grade repository
5. Use stockpile as subgrade material for planned asphalt parking lot

The screening process eliminates those alternatives that do not meet the primary requirement of protecting human health and the environment. Alternatives meeting the primary requirement underwent a more detailed analysis including evaluation of regulatory compliance, protectiveness of human health and environment, reduction of toxicity, short and long-term effectiveness, implementability, State and community acceptance, and cost. The conclusion of the FS selected Alternative 2 (transporting the stockpiled soil to an offsite commercial waste disposal facility) as the preferred remedy.

The CSMRI Site Proposed Plan for Alternative 2 is included as an appendix to this document and includes information about the public comment period, the upcoming public meeting, and the location of the administrative record.

1. Introduction

The S.M. Stoller Corporation (Stoller) prepared and implemented a characterization work plan on behalf of the Colorado School of Mines (School) on the flood plain of the Colorado School of Mines Research Institute (CSMRI) Site in Golden, Colorado (Site). The characterization activities included investigating the nature and extent of soil contamination, including contamination that may be acting as a source for the groundwater uranium plume, and further characterizing the groundwater system and uranium concentrations.

Characterization work on the Soils Operable Unit (OU 1) is complete and is the subject of this Remedial Investigation / Feasibility Study (RI/FS) report. Characterization work on the Groundwater OU is ongoing and will require monitoring, including sampling and analysis, during 2011 and perhaps 2012 before sufficient data are collected to determine the nature and extent of impacts and next steps for the groundwater. For this reason, the Groundwater OU2 is not part of this Soils OU RI/FS report but will be addressed in a future RI/FS report.

This RI/FS presents the soil results of the characterization work plan and evaluates remedial options for impacted soil characterized on the Site. The work plan is the controlling work document for assessment and characterization of the flood plain portion of the Site and was used to determine the nature and extent of contamination for all contaminants of concern (COCs), including the sources, cause, nature, and extent of the elevated concentrations of uranium in the groundwater above the groundwater standard of 30 micrograms per liter (µg/L) uranium. The work plan divided the investigation work into two phases. The first phase was a series of test pits excavations, laboratory analysis, and some modeling work. The results of the first phase supported the need to excavate source material impacting groundwater. The second phase was additional excavation to more accurately delineate the nature and extent of soil contamination.

The original investigation work plan was modified based upon comments received from CDPHE and Site potentially responsible parties (PRPs) and the results and analysis of data from first phase preliminary flood plain characterization work completed in June 2010. The second phase work was implemented in the fall of 2010 following CDPHE approval.

The objective of the investigation was to assess and characterize the nature and extent of contamination of COCs in the flood plain area, including the uranium-bearing material that is causing uranium groundwater contamination. Uranium-bearing material believed to be the source of the groundwater contamination, and material containing other COCs at concentrations above the tentative cleanup goals, were identified and excavated from the flood plain area. Excavated soils totaling 1,400 cubic yards were stockpiled nearby on the upper terrace and were characterized to determine the nature and extent of contamination, as well as to develop information necessary to progress the project toward remedial alternative selection and implementation. Groundwater is continuing to be monitored to determine the post-soil-characterization groundwater quality.

The characterization effort resulted in the collection of information necessary to continue progress toward proper management of adverse risk to public health and the environment at the Site. Short-term plans for the Site include construction of an asphalt parking lot and ticket booth on the upper terrace near the north side of the new soccer field. The City of Golden is currently in the final planning stages to extend the pedestrian/bike trail along the upper terrace to connect to portions of the trail system already in use. These construction projects are located near the area where soil excavated during the characterization is currently stockpiled. Plans for the long-term beneficial reuse of the Site have not been determined by the School at this time but it is reasonably foreseeable that future uses may include development of campus buildings, including housing, to address the anticipated continuing growth and changing needs of the School. Some discussion at the School about these types of potential uses has already occurred. The nature and extent of Site COCs in soil was determined during the characterization, as was some historical information, both of which are presented in this RI/FS.

1.1 Regulatory Initiative

This document describes the current RI/FS work for soil in the flood plain portion of the Site (Figure 1-1). The area of investigation includes portions of the formerly Fenced Area known as the flood plain. The terms “pond area,” “flood plain,” and the “lower terrace” are used interchangeably throughout this RI/FS. This RI/FS is being prepared in advance of the remedial action proposed to be conducted by the School in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 USC §§ 9601-9675, as amended (CERCLA), and the National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR 300 (NCP). This RI/FS includes a “proposed plan” that proposes a remedy for the soil portion of the lower terrace investigation area and explains the factual and legal basis for selecting the former pond soil remedy at the Site, including the stockpiled soil. Groundwater will be addressed separately in a subsequent RI/FS for that operable unit.

1.2 Purpose of Report

The purpose of this report is to:

- Describe the remedial investigations and current nature and extent of potentially affected surface and subsurface soil remaining at the Site (Sections 3 and 4),
- Quantify the current and future risk to human health and the environment (Sections 5 and 6) resulting from these materials,
- Identify and evaluate remedial action alternatives that are feasible for application at the Site (Sections 7 and 8), and
- Propose a remedial action alternative for implementation (Section 9).

Data collected during the recent RI, in conjunction with existing data from the prior RIs, were used to accomplish each of these objectives.

1.3 Site Description

The Site is located in Jefferson County, Colorado, on the south side of Clear Creek, east of U.S. Highway 6, in the northwest quarter of the northeast quarter of Section 33, Township 3 South, Range 70 West as shown in Figure 1-1. The main entrance to the Site is located at the western end of 11th Street in Golden, Colorado. A chain-link fence restricts access to the Site. A settling pond was previously located on the flood plain within the perimeter fence and within the bounds of this investigation (Figure 1-2). Starting in 1992, the U.S. Environmental Protection Agency

(EPA) cleaned up the pond as part of an Emergency Removal Action under CERCLA. The pond area was considered closed until impacted groundwater in the flood plain was recently discovered as part of the School's ongoing groundwater quality monitoring program.

The flood plain portion of the Site covers an area of about two acres and is shown in Figure 1-2. In accordance with CERCLA and the NCP, 40 Code of Federal Regulations (CFR) Parts 300.5 and 300.400(e), the term "on-site" refers to the areal extent of contamination and all suitable areas in proximity to the contamination. Consequently, the Site boundary may be modified or expanded to address the needs of the remedial action alternatives.

The CSMRI Site has historically included several now-closed areas also shown on Figure 1-2, including the EPA soil stockpile (material excavated from the settling pond) formerly located near the School's softball field, the upper terrace now containing the new soccer field, and the Clay Pits Area located south of the intersection of Birch and 12th Streets. For use in this document only, the Site is defined as the currently Fenced Area (including the former settling pond area) and portions of the Clear Creek flood plain. The 2007 RI/FS had excluded the pond area from the definition of the Site because it was believed to have been cleaned up by EPA.

1.4 Site History

Numerous mineral research projects (some of which involved the mineral extraction and beneficiation of materials that contained levels of radionuclides above background) were conducted at the CSMRI Site from 1912 until approximately 1987. The research projects were conducted in 17 buildings on the CSMRI Site that were subsequently razed in the mid-1990s. An impoundment (settling pond) also was situated between the building complex and Clear Creek to store wastewater generated in the laboratories and research facilities. Wastewater discharged from the buildings was transferred to and treated in the settling pond through a system of sumps and floor drains in the buildings.

On January 25, 1992, a water main owned by the City of Golden broke on the Site and began discharging a large volume of water into the settling pond. EPA's Emergency Response Branch responded in February 1992 and performed the following activities to stabilize conditions at the Site:

- excavation of the contaminated sediments and soil,
- stockpiling of the material (the stockpile),
- decontamination of building drains,
- demolition and removal of several buildings,
- consolidation of existing drums and disposal of compressed gas cylinders,
- sampling of sediments and water,
- closure of the settling pond, and
- pond area restoration and revegetation.

EPA subsequently contacted many of the entities that had sent materials to the Site and requested that the stockpile be removed from the Site. This culminated in the issuance of a Unilateral Administrative Order (UAO) on December 22, 1994, to certain entities (the respondents). Among other things, the UAO required the respondents to develop and evaluate disposal options for the stockpile (approximately 20,000 cubic yards) and ultimately implement the selected disposal alternative. Some of the respondents prepared a Removal Action Options Analysis (RAOA) report that was issued on June 12, 1995. The RAOA report identified and evaluated various disposal options for the stockpile. The State of Colorado through the Colorado School of Mines was the only respondent that subsequently implemented the preferred disposal option. The EPA removal action was completed in 1997.

The School hired AWS Remediation to raze the remaining research buildings from the Site in the mid-1990s. Following demolition of the buildings, the existing pits and basements were backfilled to grade; building foundations and concrete footers were left in place.

A Characterization Survey Work Plan (CSWP) was prepared by URS Corporation on July 23, 2001. The purpose of the CSWP was to guide field investigation activities to supplement existing data and evaluate the risks associated with the release of residual metals and radioactive materials found in soils within the Fenced Area and the Clay Pits Area. URS completed the characterization of the concrete and asphalt slabs and issued two draft final reports on February 11, 2002 and May 18, 2002, respectively.

The demolition of the remaining concrete and asphalt materials was an integral part of the Site characterization process. In April 2002, the School hired New Horizons Environmental Consultants, Inc. (New Horizons) to demolish the remaining concrete and asphalt slabs and to characterize surface and subsurface soils on the Site. New Horizons prepared a comprehensive set of work plans, which guided the characterization activities that were conducted at the Site.

During November and December 2002, all remaining concrete and asphalt were excavated and either transported as demolition debris to BFI's Foothills Landfill in Golden, Colorado (a permitted Subtitle D solid waste facility), or transported to Recycled Materials, Inc.'s plant in Arvada, Colorado, for recycling. Detailed documentation regarding the removal of the concrete and asphalt slabs is provided in a report entitled *Concrete and Asphalt Removal and Disposal* (New Horizons 2003a).

During December 2002 and January 2003, New Horizons collected surface and subsurface soil samples, which were analyzed for metals and radionuclides. Quarterly groundwater samples were collected for four quarters beginning in February 2003. The results of the New Horizons' Site investigation activities were presented in the *Remedial Investigation/Feasibility Study and Proposed Plan* (New Horizons 2004).

The 2004 Proposed Plan recommended the excavation and offsite disposal of contaminated soils (Alternative 5). The School then received and considered oral and written public comments on the 2004 Proposed Plan. The public comments supported Alternative 5 as the remedial plan for the Site. The School selected Alternative 5 as the remedial action for the Site and documented the remedy selection in a Record of Decision (ROD), which was signed on March 31, 2004. New Horizons was selected to identify, excavate, and dispose of contaminated soils at the Site. Field work began in April 2004. During the 2004 field work, six areas were excavated, and a seventh area was partially excavated. By May 2004, it was apparent that excavated soil volumes, concentrations, and projected costs exceeded previously estimated volumes, concentrations, and costs. The work needed to return to the investigation phase to correctly delineate the nature and extent of contamination. Field work was halted, and the Site was stabilized. Approximately 1,870 cubic yards of soil had been excavated, bagged, and stored on the Site by New Horizons during the 2004 excavation work. This bagged soil had been initially slated for disposal at the U.S. Ecology RCRA facility in Idaho. The contract with New Horizons was terminated in the fall of 2004.

In December 2004, Stoller was retained by the School to collect representative soil samples from a random subset of the 455 super-sack containers staged at the Site and to generate a legitimate data set to evaluate potential disposal options of the containerized material. The soil in the bags averaged 12.6 picocuries per gram (pCi/g) Ra-226. After negotiations between the School and CDPHE, CDPHE agreed to consider a risk assessment, which demonstrated that the Foothills Landfill in Jefferson County could safely manage the bagged soils even though they contained concentrations greater than 3 pCi/g Ra-226 above background, which was CDPHE's previous threshold for waste acceptance into the solid waste landfill. The analytical and risk assessment results were submitted to CDPHE for review in the April 5, 2005 report, *Dose Assessment for the Emplacement of the CSMRI Site Containerized and Remaining Subsurface Soil into a RCRA Subtitle D Solid Waste Landfill* (Stoller 2005a). After review of the dose assessment report, the CDPHE approved shipment of the bagged soils to the Foothills solid waste landfill in a letter dated August 26, 2005. At CDPHE's request, the dose assessment included a hypothetical scenario of 30,000 cubic yards of soil similar to the soil contained in the bags. This scenario reflected possible further soil excavation at the Site and prevented the need for having to perform a second dose assessment if soils were excavated that were similar to the soils in the bags. CDPHE also approved this hypothetical scenario.

In May 2005, the School contracted Stoller to examine further Site investigation alternatives to move the project toward completion while maintaining the CERCLA framework.

In October 2005, Stoller obtained CDPHE approval and a Colorado Department of Transportation (CDOT) permit (Permit Request number 605167) to transport the bagged soil offsite via an access lane on Colorado Highway 6 to BFI Foothills Landfill. Physical construction of this access was completed by New Horizons in 2004 under CDOT Access Permit No. 603100.

All bagged soils from the Site were shipped to BFI Foothills Landfill from December 12 through 15, 2005, in accordance with the approved *CSMRI Creekside Site Contaminated Soil Disposal Work Plan* (the Materials Transportation Plan is Appendix A of the work plan) (Stoller 2005c).[1] A total of 112 truck loads containing bagged soil plus two trucks containing other debris from the Site were shipped.

In September 2005, Stoller prepared a Background Evaluation Report for the Site (Stoller 2005b). This report summarized and assessed the results of three previous background studies, two by URS in 2000 and 2002, and one by New Horizons in 2004 (included in the 2004 RI/FS), which attempted to establish background concentrations for metals and radioisotopes. CDPHE

[1] A small amount of bagged soils had been shipped by New Horizons to the U.S. Ecology facility in Idaho during the April and May 2004 field work.

reviewed the Stoller background report and indicated inadequate soil analytical data existed to justify increasing the proposed cleanup standards for the Site. However, the CDPHE agreed to adjust the background level of arsenic to 38 parts per million (ppm), resulting in a tentative Derived Concentration Guideline Level (DCGL) of 39 ppm. Additionally, the CDPHE agreed to use a total mercury standard to guide characterization with some speciated confirmatory data in support. The School determined that pursuing further background studies at that time in response to CDPHE's concerns would not be cost effective and directed Stoller to proceed using tentative cleanup goals approved by CDPHE. However, the School and CDPHE agreed that the School could later demonstrate to CDPHE alternative background conditions for different portions of the Site during field excavation work upon field observations and further data. This was a more cost-effective strategy.

Stoller assisted with designing a strategy to meet the goals of the School while also collecting the necessary site data for nature and extent determination. Multiple meetings with the CDPHE led to the approved *CSMRI Creekside Site Final Site Characterization Work Plan* (Stoller 2006b). This work plan was implemented by Stoller beginning in June 2006. The investigative method selected was to excavate the impacted soil and stockpile it onsite to determine the nature and extent of contamination. This excavation method is analogous to the method used by the EPA to address the former settling pond at the Site. EPA had excavated the former settling pond down to cleanup goals then stockpiled the soil at another location on the Site for further characterization work and disposal purposes. The New Horizons' baseline risk assessment in the 2004 RI/FS had already demonstrated that some proactive remedial action was necessary at the Site for the remaining contaminated soils. Because New Horizons was discovering during filed work volumes and concentrations greater than those used in the baseline risk assessment, it was clear that the no-action alternative would not be a viable alternative. The excavation and segregation investigative method used by Stoller resulted in contaminated soil above the tentative cleanup goals being segregated in two soil stockpiles onsite, with the remainder of the main site (upper terrace) meeting the tentative Site cleanup goals. The lower terrace, including the west end of the flood plain but excluding the location of the former settling pond that was closed by EPA, has been characterized, and a small volume of contaminated soils exceeding the tentative Site cleanup goals was excavated and managed in the onsite stockpiles in spring 2007.

The results of Stoller's soil excavation and segregation investigation further demonstrated the reasonableness and necessity of halting the 2004 remedial work by New Horizons. Stockpile B consisted of approximately 12,500 cubic yards with an average of 13.55 pCi/g Ra-226. Under the 2004 RI/FS and 2004 ROD, all of this soil, plus the 1,800 cubic yards of bagged soil, would have been shipped and disposed of at the U.S. Ecology facility in Idaho at a cost of $9,689,823. In addition, the excavation and segregation investigation created approximately 200 cubic yards in Stockpile A, which averages 84.75 pCi/g Ra-226. This material would have cost $135,522 to dispose of in Idaho under the 2004 RI/FS and 2004 ROD. New Horizons had estimated the cost of implementing Alternative B to be only $1,540,712.86. Under the 2004 RI/FS and 2004 ROD, none of the contaminated soil would have been shipped and disposed at the Foothills Landfill, even though 9,500 yards had been estimated to go to the Foothills Landfill. Thus, if New Horizons had continued its field work, there would have been a cost overrun of $8,284,632, or 538 percent above the expected costs under New Horizons' contract to implement the remedy. In addition, the volumes that would have been excavated by New Horizons would have been significantly greater than that estimated by New Horizons in the 2004 RI/FS, because the arsenic background level was changed for the Revised RI/FS (Stoller 2007a) to reflect an accurate arsenic background level. While the 2006 investigation resulted in a similar volume of impacted soil as that estimated in the 2004 RI/FS, the field methods used in the 2004 remedial action would have yielded a much larger volume of impacted material subject to disposal.

On the basis of New Horizons' inability to fully delineate the nature and extent of contaminants at the Site using the traditional approach of collecting soil samples from numerous boreholes, it was determined that the standard characterization approach would not succeed in identifying many areas onsite where contaminants were present. This is due to the heterogeneous distribution of contaminants, and their lack of lateral continuity as a result of the historical practice of dumping small quantities of raw and beneficiated materials from research activities over the large footprint of the Site. Simply stated, the accepted approach of drilling boreholes on a grid was impracticable, due to the likelihood of borings failing to locate these isolated piles of impacted material. To delineate nature and extent, understand the volume of impacted material, and develop cost for remedial alternatives, Stoller selected the investigative method of excavating the impacted soil in 1-foot vertical lifts and stockpile it onsite.

Work control documents were prepared and approved by the CDPHE that detailed the RI and associated cleanup targets. The plans were implemented in the summer and fall of 2006. Segregated impacted soils were managed in two stockpiles—stockpile A and stockpile B. Stockpile A managed the more highly impacted material. Following soil segregation, a RI/FS document was produced that identified offsite disposal as the most appropriate alternative. Following a public meeting and comment period, a ROD was produced containing the offsite disposal option.

Implementation of the selected alternative was completed in August and September 2007. Eleven trucks filled with soil from Stockpile A were shipped to Clean Harbor's Deer Trail facility in eastern Colorado. Stockpile B soil was shipped to the Allied Waste BFI Foothills Landfill. This shipment included 615 trucks filled with soil and nine trucks filled with site debris. Details of this remediation are presented in a report titled *Remedial Action Implementation Report, Colorado School of Mines Research Institute, Golden, CO* (Stoller 2009).

Following receipt of the implementation report, the CDPHE issued a letter granting free release of the upper terrace from the radioactive materials license. This release was later rescinded by CDPHE, and the CDPHE required the fence be replaced around the newly constructed soccer field. Following several months of negotiations, the CDPHE again granted release of the soccer field for play and the fence around the soccer field was removed.

Groundwater monitoring following the remediation of upper terrace soil indicated a persistent uranium plume predominantly at the west end of the flood plain area. Further characterization work was requested of the School by CDPHE to better define the source of the groundwater impacts. After a collaborative effort, including a mid-approval work plan revision, a final work control document was submitted to the CDPHE and approved prior to start of work. This report presents the results of that work. The work was performed in two phases.

The first phase of work was performed on June 2 and 3, 2010, when eight test pits were dug on the flood plain and data were collected as part of a preliminary Site characterization. Results of this preliminary investigation confirmed the need to take action and were used to prepare for the second phase of work described herein and address concerns brought forth by the CDPHE and the PRPs. The findings of the preliminary flood plain characterization are described in the *Preliminary Flood Plain Characterization* report, which is Appendix A to the characterization work plan (Stoller 2010a).

1.5 Clay Pits Area History

In the late 1800s, clay was mined from the Clay Pits located west of South Table Mountain, immediately south of Clear Creek in Golden, Colorado. Figure 1-2 shows the location of the Clay Pits. The pits were a series of open trenches that extended from Clear Creek approximately one mile south, almost to the current location of the Jefferson County Courthouse. The clay was mined from between the near vertical sandstone walls of where the Laramie Formation outcrops against the front of the Rocky Mountains. In addition to the clay, coal was also mined from the surface outcrop of the Laramie Formation.

By the mid-1900s, the pits were depleted of clay and remained as open trenches. The pits were soon backfilled with trash and debris, including flood material debris from the 1965 flood of the South Platte River that impacted a significant portion of the lower downtown Denver area (Havelick, personal communication 2006). In May 1973, sediment from the onsite settling pond located on the CSMRI Site was placed in one of the open trenches of the Clay Pits. Over the course of six days, the sludge was buried at an approximate depth of 15 to 20 feet and then covered with crushed ore and earth. This relatively small area, in the context of the entire Clay Pits, is referred to as the Clay Pits Area.

In 1977, the Clay Pits Area where materials dredged from the CSMRI pond had been placed was surveyed by Louis E. Bolis. Mr. Bolis also provided a stamped drawing (Bolis Drawing) of the results of the survey, “Location of Waste Dump, CSM Research Institute.” Correspondence from John Schmerber of CSMRI to Larry Doerr of CDPHE in January 1985 states that approximately 500 cubic yards of dredged pond sediments were buried prior to 1972 in the clay pits located just south of the main entrance to CSMRI and that the burial was conducted between vertical sandstone walls and well above the existing water table. The correspondence goes on to say that… “the activity of the sludge was never determined but it is assumed to be at or near background levels. This statement is supported through previous correspondence submitted to [CDPHE] by Colorado School of Mines. Further, numerous surveys conducted by your department [CDPHE] have not offered any evidence to the contrary.”

The School had previously retained New Horizons and URS to investigate the Clay Pits Area. In 1998, New Horizons prepared the *Conceptual Subsurface Sampling & Analysis Plan, CSMRI Site*. URS implemented the New Horizons’ plan in early 1999 with the drilling of two boreholes. The URS report, *Analytical Results Report, Colorado School of Mines Research Institute Site*, apparently, based on additional information located during file research, did not look for the sediments in the correct location.

Additional study of the Clay Pits Area was conducted by Stoller in 2007. During this investigation, several borings were advanced into the area of suspected waste without encountering any indications of CSMRI waste. The report of findings was submitted to the CDPHE, and the CDPHE concluded that no further action was necessary at the Clay Pits Area.

1.6 Previous Investigations

A number of historical investigations have been completed at both the Fenced Area and the Clay Pits Area. Results from these investigations are included in the following reports:

- Surface Gamma Ray Scanner Survey, U.S. Environmental Protection Agency, 1982
- CSMRI Environmental Assessment, Jacobs Engineering Group Inc., October 1987
- Claypits Report to CDPHE, Robert MacPherson, October 20, 1988
- Preliminary Assessment of Radiological Risks at CSMRI, Creekside, L. Hersloff, Radiant Energy Management, September 1989
- Tailings Pond, CSMRI, Creekside Sampling Report, Industrial Compliance Inc., October 1989
- Preliminary Assessment of the Potential for Water-Borne Migration of Contaminants in the Claypits, J. Kunkel, Advanced Sciences, October 20, 1989
- CSM Environmental Sampling & Analysis Program: Claypits Site & CSMRI Facility, James L. Grant & Associates, August 9, 1990
- Characterization Plan for Claypits & CSMRI Creekside and Table Mountain Research Center Sites, James L. Grant & Associates, March 22, 1991
- Preliminary Remedial Alternative Evaluation for the CSM Creekside Stockpile, SR & K, August 25, 1994
- Removal Action Options Analysis (RAOA), Multiple authors, June 12, 1995 (3 vols.)
- Background Characterization Report, prepared for Colorado School of Mines Environmental Health and Safety, prepared by URS Greiner Woodward Clyde International-Americas, Inc., July 7, 2000
- Colorado School of Mines Research Institute Supplementary Background Characterization draft final report, prepared by URS Corporation, January 28, 2002
- Concrete and Asphalt Characterization Report, URS Corporation, May 18, 2002
- Concrete and Asphalt Removal and Disposal, New Horizons Environmental Consultants, Inc., April 11, 2003
- CSMRI Characterization Summary, New Horizons Environmental Consultants, Inc., August 21, 2003
- Remedial Investigation / Feasibility Study and Proposed Plan, CSMRI Site, New Horizons Environmental Consultants, Inc., January 21, 2004
- CSMRI Creekside Site Bagged Soil Disposal Summary Report, The S.M. Stoller Corporation, February 6, 2006
- CSMRI Creekside Site Final Site Characterization Work Plan, The S.M. Stoller Corporation, May 12, 2006
- Revised Remedial Investigation / Feasibility Study and Proposed Plan, Colorado School of Mines Research Institute Site, The S.M. Stoller Corporation, original RI/FS date: January 21, 2004, revision date: May 2007

- Colorado School of Mines Research Institute Site Record of Decision, The S.M. Stoller Corporation, original ROD date: March 31, 2004, revision date: July 9, 2007
- Remedial Action Implementation Report, CSMRI Site, The S.M. Stoller Corporation, September 2009
- Final Work Plan, Environmental Assessment and Characterization, Colorado School of Mines Research Institute Site Flood Plain Area, Golden, Colorado, The S.M. Stoller Corporation, August 2010

1.7 Report Organization

This RI/FS report addresses the Soil OU for this project and includes the main text, tables, figures, and appendices. Section 1 describes the regulatory setting and Site history. Section 2 broadly portrays the physical characteristics of the Site. Section 3 describes Site investigations pertinent to the RI. Section 4 describes the nature and extent of affected materials. Section 5 describes contaminant fate and transport, and Section 6 assesses the baseline risk to human health and the environment. Section 7 develops and compares the remedial alternatives, and Section 8 presents a detailed analysis of the alternatives. Section 9 describes the selected remedy and proposed plan for Site cleanup completion. The references are presented in Section 10. All figures in this document result from the 2010 investigation except as otherwise noted on the figure.

1.8 Schedule

Depending on the selected alternative, the remedial action is expected to take between one to eighteen months to complete. Estimated schedules for each alternative are located in Section 8.

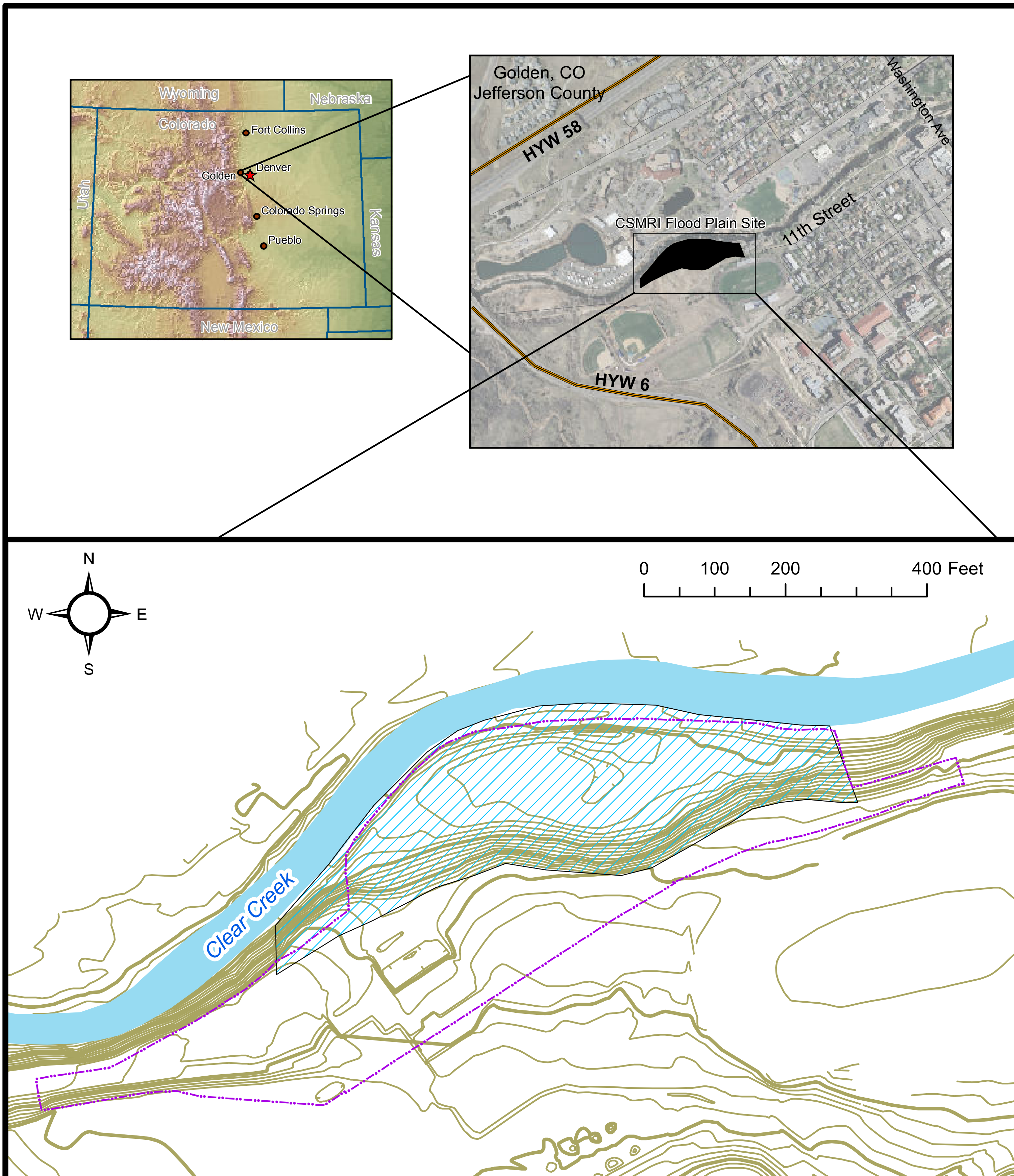


Figure 1-1

CSMRI Site Location Map
Flood Plain Area

Explanation

- CSMRI Flood Plain Site
- Fences
- Topography (2Ft Intervals)
- Topography (10Ft Intervals)

CSMRI
Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

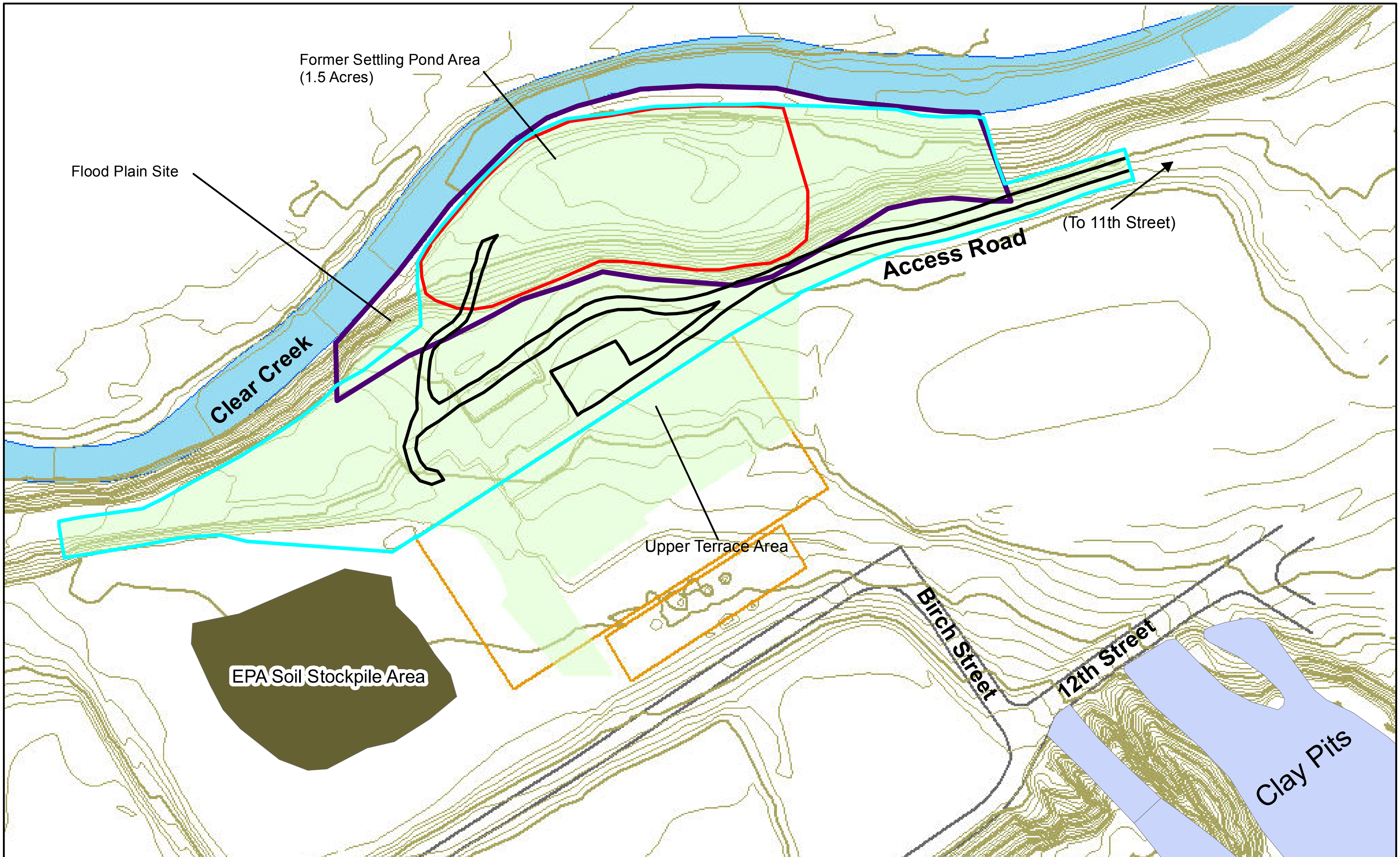


Figure 1-2

CSMRI Site Map
Showing the Flood Plain Area

Explanation

- Fences
- Temporary Access Road
- Greater Clay Pits Mined Area
- EPA Soil Stockpile
- Upper Terrace
- Settling Pond
- CSMRI Flood Plain Site
- SoccerField
- Topography (2Ft Intervals)
- Topography (10Ft Intervals)

N
W E
S

0 65 130 260 Feet

CSMRI
Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\rifs_site_map_temp.mxd PLD @ 11/7/11

Table of Contents for Section 2

2. Physical Characteristics of Study Area 2-1
- 2.1 Surface Features and Utilities 2-1
- 2.2 Meteorology 2-1
  - 2.2.1 Precipitation 2-1
  - 2.2.2 Temperature 2-2
  - 2.2.3 Wind Direction and Speed 2-2
- 2.3 Surface-Water Hydrology/Quality 2-3
- 2.4 Geology 2-3
  - 2.4.1 Bedrock Structure 2-4
  - 2.4.2 Bedrock Stratigraphy 2-5
  - 2.4.3 Geologic Characteristics of the Surficial Deposits / Soils 2-6
  - 2.4.4 Water-Bearing Units 2-8
- 2.5 Groundwater Hydrology 2-9
- 2.6 Demography, Land Use, and Water Use 2-11
  - 2.6.1 Demography 2-11
  - 2.6.2 Land Use 2-11
  - 2.6.3 Surface-Water Uses 2-11
  - 2.6.4 Groundwater Uses 2-12
  - 2.6.5 National Historic Preservation Act Considerations 2-12
- 2.7 Ecology 2-13

List of Figures

Figure 2-1 CSMRI Flood Plain Site Map with Topography
Figure 2-2 Meteorological Monitoring Location in Clear Creek Canyon
Figure 2-3 Bedrock Geologic Map of Site
Figure 2-4 Surficial Geologic Map of Site
Figure 2-5 Soil Profile
Figure 2-6 Weimer’s Cross Section
Figure 2-7 Groundwater Potentiometric Surface Map –Sept 2010

2. Physical Characteristics of Study Area

This section of the RI/FS summarizes the physical properties of the flood plain site. Features discussed either have the potential to impact or have impacted Site activities. The impact to Site activities, as well as controls used to mitigate the impact, are also discussed when appropriate.

2.1 Surface Features and Utilities

In general, the Site slopes gently to the north with a major elevation break above the former settling pond (Figure 2-1). Following the 2007 characterization and subsequent excavation, the School was granted free release of the upper terrace from the radiological materials license, and a new soccer field was constructed on the upper terrace. Grading to accommodate an access road and parking lot was completed on the upper terrace along the top of the slope that drops down to the active flood plain of Clear Creek. This access road was used for this investigation and will likely be used during the remedial alternative implementation. The graded parking area was used to stage the job trailer and lined soil stockpile as shown on Figure 2-1.

Three City of Golden water lines traverse the area suspected to contain source material for the groundwater plume. These utilities were located accurately by the City and were visually located using a water/vacuum system prior to adjacent excavation by heavy equipment. During soil characterization activities, caution was used whenever the work was in close proximity to the utilities. As the utility was approached, the data were scrutinized to determine if soil characterization immediately around or under the utility was absolutely necessary.

The current characterization work covered the entire area of the former settling pond; however, it focused on that portion of the flood plain containing the west end of the former settling pond. This area consists of an essentially level terrace of Clear Creek, which pinches out to the west into a meander scarp with a steep slope up to the upper terrace.

2.2 Meteorology

Information for the local meteorology, gathered by the previous consultant, was obtained from a number of sources. Local weather observation stations in the vicinity of the Site include a National Oceanic and Atmospheric Administration (NOAA)-maintained weather station (precipitation) located about 3.5 miles south of the Site (operational record 1975 to present). The RAOA referenced information weather stations in Wheat Ridge (operational record 1981 through 1988), Lakewood Station (operational record 1962 to 2000), and Golden (operational record 1989 to 1995). Average temperatures and precipitation for the area are available from websites such as http://www.weather.com. The RAOA referenced an anemometer that operated during a period from May 1979 to March 1980. The meter was located about 4,000 feet west of the Site in Clear Creek Canyon (Figure 2-2). Wind speeds at the anemometer location are biased by the canyon but provide directional information relevant to the Site.

2.2.1 Precipitation

Average annual precipitation listed for the Golden area is about 17.1 inches (www.weather.com) but varies significantly along the Front Range. The NOAA weather station located to the south indicates a precipitation average of 13.4 inches (maximum 18.7 inches, minimum 7.5 inches) over 27 years. For the Front Range area, about 70 percent of the total annual precipitation occurs between April and September due to upslope conditions and thunderstorm activity. The greatest amounts of precipitation typically occur in April, May, and June when the average monthly totals exceed two inches. Precipitation minimums occur in December, January, and February when the average monthly precipitation is generally less than one inch. Front Range evaporation potential exceeds the annual total precipitation. Typical total annual pan-evaporation is about 60 inches, and total annual lake evaporation averages about 41 inches. Approximately 71 percent of the evaporation occurs between May and October.

2.2.2 Temperature

The average annual temperature is about 47.3 degrees Fahrenheit (°F). The highest average monthly temperatures typically occur in July and August and range between 68°F to 70°F. In December and January, the lowest average monthly temperatures are generally observed and range between 28°F to 29°F. Area temperatures can range from –26°F to 104°F.

2.2.3 Wind Direction and Speed

Average wind speed information collected from the three weather stations varied little from month to month. The data indicate, however, that maximum winds and wind gusts are higher in the winter than in the summer. Increased wind speeds in the winter are probably due to the passage of storm fronts causing strong downslope conditions. Average annual wind speed in the Denver area is about 9 miles per hour. However, wind speeds are often higher along the foothills near the Site (no Site-specific data were located).

Basically, two major meteorological conditions determine the direction of air movements in the Golden area: synoptic flows and local flows. Synoptic flows are wind patterns that affect areas on the order of several thousands of square miles that are characterized by meteorological systems on the scale of high and low pressure systems as shown on weather maps. In the absence of a dominant synoptic flow, local flows become the prevalent factor in the air movement. These winds typically follow the topography of an area with air flows draining from higher elevations toward the lower elevations.

The Site area is in a unique location relative to wind direction that is best represented by the wind direction information from the meteorological monitoring location shown in Figure 2-2. The wind direction information from that location was evaluated and a wind rose developed for that data (Figure 2-2). Wind data are an incomplete data set collected from May 1979 to March 1980 and were used as part of the RAOA evaluation. The wind rose in Figure 2-2 shows the percentage of time that the wind blew from each of the 16 wind directions monitored. The wind was calm for only about 1.4 percent of the time during the measurement period. Based on a review of Figure 2-2 and area weather data, the predominant wind direction is from the west to east and reflective of drainage flows that are common along the Front Range. On an annual basis, the wind blows from the west approximately 60 percent of the time and from the east approximately 35 percent of the time with minor excursions from the north and south. Midday warming of the plains can generate east to southeast winds, creating an upslope flow along the Front Range. During the night, the cooler air flows down the mountainside across Golden and into the Denver Basin to the east. The night-time flows can start early in the evening and persist into the midmorning and early afternoon.

2.3 Surface-Water Hydrology/Quality

The Site is located immediately south of Clear Creek, the primary surface-water conveyance in the area. Clear Creek is a perennial tributary of the South Platte River with a drainage basin area above the Site of approximately 400 square miles. The headwaters of Clear Creek are located along the Continental Divide near Loveland Basin Ski Area. From the headwaters, the stream drops over 8,000 feet in about 50 miles, passing through steep canyons on its way to the Golden area. East of Golden, Clear Creek flows through the plains for about 14 miles to its confluence with the South Platte River in Denver, Colorado.

Gingery and Associates, Inc. (1979) developed discharge information for flood analysis of Clear Creek. Peak flows calculated for the reach of Clear Creek up to the western edge of the City of Golden are listed below:

Return Period	Peak Flow (cfs)
10-year	3,300
50-year	8,000
100-year	12,500
500-year	25,000

In the vicinity of the Site, the 100-year flood elevation is 5,682 feet. Based on work summarized in Advanced Sciences, Inc. (1989), the 500-year flood level is about 5 feet higher than the 100-year elevation or about 5,687 feet. The elevation at the lowest point of the Site is approximately 5,670 feet (former settling pond area next to Clear Creek), which is on the flood plain. This lowest elevation area is the subject of this characterization effort.

Chimney Gulch is a small drainage that passes about 100 feet west of the western gate of the Site (Figure 2-2). Chimney Gulch is a tributary of Clear Creek with a drainage basin of approximately 482 acres. This tributary’s headwaters begin on Lookout Mountain, and its confluence with Clear Creek is about 200 feet northwest of the Site. During most of the year, Chimney Gulch is dry.

Clear Creek passes through an historic mining region of the Colorado Mineral Belt. Several reaches of Clear Creek have been designated EPA Superfund Sites because of the extensive mining operations. Numerous mine adits along the stream contribute to seasonally elevated concentrations of metals, primarily manganese and zinc.

2.4 Geology

The Site is located along the eastern edge of the Rocky Mountain Front Range foothills. The Front Range is a complexly faulted anticlinal arch of primarily Precambrian crystalline rocks that reach elevations of over 14,000 feet. The foothills include the areas where “older” deposits were folded and pushed aside as the “younger” Rocky Mountains uplifted. The foothills rock types range from unconsolidated sediment deposits (25 thousand to 1 million years old) to sedimentary rocks (primarily sandstone and shale – 300 million to 63 million years old) to igneous and metamorphic rocks (over 1 billion years old). These formations remain as horizontal layers beneath Denver and the eastern plains. The Clay Pits area is a surface expression of the unconsolidated sediment deposits (Laramie – Fox Hills Sandstone – these deposits have been tilted almost vertical) and the bedrock underlying the Site is a sedimentary rock (Pierre Shale). The Golden fault, a high-angle reverse fault, is present along the eastern edge of the foothills west of the Site.

2.4.1 Bedrock Structure

Figure 2-3 is a bedrock geologic map of the area showing the Site location and surrounding features. Figure 2-4 shows the surficial geologic deposits found on site. Weimer (1976) developed a geologic cross-section of the Site vicinity. Weimer's cross section shows that the geologic strata are overturned and steeply dipping. Measurements of the strike of the beds in the Clay Pits area show a North 37° West trend with dips ranging from about 70° to 80° to the west (Grant 1990a). Farther east, the beds become vertical and then east dipping. Erosion activity of an earlier Clear Creek event along with construction activities appear to have removed the surface expression of the Laramie-Fox Hills sandstone north of the Clay Pits. The Site is located in an area of surficial deposits overlying the Pierre Shale. As shown in Figure 2-5, the Site is located in the Pierre Shale unit, a sequence that is at least 2,000 feet thick at this location.

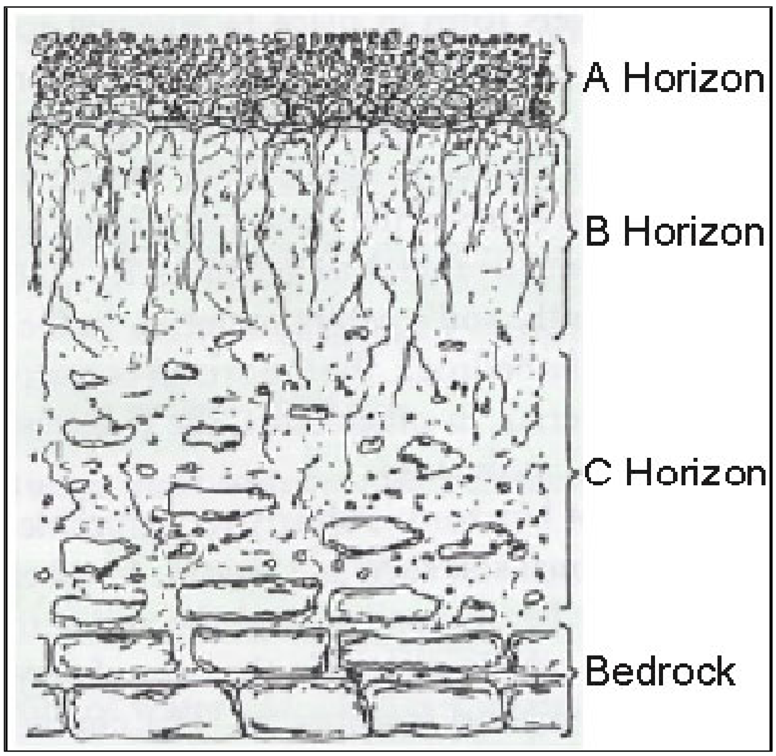


Figure 2-5 Schematic Representation of a Hypothetical Soil Profile with Underlying Parent Rock

As evident on Figures 2-3 and 2-4, the Golden fault cuts through the area just west of the Site. Van Horn (1976) characterizes the fault as a moderately to steeply west-dipping reverse fault of large displacement. This fault was extensively evaluated as part of investigations at the Rocky Flats Plant to the north. As a result of these evaluations (summarized in Appendix B of the RAOA), the Golden fault is not an active fault (i.e., movement has not occurred in the past 35,000 years and multiple movements have not occurred in the past 500,000 years).

2.4.2 Bedrock Stratigraphy

The stratigraphic units presented in Figure 2-3 are described below in order of decreasing age, oldest to youngest. These summaries are primarily from Van Horn (1976, 1995 – oral communication for RAOA) and Weimer (1976).

Precambrian (pC) – These metamorphic rocks are resistant but mostly covered by colluvium west of the Site and form the eastern-most slopes of the Front Range. Although outcrops are present, individual units are generally difficult to follow for any distance. Precambrian rocks in this area are believed to be overlain with angular unconformity by the Fountain Formation.

Fountain Formation (PPf) – This sedimentary unit is not exposed in the immediate vicinity of the Site but is believed to be present on the west side of the Golden fault under the alluvial fan materials shown in Figure 2-4. The Fountain is a pink to reddish-orange, coarse- to fine-grained, arkosic conglomeratic sandstone and conglomerate interbedded with lenticular, dark-reddish brown, silty, indurated mudstone and pinkish-gray, fine-grained, quartzose sandstone.

Pierre Shale (Kp) – Small areas of Pierre Shale are evident along the western end of the former settling pond, exposed by the erosion action of Clear Creek. Weimer (1976) characterized the unit as consisting of dark gray shale with minor, thin laminae of tan-weathered limonitic siltstone and silty, very fine-grained sandstone. Pierre Shale underlies much of the Site, including part of the parking area. The Pierre Shale is estimated to be at least 2,000 feet thick beneath the Site.

Fox Hills Sandstone (Kfh) – In the immediate vicinity, exposures of the Fox Hills are limited because of localized faulting. Where exposed, the sandstone is tan to yellow, fine-grained, subrounded, friable, calcareous sandstone with thin beds or laminae of siltstone and gray montmorillonitic claystone. The exposed thickness of the Fox Hills near 12th Street (Figure 2-3) is about 40 feet; however, the exact thickness is questionable because of faulting and could be as much as 75 feet (Weimer 1976). As shown in Figure 2-3, the Fox Hills underlies a part of the eastern-most practice field and some of the former Site buildings and parking area. The outcrop of this formation is visible to the west of the Clay Pits site.

Laramie Formation (Kl) – The Laramie is well exposed in a clay excavation south of Birch and 12th Streets. The thickness of the Laramie is about 350 feet and the formation is subdivided into two stratigraphic units. The lower unit (western-most unit) is about 190 feet thick near 12th Street and consists of four major sandstones that alternate with mineable kaolinitic claystone. The thickness of the individual sandstones and claystones varies from 20 to 40 feet. The sandstones are light gray to buff, fine- to coarse-grained, poorly sorted, subangular, and silty. The kaolinitic claystone units contain light to medium-gray, blocky weathering claystone with lesser amounts of dark gray to black carbonaceous claystone and thin coal streaks. Additionally, the lower Laramie contains a mineable coal seam. A monument over the Old White Ash coal mine is located at the intersection of Birch and 12th Streets. The surface trace of the main worked seam is located to the east of the monument and is 8 feet thick; a second mined seam, 10 to 20 feet to the west of the primary seam, is 3 feet thick (Emmons, *et al.*, 1896). These seams were mined to a distance of about one mile north of Clear Creek and several hundred feet south of 12th Street. The surface trace of the coal mine is presented in Figures 2-3 and 2-4.

The upper Laramie is about 160 feet thick and is similar in lithology to the lower Laramie, except that the sandstones are much thinner and finer grained. Neither coal nor carbonaceous shale is associated with the upper Laramie claystone. As is evident from Figure 2-3, the Laramie underlies the western half of Brooks Field and the eastern portion of the Site.

<u>Arapahoe Formation</u> (Ka) – The Arapahoe overlies the Laramie to the east and is 300 to 500 feet thick. It is composed of discontinuous beds of sandstone and claystone. The exposure in the Clay Pits south of Brooks Field shows the lower Arapahoe is predominantly a conglomerate and conglomeratic sandstone with minor intercalations of gray claystone and siltstone. The upper Arapahoe is not exposed in the immediate area. As is evident in Figure 2-3, the Arapahoe underlies the eastern half of Brooks Field and part of the eastern Site access road.

<u>Denver Formation</u> (TKdv) – To the east of the Arapahoe lies the Denver Formation, which is not exposed in the immediate vicinity. The Denver consists of light gray to brown tuffaceous silty claystone, tuffaceous arkose, and esitic conglomerate. The base is marked by the first appearance of volcanic material.

2.4.3 Geologic Characteristics of the Surficial Deposits / Soils

The surficial deposits that overlie the bedrock in the vicinity of the Site include the following (the order presented below does not show the age relationship) and are depicted on Figure 2-4:

- Louviers Alluvium
- Younger Alluvial Fan Colluvium
- Post-Piney Creek Alluvium
- Artificial Fill

More information (e.g., thickness of these surficial deposits) can be found in the test pit and boring logs included in previous RI/FS documents.

<u>Louviers Alluvium</u> (Qlo) – The Louviers forms a well-defined terrace in the Clear Creek valley and is the oldest of the alluvial deposits present in the area shown in Figure 2-4. The deposit is typically a coarse cobbly sand and gravel that is poorly sorted. Generally, less than 10 percent silt and clay is present. Just east of the area shown in Figure 2-4, the Louviers has sub-round to round pebbles and cobbles of granitic rocks. Boulders as large as one-foot across are present, but the common large size is 6 inches. Based on the subsurface work performed at this location, this unit is about 10 feet thick and extends south under the baseball and practice fields to the approximate location shown where it narrows against the bedrock. The Louviers is overlain by younger alluvial fan, colluvium, and artificial fill deposits. Locally, the post-Piney Creek Alluvium overlies eroded Louviers deposits.

<u>Younger Alluvial Fan</u> (Qyf) – In the location shown in Figure 2-4, this unit is associated with the current Chimney Gulch drainage and overlies the Louviers. This deposit is believed to have formed before the deposition of the post-Piney Creek Alluvium. The materials present in the deposit associated with the Chimney Gulch drainage consist of a poorly sorted, heterogeneous mixture ranging from boulders to clay. The upper few feet are clayey silt grading downward to

coarser materials. The thickness of this unit varies but is expected to be as much as 40 feet in the area mapped in Figure 2-4.

Colluvium (Qco) – Colluvium consists of materials that have been moved down steep slopes by creep and sheet wash, and, at a few places, they represent minor alluvial fan deposits. The colluvial deposits grade into, and interfinger with, alluvial terrace deposits and the younger alluvial fan deposits. It is mostly a massive to crudely bedded sandy to clayey silt but locally either sand or clay can predominate. Colluvial deposits generally overlie very irregularly sloping bedrock surfaces. While this may be typical at many locations, they are known to overlie the Louviers deposits over a portion of the area covered in Figure 2-4.

Underlying the colluvial material is an alluvial cobble zone. The cobble zone consists of a small quantity of pinkish-reddish sand intermixed with numerous flat cobbles/boulders (up to 12 inches). See the following description of the Post-Piney Creek Alluvium. Up to 13 feet of this alluvial material was encountered in the borings. During the 2004 RI, this zone could not be penetrated by the backhoe used for the test pits.

Post-Piney Creek Alluvium (Qpp) – This alluvial unit is present along Clear Creek and the youngest alluvial unit in the area mapped in Figure 2-4. It consists of coarse sand and gravel deposits. This unit was the main unit involved in the characterization effort described herein.

Artificial Fill (af) – Artificial fill areas were identified during the RAOA and are shown in Figure 2-4. The identified fill was used primarily for highway construction and for enhancing the usable area of the athletic fields and the adjacent area. The fills include tan to brown clay, medium to stiff, silty, sandy, and slightly gravelly (athletic field) and the artificial fill consists of silty clay to clayey sand with some gravel and construction debris (softball field area).

Upon completion of the 2007 RI/FS and implementation of remedial activities, the upper terrace portion of Site was released by CDPHE. The School re-graded a large portion of this area and imported fill material to accommodate construction of a new soccer field and an access road from 11th and Maple west to the proposed site of a new parking area immediately north of the soccer field.

In large part, the fill encountered during the RI in the flood plain did not appear to be placed to enhance the useable area on the flood plain or to extend the footprint of the upper terrace for development. Fill material was heterogeneous, non-compacted, and contained a wide variety of debris with no evidence of building foundations or infrastructure. In short, fill on the terrace slope and flood plain appeared to be dumped from the top of the terrace rather than placed. The fill included debris (i.e., large timbers, crucibles, concrete, drum carcasses, metal, pipes, ore, etc.) in a poorly sorted matrix ranging from clay to large boulders. In places the fill appeared to be native alluvial material; however, the presence of manmade objects within this matrix clearly permitted soils to be classified as imported fill.

The following additional artificial fill was identified during the RI:

- Sandy, silty cobbles mixed with debris assumed to be excavated soil from building foundations and infrastructure on top of the terrace and dumped over the slope
- Imported uniform sand used as bedding material around drainage lines
- Ore from offsite mining operations
- Imported heterogeneous fill mixed with waste from historic laboratory operations
- Bricks and miscellaneous building debris mixed with varying mixtures of clay and sand and cobbles
- A variety of bricks, large hand-hewn timbers, metal, and miscellaneous debris that may in some instances pre-date CSMRI activities

The topographic evaluation also shows that the channel of Chimney Gulch formerly may have been located about 130 feet east of its current location, which would place the old channel beneath the western access road.

Because of the extensive construction activities on the Site, very little "A" horizon material remained (Figure 2-5). Small areas of an "A" horizon were encountered along the northern side of the eastern and western access road. A treed area located along Clear Creek in the northeastern corner of the Site has a shallow "A" horizon underlain by sandy, silty sub-soils. The majority of the Site is covered with "B" or "C" horizon subsoils that were exposed as the buildings and roads were constructed.

2.4.4 Water-Bearing Units

In the area shown in Figure 2-6, groundwater is present in the following bedrock units: the Laramie/Fox Hills units, the Arapahoe, and some of the Denver Formation. Groundwater is also present in the Louviers Alluvium and post-Piney Creek Alluvium. The Laramie/Fox Hills and the Arapahoe are important aquifers of regional significance and the Louviers Alluvium, post-Piney Creek Alluvium, and the Denver Formation can be locally significant. Regional studies by Robson (1983 and 1984) and Robson *et al*. (198la, 1981b) indicate that the outcrop areas for these units in the area covered in Figure 2-6 are part of the recharge area. Recharge is primarily expected to occur from direct rainfall and snowmelt infiltration and by percolation from Clear Creek directly through the alluvium. However, RI observations suggest the reach of Clear Creek along the northern Site border may be a gaining reach because of the artesian nature of Laramie Fox-Hills aquifer in this area (several seeps are visible in the area).

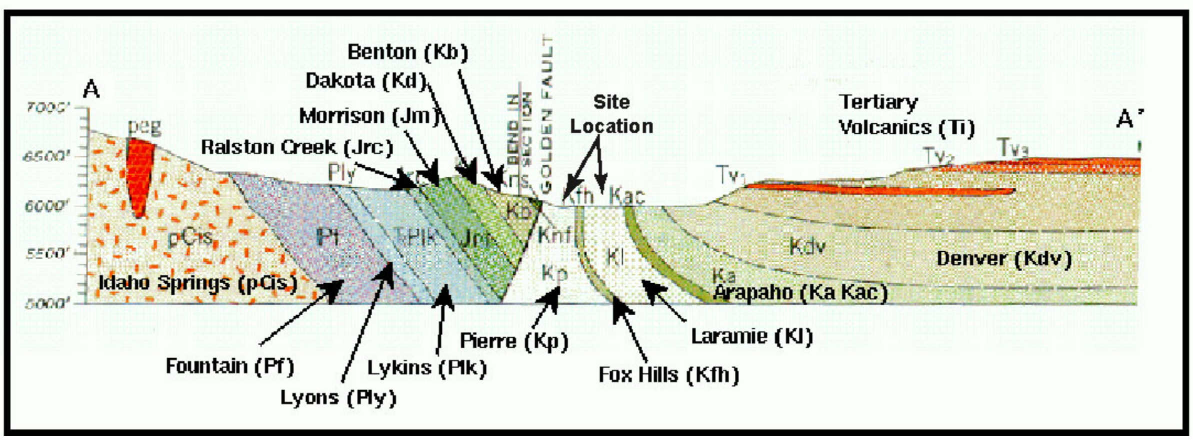


Figure 2-6 Geological Cross Section in the Vicinity of the Site

The most relevant water-bearing unit on the western side of the Site is the alluvial deposit above the weathered Pierre Shale (Figures 2-3 and 2-4). The Pierre Shale acts as an aquitard, allowing water from infiltration and nearby stream losses to move downgradient to Clear Creek. The Pierre Shale was encountered in four of the borings installed as part of the 2004 RI. Depth to the unit varied from about 10 feet below ground surface (bgs) north of the former Building 101N location to about 40 feet bgs near the baseball field. The groundwater-bearing zone above the formation varies between about 1 to 4 feet above the unit near the former Building 101N location and between about 6 to 15 feet near the baseball field. Groundwater was encountered about 30 feet below the baseball field and about 54 feet below the practice fields during the RAOA. More detailed discussions of the subsurface conditions, including groundwater are provided in Section 4.

The most relevant water-bearing unit on the eastern side of the Site is the Laramie Fox-Hills aquifer (Figure 2-6). The outcrop of the Arapahoe Formation appears to be located to the east of the Site and does not influence Site hydrology. The water bearing unit underlying the flood plain and observed during this RI field work was the post-Piney Creek Alluvium.

2.5 Groundwater Hydrology

This section discusses the local groundwater hydrology of the bench terrace and flood plain areas. Groundwater sampling is conducted quarterly at the Site to assess water quality impacts and long-term trends.

A complex groundwater system underlies the Site because of the area geology (Section 2.4). Bedrock in the vicinity is a complicated system of nearly vertical sediment deposits overlying Precambrian, crystalline bedrock (Figure 2-6). Sediment layers that once were located deep under the Denver Basin were pushed up as a result of the uplift of the Rocky Mountains. The Site is located at the western edge of the Denver Basin aquifer system, which includes the Dawson, Denver, Arapahoe, and Laramie-Fox Hills aquifers. These aquifers are unconfined along these uplifted beds, and the potentiometric surface (water table) associated with each aquifer is typically closer to the surface than the majority of the aquifer. The aquifers are confined in the deeper, central portions of the basin, providing the pressure required to raise the groundwater potentiometric surface.

Two groundwater-monitoring wells were installed as part of the 2004 RI (CSMRI-6 and CSMRI-7) and seven additional wells (CSMRI-1B, CSMRI-6B, CSMRI-7B, CSMRI-8, CSMRI-9, CSMRI-10, CSMRI-11) were installed in February 2007. These wells were used in conjunction with five existing wells to determine groundwater quality and to estimate groundwater flow directions.

Monitor wells CSMRI-6B and CSMRI-11 were abandoned in July 2008 to accommodate construction of the soccer fields. These two wells were replaced by CSMRI-6C and CSMRI-11B, respectively, in December 2008.

Monitor wells CSMRI-7B and CSMRI-8 were abandoned in October 2010 due to soil characterization activities associated with the flood plain area and the hillside to the west. These two wells were replaced by CSMRI-7C and CSMRI-8B. Three new flood plain monitor wells

(CSMRI-12, 13 and 14) one of which (CSMRI -14) was installed into the deep underlying Foxhills Sandstone, were installed in January 2011.

Figure 2-7 shows the locations of Site monitoring wells and presents the potentiometric surface for the Site. The potentiometric surface map is based on depth to groundwater measurements of early September 2010 and incorporates potentiometric surface elevation data from monitor wells CSMRI-7B and CSMRI-8 (prior to abandonment) and from four piezometers that were installed in flood plain test pits that were dug in June 2010. The piezometers provide shallow, near-surface potentiometric surface information within the flood plain area and document the seasonal rise and fall of the water table in response to Clear Creek seasonal cycles (Stoller 2010b).

The groundwater flow direction is governed by the subsurface topography of the weathered Pierre Shale and historically has been flowing to the northeast in the upper bench terrace area with a hydraulic gradient at approximately 0.03 ft/ft. Near the topographical break between the upper bench terrace and the flood plain, the groundwater direction of flow appears more northerly with an increasing gradient. Within the flood plain area, the hydraulic gradient flattens significantly. Potentiometric surface elevation data from monitoring wells CSMRI-1 and CSMRI-2 and groundwater elevation data are shown on Figure 2-7 but are not used in developing elevation contours. Monitor well CSMRI-1 is located too far upstream of the CSMRI Site to add useful information regarding groundwater flow direction, and CSMRI-2 is screened in the Foxhills Sandstone, a completely different hydrologic regime compared to the alluvial system at the CSMRI Site.

Figure 2-7 suggests uniform flow occurring along the interface of surficial deposits down the terrace slope; however, preferential pathways resulting from the uneven bedrock/alluvial interface contact are more likely to exist.

Graphing of the water table elevation of monitor wells since early 2007 indicates the monitor wells located in the flood plain area seasonally rise and fall up to 3 feet in elevation in response to the seasonal stages of Clear Creek. Monitor wells in the upper bench terrace area also indicate significant changes in elevation, up to 5 feet at monitor well CSMRI-9 over the course of one to two quarters, but a consistent seasonal response is not as obvious.

Groundwater pump tests were conducted on each of the three flood plain monitor wells (CSMRI-4, CSMRI-5, and CSMRI-8) in early June 2010. Details of these tests and results were presented in Attachment H of Appendix A, *Preliminary Flood Plain Characterization, Final Work Plan* (Stoller 2010a). Transmissivities ranged from 863 feet per day in well CSMRI-4 located immediately adjacent to Clear Creek to 22 feet per day in well CSMRI-8 located adjacent to an area containing artificial fill.

Analyses of the geochemical facies of the groundwater are conducted quarterly to assess the different types of groundwater within the CSMRI Site. Most of the alluvial monitor wells vary between a calcium-chloride, calcium-bicarbonate, or calcium-sulfate type waters. Monitor well CSMRI-2 is always a calcium-bicarbonate type water, and the surface water samples from Clear Creek are almost always a calcium-sulfate type water.

2.6 Demography, Land Use, and Water Use

The demographics and potential resource utilization of the Site and surrounding area are important in furthering the understanding of the remedial objectives. Remediation will focus on reducing, or if possible, eliminating impacts to resources and health effects to the surrounding population.

2.6.1 Demography

In 2010, the population of the City of Golden was approximately 18,000 based on preliminary data from the 2010 U.S. Census. The Golden city limits extend approximately 1.7 miles to the north of the Site, 1.5 miles to the east of the Site, and 3.2 miles south of the Site.

2.6.2 Land Use

Land usage in the vicinity of the Site includes residential, commercial, and rangeland. A large portion of the surrounding area is owned by the State of Colorado and has a variety of university-related uses, including athletic fields, classrooms, recreational facilities, housing, maintenance, and administration. Additionally, the City of Golden has offices and a water treatment plant on the north side of Clear Creek across from the Site. The residential, commercial, municipal, and agricultural facilities and their distances from the Site as obtained by direct field reconnaissance and map measurements are as follows:

- West - condominiums along Clear Creek are located about 1,500 feet west of the Site.
- South - a housing area along Parfet Estates Drive. The closest house is about 1,300 feet from the Site.
- North - a public campground is located about 50 feet from the Site on the north side of Clear Creek. Ponds associated with the City of Golden's water treatment plant are about 200 feet northwest of the Site. The City of Golden's offices are about 100 feet to the north. A recreation center is located about 300 feet to the north with a 40-unit apartment building about 300 feet north of the recreation center (600 feet north of the Site). The dairy originally located 3.6 miles north of the Site is no longer in business.
- East - the School's football stadium shares the eastern boundary with the Site. Condominiums are on the west side of Maple Drive within 150 feet of the eastern gate. The closest house on 12th Street is about 600 feet from the Site. The closest School building is 700 feet to the southeast.

2.6.3 Surface-Water Uses

Surface water diverted from Clear Creek is primarily used for water supply and secondarily for recreation and irrigation purposes. Diversions present within approximately one mile of the Site are described in the following sections.

2.6.3.1 Welch Ditch Diversion

This ditch originates on the south side of Clear Creek about 1.8 miles upstream of the Site (west). The Welch Ditch passes approximately 900 feet south of the south end of the Site (about 650 feet south of the Clay Pits) near monitor well CSMRI-2. The water from the ditch is used for irrigation and is not used for domestic purposes. The ditch is unlined and flows along the side of the hill above the Site to the east, through a tunnel and culverts in the vicinity of the

School student housing and the Clay Pits. From here, it flows around the southern perimeter of Golden, along the north side of South Table Mountain above the Coors brewery, and then to the east into the Federal Center. The ditch is a major source of groundwater recharge for the Site drainage when it is in operation. Overflow from the ditch is diverted down the Chimney Gulch drainage. The Welch Ditch was permanently closed in 2006.

2.6.3.2 Church Ditch/City of Golden Diversions

This ditch originates on the north side of Clear Creek about 0.9 miles upstream of the Site (west). The major water users served by the Church Ditch include the cities of Broomfield, Northglenn, Thornton, Westminster, and Arvada. Water is used for municipal purposes, including drinking water. The City of Golden also diverts some of its municipal water at the Church Ditch headgate and that water is incorporated into the city's drinking water supply. Treatment facilities for Golden are located on the northern side of Clear Creek near the Site.

2.6.3.3 Agricultural Ditch Diversion

This diversion originates on the south side of Clear Creek about 3,000 feet downstream (east) of the Site. The Agricultural Ditch is the first surface-water diversion downstream of the Site. The major water users served by the Agricultural Ditch include a major municipal supplier to the cities of Lakewood and Wheat Ridge. Some of the water is also used by Arvada, Golden, and unincorporated areas of Jefferson County, in additional to a number of other smaller industrial and agricultural users.

2.6.3.4 Farmers' Highline Canal and Ditch

This diversion originates on the north side of Clear Creek about 3,500 feet downstream (east) of the Site. The major water users served by the Farmers' Highline diversion include the cities of Westminster, Thornton, Northglenn, and Arvada. Water is used for municipal purposes, including drinking water. Coors and several small irrigation users also divert from the ditch.

2.6.4 Groundwater Uses

Groundwater wells, applications, and permits were identified for a 1-mile radius around the Site from information provided by the Colorado Division of Water Resources. A copy of that information is included in Appendix B of the New Horizons' 2004 RI/FS. An evaluation of that information shows that as many as 20 wells may be in use within a 1-mile radius of the Site. The identified uses include nine for industrial, ten for domestic, and one for household purposes. Yields range from 1 gallon per minute to as much as 85 gallons per minute. The nearest wells are located on the north side of Clear Creek within 500 to 1,000 feet of the Site. The nearest well on the south side of Clear Creek is over 2,000 feet away. The nine industrial use wells are alluvial wells owned by Coors Brewing Company are to the northeast of the Site at distances in excess of about 2,000 feet in locations near Clear Creek. Water taken from the industrial use wells, as well as the domestic and household wells, may be used for drinking water purposes according to the Colorado Division of Water Resources use classification.

2.6.5 National Historic Preservation Act Considerations

Potential historical and archeological resources were previously evaluated during preparation of the RAOA. The Colorado Historical Society advised that no significant historical or archeological resources are known in the immediate vicinity of the Site. Additionally, the City of Golden's Planning Department also advised that no known historical or archeological resources would affect the FS alternatives evaluation or selection process.

2.7 Ecology

The ecosystem of the area surrounding Golden is a diverse habitat influenced by a range in elevations that encompasses the plains, foothills, and mountains. The channelization of Clear Creek, construction of artificial ponds, grading projects, changes in vegetation, and other works of man have created new habitats by altering the natural habitat in the vicinity. Extensive residential development also has occurred over the years, and new development is continuing to the north and south of the Site.

The U.S. Fish and Wildlife Service was previously contacted during preparation of the RAOA to determine if sensitive ecosystems or species are present in the area. They indicated that a federally threatened plant species, the Ute Ladies' Tresses Orchid (*Spiranthes diluvialis*) is present in the Clear Creek area in the vicinity of the Site. The RAOA includes a survey performed by a local botanical expert, recommended by the U.S. Fish and Wildlife Service, in an area adjacent to the Site for potential Ute Ladies' Tresses Orchid habitat. The surveyed areas included Chimney Gulch below U.S. Highway 6 and a tributary of Chimney Gulch that runs parallel to U.S. Highway 6 on the north. The results of that survey showed that neither Chimney Gulch nor its tributary provide adequate habitat for *Spiranthes diluvialis* and that both drainage courses are in poor condition relative to natural habitats. The only portion of the Site that could potentially have suitable habitat would be the lower area along Clear Creek. This area has significant disturbance because of the excavation of the prior settling pond and installation of the monitoring wells. A wooded area east of the settling pond area is unsuitable habitat for the Ute Ladies' Tresses Orchid because the plant prefers wet meadows. Using published habitat descriptions and the results of the previous investigation, it was determined that onsite habitats were unsuitable for Ute Ladies' Tresses. However, Ute Ladies' Tresses were found in the flood plain many years later during the 2010 investigation, when efforts were being made by the federal government to de-list the plant as a threatened species.

A wetlands delineation was completed in 2006 on the portion of the Site adjacent to the former settling pond, within the flood plain of Clear Creek. The study was completed to determine if wetlands existed on the flood plain of Clear Creek immediately adjacent to the Site. The study determined a limited area with wetland characteristics does exist in the vicinity of the former pond area. The work detailed herein was designed to minimize impacts to the wetlands, and upon completion no impacts had taken place. As a precaution, because the extent of the characterization effort was not known prior to the start, a U.S. Army Corps of Engineers Nationwide 38 permit was acquired to allow intrusion into the wetlands if necessary. Although Ute Ladies' Tresses are present on the flood plain area, no mitigation for these plants was required in the permit.

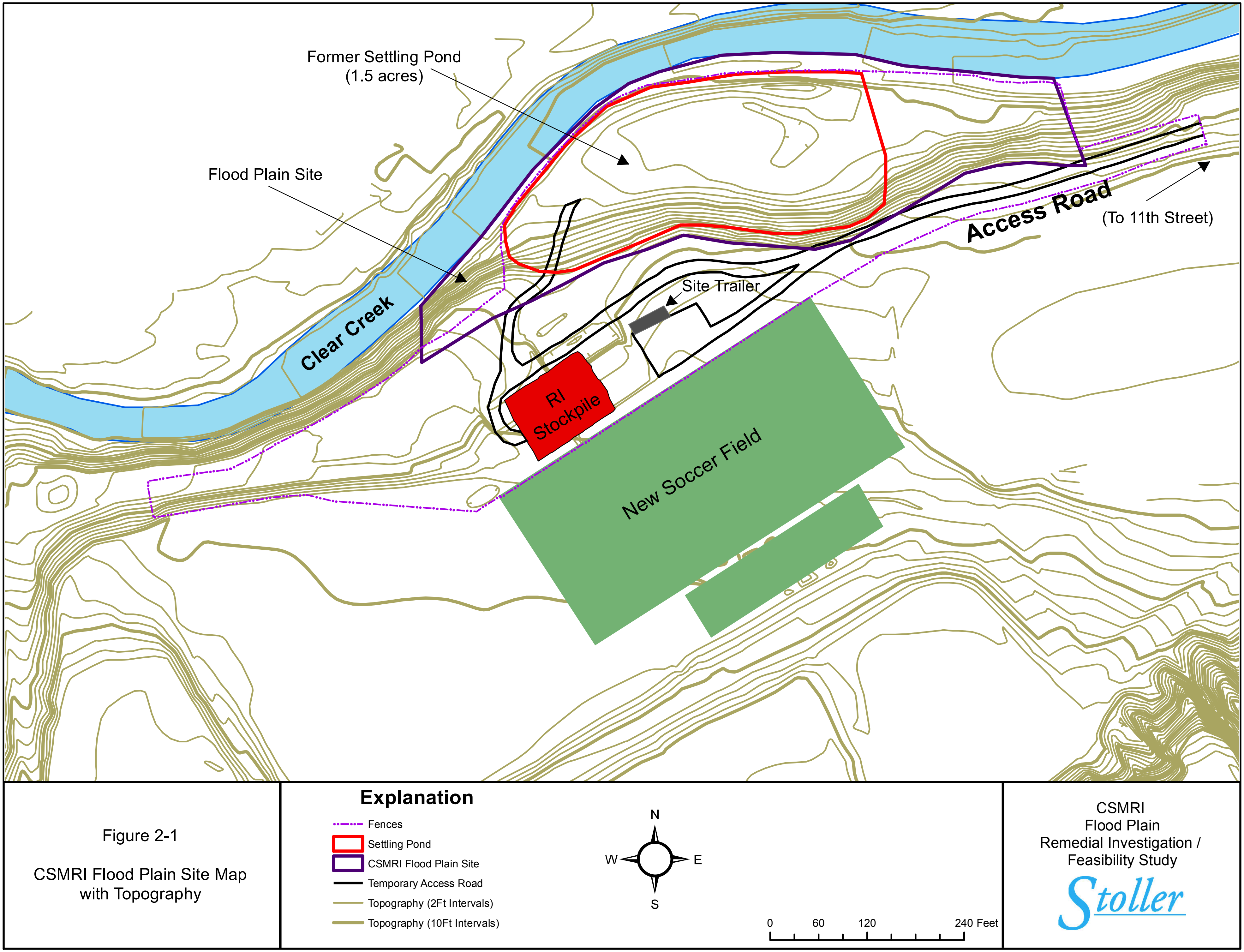


Figure 2-1

CSMRI Flood Plain Site Map with Topography

CSMRI Flood Plain Remedial Investigation / Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\rifs_site_topo_temp.mxd PLD @ 11/7/11

Figure 2-2

Meteorological Monitoring Location in Clear Creek Canyon

Explanation

CSMRI Flood Plain Site

Meteorological Station

CSMRI
Remedial Investigation / Feasability Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\rifs_figure_2_2.mxd PLD @ 11/7/11

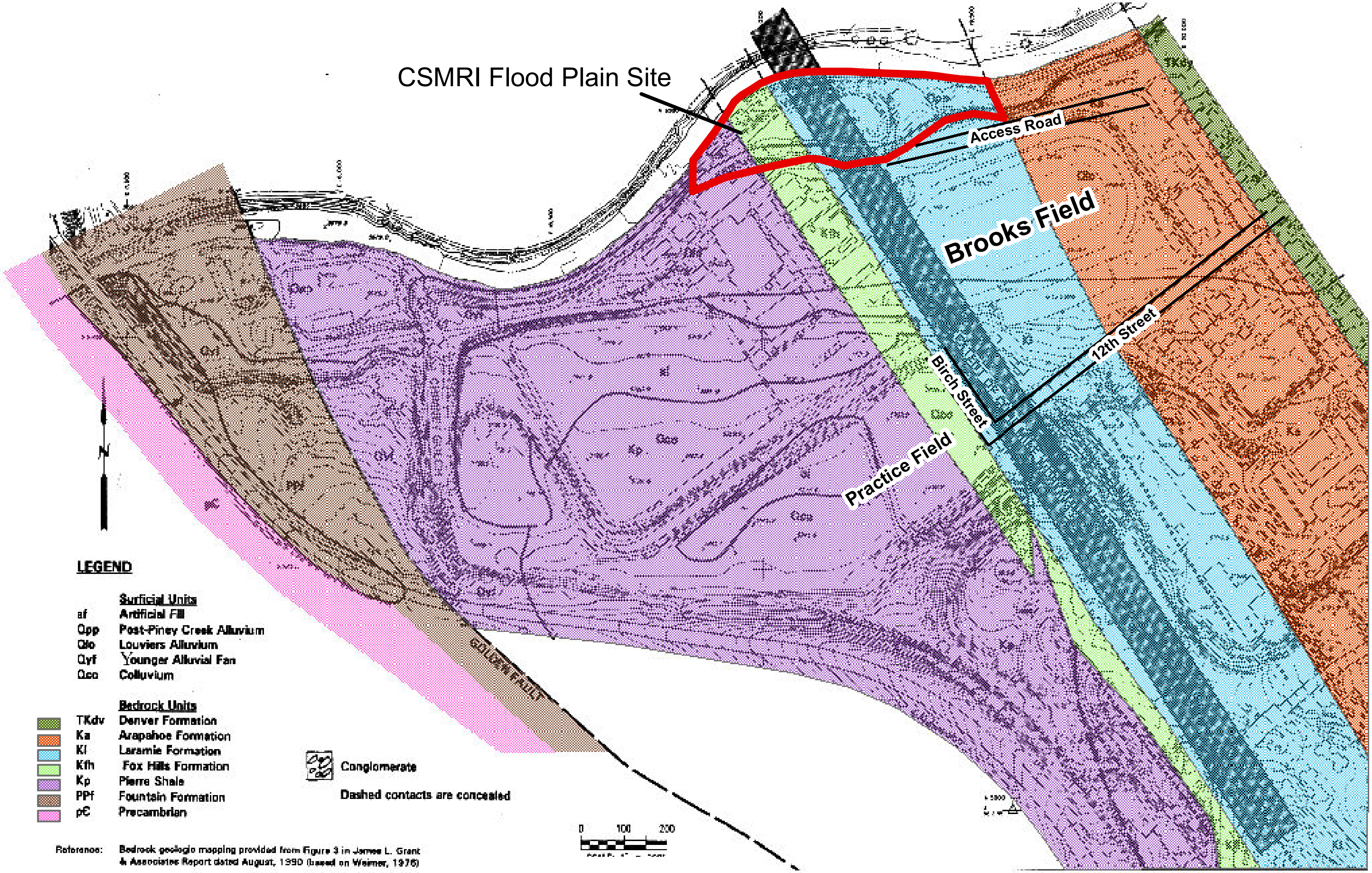


Figure 2-3

Bedrock Geologic Map of Site

CSMRI Flood Plain Remedial Investigation / Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\rifs_bedrock_geology.mxd PLD 11-7-11

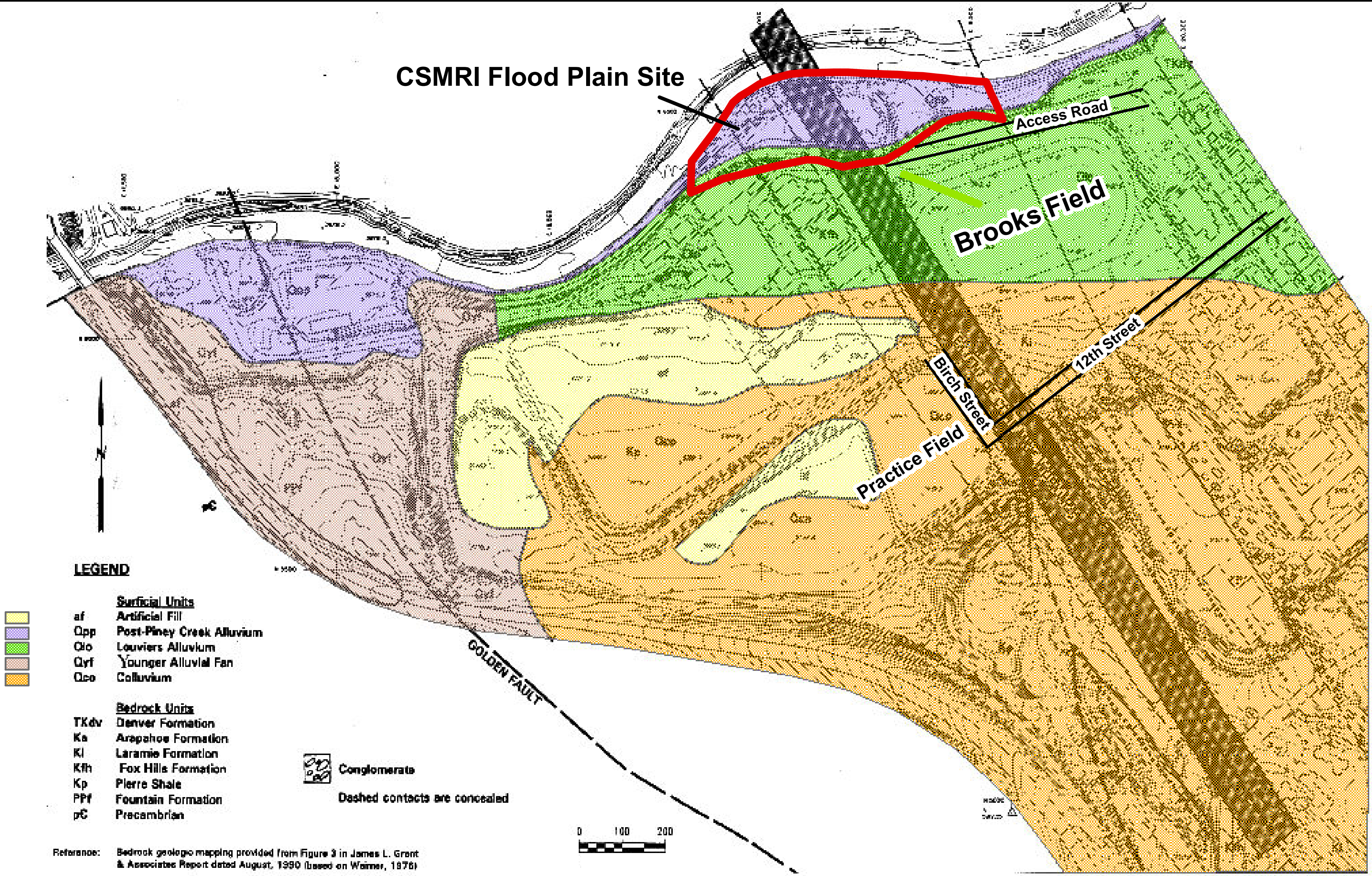


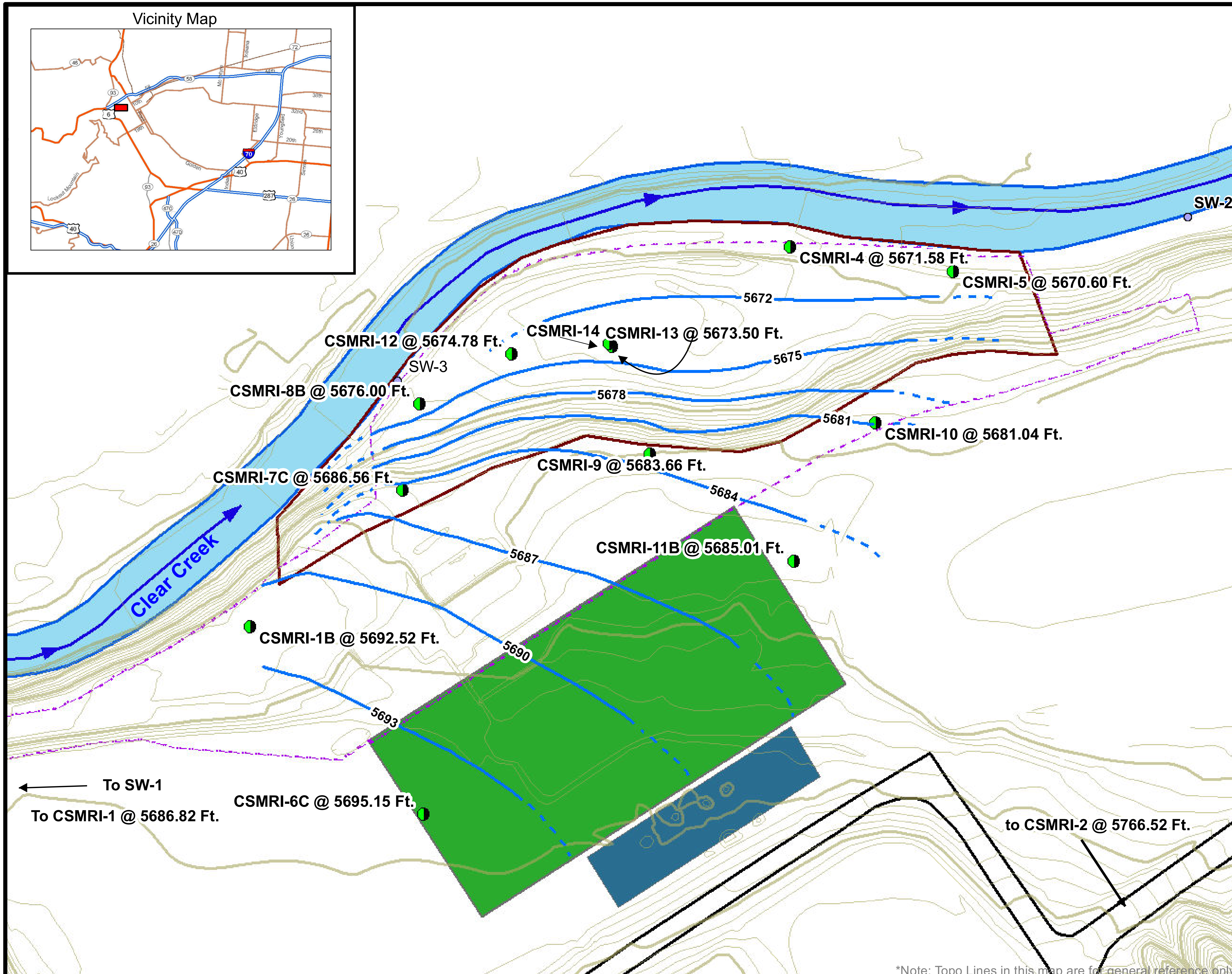
Figure 2-4

Surficial Geologic Map of Site

CSMRI Flood Plain Remedial Investigation / Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\rifs_surficial_geology.mxd PLD 11-7-11



Explanation

Potent. GW Contours (3Ft) September 2011
- Known Contour
- Inferred Contour
- Monitor Well
- Surface Water Sample Location
- Roads
- Fences

Contours 2009
- Topography (2Ft Intervals)
- Topography (10Ft Intervals)

Soccer Field Related
- Soccer Field
- Stands
- Flood Plain Characterization Area

*CSMRI-14 (Foxhills Fm, Not Used)
Water Elevation: 5674.81 Ft.

N
W E
S

0 50 100 200 Feet

Figure 2-7

Groundwater Potentiometric Elevation Map - September 2011

CSMRI
Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\csmri_potentiometric_sept_2011.mxd PLD @ 11/7/11

Table of Contents for Section 3

3. Study Area Investigations 3-1
3.1 EPA Removal Action 3-1
3.2 Investigation and Cleanup, Stoller 2007 3-1
3.3 Flood Plain Test Pit Investigation, Stoller 2010 3-2
3.3.1 Extent of COCs 3-2
3.3.2 Study of Site Ambient Uranium Levels 3-3
3.3.3 Geochemical Modeling for Site-Specific Cleanup Level 3-7
3.4 Establishment of Tentative Site Cleanup Goals 3-9
3.5 Flood Plain Soil Investigation 3-11
3.5.1 Site Preparation 3-14
3.5.2 Instrument Bias/Correlation 3-14
3.5.3 Iterative Lateral and Vertical Extent Determination and Excavation 3-15
3.5.4 Confirmation Sampling 3-16
3.6 Air Monitoring 3-17
3.7 Groundwater Investigation 3-18

List of Tables

Table 3-1 Soil Analytical Results from Flood Plain Test Pits: (Tentative Cleanup Goal Exceedances in Red) 3-4
Table 3-2 Summary of Ambient Soil Sample Results for Alluvium 3-5
Table 3-3 Comparison of Normal and Log Normal Statistics 3-5
Table 3-4 Ambient Alluvial Uranium Normal Descriptive Statistics (mg/kg) 3-6
Table 3-5 Flood Plain Bedrock and Background Bedrock Analytical Results 3-7
Table 3-6 Tentative Site Cleanup Goals and Established Background Levels 3-9
Table 3-7 Effluent Concentration Standards[1] 3-17
Table 3-8 Air Monitoring Summary CSMRI Creekside Site Characterization October – November 2010 3-18

List of Figures

Figure 3-1 Test Pit Locations and Total Uranium Concentration in Soil (mg/kg)

3. Study Area Investigations

The area investigated was the flood plain portion of the CSMRI Site. The flood plain consists of a relatively flat area, approximately 2 acres in size, located between the upper terrace, where the CSMRI buildings were located, and Clear Creek. Previous investigations conducted on this area include the EPA removal action in 1992 and the Stoller characterization and cleanup on the far eastern end in 2007. These actions, the data generated, and their relationship to the investigation reported herein, are summarized in the following sections.

A persistent dissolved uranium plume in the groundwater under the flood plain discovered during groundwater monitoring performed in 2008-2010 indicated that additional investigation was necessary. This investigation was designed to determine the nature and extent of contaminated soil providing a source for the groundwater impacts.

3.1 EPA Removal Action

The EPA emergency removal action was initiated due to a City of Golden water main break that released water to Clear Creek from the former settling pond located on the flood plain. Data collected during the EPA-managed emergency pond removal in 1992 were evaluated by Stoller to determine if any data could be used to determine nature and extent of COCs in soil. Surface samples, test pit samples, and samples from borings were analyzed to determine if the resulting data were representative of soil remaining onsite or soil excavated during the removal action. Surface samples were collected by EPA from the entire area surrounding the settling pond in a uniform grid prior to the excavation portion of the removal action. The soil represented by the data was excavated from the Site during the removal action. Because the EPA action had cleanup levels of 5 pCi/g (average per 100 square meters for the top 6 inches of soil) and 15 pCi/g for Ra-226 (average per 100 square meters for each successive 6-inch layer below the top 6 inch layer of soil) (the Uranium Mill Tailings Radiation Control Act or UMTRCA standard, and CDPHE Part 18 Radiation Control regulations standard), very little characterization data and no confirmatory data included uranium concentrations. Thus, the data generated during that work were of limited use in this effort to develop data for uranium, but the information was useful for providing existing data on Ra-226 concentrations remaining in soil, which is a COC at the Site. The groundwater is currently contaminated with uranium, not Ra-226.

The EPA removal action was conducted over the same area addressed by this current investigation. Action taken by the EPA reduced the risk to the environment and the public, but EPA did not remediate the soil to the cleanup standards currently applied to the Site, which is 25 millirem per year above background under Part 4 of the Colorado radiation control regulations, that translates to approximately 1 pCi/g Ra-226 above background, which is considerably lower than the 5/15 above background standard used by EPA. For this reason, this investigation includes all the COCs evaluated on the upper terrace with the addition of uranium.

3.2 Investigation and Cleanup, Stoller 2007

The eastern flood plain (i.e., portions of the flood plain that are to the east of the former pond location and east of the area cleaned up by the EPA removal action) investigation and remediation were completed by Stoller. Stoller's effort focused on metals (not including uranium) and radium, identical to the investigation/removal completed on the upper terrace. This effort did not generate uranium-specific data for this investigation. Additional information concerning the results of metals analysis and sample locations for the eastern portion of the flood plain is provided in the Stoller RI/FS (2007a).

3.3 Flood Plain Test Pit Investigation, Stoller 2010

The preliminary flood plain characterization was completed in June 2010 by Stoller to address comments by some of the Site PRPs and CDPHE. PRP and CDPHE comments led to the following revisions to the work plan for the investigation:

- The proposed non-engineered slurry wall was removed from the plan
- A numeric cleanup level for uranium in soil was determined and added to the plan
- Proposed passive geochemical alteration of groundwater was eliminated from the plan

The preliminary characterization focused on collecting geologic and hydrologic information to assist with the flood plain characterization activities as well as measuring uranium concentrations in both soil and water across the flood plain area. In addition, samples were collected and analyzed to determine a Site-specific cleanup level for uranium in soil that would be protective of groundwater and determine ambient uranium soil concentrations.

The following subsections summarize the data collected and the results of the test pit characterization. Details of the flood plain test pit results are presented in the Work Plan (Stoller 2010a).

3.3.1 Extent of COCs

A total of 22 soil samples were collected from the eight test pits and sent to ALS/Paragon Laboratories of Fort Collins, Colorado for analysis of total metals (As, Hg, Mo, Pb, U, and V) and total radium (Ra). Samples included duplicates from two test pits, one from CLT-1 and one from CLT-2, for laboratory QA/QC.

In general, one soil sample from each test pit was collected from unsaturated soil above the water table, one sample from within the saturated zone, and one at the total depth of the excavation in the bedrock. The groundwater table was approximately 2 feet bgs. Analytical results are summarized in Table 3-1, with exceedances of CSMRI's tentative cleanup goals highlighted in bold font. For reference, the table includes the tentative cleanup goal for each COC that was established during the upper terrace characterization performed in 2006. The tentative cleanup goal for total uranium was 14 ppm.

Only two of the eight test pits (CLT-1 and CLT-6) had COC concentrations above the tentative cleanup goals. Soils from test pit CLT-1 had values exceeding the cleanup goal for As, Pb, and total radium. In addition, a soil sample collected from this test pit had the highest concentration of uranium found in any of the test pit samples (33 mg/kg [ppm]). Test pit CLT-1 was dug in an area upgradient of monitoring well CSMRI-8 and downgradient of two former process outfalls that were not removed during previous activities. CLT-1 was dug in this location, because the area was previously identified as a potential contamination source area for groundwater in CSMRI-8 based on field observations and evaluation of historical aerial photographs.

The only other test pit that had a COC concentration above the tentative cleanup goal was CLT-6, which detected total uranium at 19 and 24 ppm in the unsaturated and saturated soil samples, respectively. Test pit CLT-6 was located in the site berm along Clear Creek at the boundary of the earlier EPA cleanup action and may have represented the northernmost boundary of the extent of flood plain soil contamination. CLT-6 is partially located within the setback from Clear Creek established for the characterization work. Soil sample laboratory analytical results for total uranium from all test pit locations are shown on Figure 3-1.

Data from the test pits provided sufficient information to allow the characterization of impacted soils acting as a groundwater source to be more cost-effectively focused on the area in the vicinity of well CSMRI-8 and on the western reaches of the flood plain. Additionally, the data confirmed the need to excavate the source to reduce further impacts to the environment.

3.3.2 Study of Site Ambient Uranium Levels

The flood plain consists of Clear Creek alluvial deposits lying unconformably above three steeply dipping bedrock formations. Samples from each of these four deposits were collected from an upstream location and analyzed for total uranium metal to determine a background uranium concentration.

The term “ambient” is used in this document to describe background samples collected within the Clear Creek drainage system but upstream of the Site and outside the area influenced by historic activities conducted at the CSMRI Site. The term ambient was selected to acknowledge that background samples unaltered by human activities do not exist along the Clear Creek drainage because of historic mining in the Clear Creek drainage for more than a century. Evidence of this is shown in the 1888 photograph (Appendix G of the *Flood Plain Characterization Work Plan*) where smelter operations are present just northwest of the CSMRI flood plain site prior to its being developed. Although ambient soil samples were collected from an alluvial bar upstream of these historic smelter activities, there is little doubt that it was impacted by mining operations farther upstream.

To properly assess ambient/background soil conditions and to eliminate contributions from previous activities associated with CSMRI, the sediment samples were collected upstream of CSMRI. Alluvial river material similar to the CSMRI flood plain deposits was collected from a similar depositional feature (flood plain) approximately 1,000 meters upstream of the Site.

Ambient bedrock samples were collected from the formations that underlie the flood plain area from outcrops near the Site. Bedrock formations at the Site include, from older to youngest in age, and from west to east across the Site, the Pierre Shale, Fox Hills Sandstone, and Laramie Formation. Each of these formations was encountered in the test pits, and each is well exposed as near vertical outcrops immediately south of the Site.

Fifteen alluvium and three bedrock samples were collected that were representative of area background conditions in areas unaffected by historic activities associated with the Site. These samples were submitted to an analytical testing laboratory and tested for the presence of uranium. The analytical results were then used to statistically determine an ambient uranium concentration for the alluvial sediments. Statistical analysis was conducted for ambient concentration determination using the guidelines established by the CDPHE (1997).

Table 3-1
Soil Analytical Results from Flood Plain Test Pits: (Tentative Cleanup Goal Exceedances in Red)

Test Pit No.	Lithologic Zone	Arsenic (As) (mg/kg)	Mercury (Hg) (mg/kg)	Molybdenum (Mo) (mg/kg)	Lead (Pb) (mg/kg)	Uranium (U) (mg/kg)	Vanadium (V) (mg/kg)	Total Radium (pCi/g) ± TPU
CLT-1	unsaturated	**48**	11	23	**730**	**19**	46	**21.1 ± 5.6**
	Saturated	**150**	14	46	**1,100**	33	**120**	**141 ±36**
	Pierre Shale	na						
	duplicate unsaturated	**39**	9.2	24	**570**	**19**	44	**18.8 ± 5**
CLT-2	unsaturated	14	0.68	3.6	70	13	21	5.2 ±1.5
	Saturated	na						
	Pierre Shale	6	0.016	0.12	7.9	2.4	13	1.38 ± 0.55
CLT-3	unsaturated	16	0.23	6.9	160	11	7.7	1.4 ± 0.61
	Saturated	15	0.62	4.4	85	5.4	12	2.53 ± .92
	Pierre Shale	6.4	0.052	4.5	19	7.7	40	2.65 ± 0.91
CLT-4	unsaturated	17	1.9	6.7	150	4.9	48	2.63 ± 0.92
	Saturated	6.2	0.22	3.4	31	2.6	18	2.24 ± 0.82
	Fox Hills Formation	6.6	0.1	0.18	14	2	14	2.02 ± 0.74
CLT-5	unsaturated	2.5	1.1	1.9	21	2.1	30	4.7 ± 1.4
	Saturated	20	0.32	22	84	7.5	36	4.8 ± 1.4
	Laramie Coal Seam	na						
CLT-6	unsaturated	7.1	0.072	7.3	36	**24**	7.4	1.12 ± 0.46
	Saturated	8.5	0.093	7.7	48	**19**	14	1.64 ± .06
	Pierre Shale	8.8	0.038	0.72	26	2	37	1.87 ± 0.66
CLT-7	unsaturated	21	0.41	6.7	100	7.3	41	2.38 ± 0.82
	Saturated	5.2	0.35	3	29	5	32	1.45 ± 0.57
	Na	na						
CLT-8	unsaturated	12	0.61	4.8	120	6.6	20	3.4 ± 1.1
	Saturated	6.3	0.7	5.3	47	3	17	2.91 0.95
	Laramie Coal Seam	1.7	0.021	1.1	3.5	0.41	5.2	0.060. ± 0.18
	duplicate saturated	5.4	0.65	3.6	48	3.1	13	3.1 ± 1
Tentative Cleanup Goal		**39**	**23**	**390**	**400**	**14**	**78**	**7.0***

mg/kg - milligrams per kilogram
pCi/g – picocuries per gram
TPU – total propagated uncertainty
Pierre Shale, Laramie Coal seam, and Fox Hills are bedrock formations
*5.0 pCi/g per 40 CFR 192 plus 2.0 pCi/g background

Analytical results for the ambient concentration of uranium from the alluvial sediments upstream of the Site and from bedrock outcrops south of the Site have been tabulated and are presented in Table 3-2. The laboratory analytical certificates and QA/QC documents are presented in Appendix A, Attachment E of the *Flood Plain Characterization Work Plan* (Stoller 2010a).

Table 3-2
Summary of Ambient Soil Sample Results for Alluvium

Ambient Alluvial Sample Number	Uranium Concentration (mg/kg)
00010-001 (Way point 77)	5.50
00010-002 (Way point 78)	2.50
00010-003 (Way point 78) (duplicate of 00010-002)	2.10
00010-004 (Way point 79)	2.40
00010-005 (Way point 80)	1.90
00010-006 (Way point 81)	2.90
00010-007 (Way point 82)	1.70
00010-0081 (Way point 83)	1.50
00010-009 (Way point 84)	1.90
00010-010 (Way point 85)	4.10
00010-011 (Way point 85)	1.60
00010-012 (duplicate of 00010-011)	2.00
00010-013 (Way point 86)	2.90
00010-014 (Way point 87)	7.40
00010-015 (Way point 88)	1.70
00010-016 (Way point 89)	4.50
00010-017 (Way point 90)	5.20
Bedrock Background Sample #	Uranium Concentration (mg/kg)
00010-018 (Way point 91) Pierre Shale	1.2
00010-019 (Way point 92) Fox Hills Sandstone	0.430
00010-020 (Way point 93) Laramie Formation	0.100

mg/kg - milligrams per kilogram

The data set for the ambient alluvial soil results has a non-normal distribution. This requires the data set be log transformed before statistical analysis. CDPHE guidance (1997) indicates that log transformed data should have a reverse transformation performed after statistical analysis to obtain meaningful results. Table 3-3 provides summary statistics for both normal statistics and log transformed/reverse transformed results.

Table 3-3
Comparison of Normal and Log Normal Statistics

	Raw Data (Normal) (mg/kg)	**Log-Transformed Data (mg/kg)**
Mean (μ)	3.047	0.991
Standard deviation (σ)	1.702	0.492
μ+2σ	6.450	7.199
95% UCL	3.922	3.468

mg/kg - milligrams per kilogram

Descriptive statistics (normal) of the ambient alluvial samples collected west of the Site are presented in Table 3-4. The ambient alluvial analysis incorporates the two duplicate alluvial samples for a total of 17 samples (15 samples + 2 duplicates) in the data set.

Table 3-4
Ambient Alluvial Uranium
Normal Descriptive Statistics (mg/kg)

Mean	3.05
Standard Error	0.41
Median	2.40
Mode	2.90
Standard Deviation	1.70
Sample Variance	2.90
Kurtosis	1.18
Skewness	1.36
Range	5.90
Minimum	1.50
Maximum	7.40
Sum	51.80
Count	17.00
Largest (1)	7.40
Smallest (1)	1.50
Confidence Level (95.0%)	0.88

mg/kg - milligrams per kilogram

The descriptive statistics indicate the average of the ambient alluvial samples is 3.05 mg/kg (ppm) with a standard deviation of 1.7 mg/kg (ppm) and a 95 percent confidence level of 0.88 mg/kg (ppm). The value of uranium concentrations in ambient soil samples ranges from a maximum of 7.4 mg/kg (ppm) to a low of 1.5 mg/kg (ppm). The positive skewness value indicates more observations below the mean than above the mean, and that the mean is greater than the median value. The positive kurtosis value indicates a peaked distribution.

An evaluation of the relative percent different (RPD) between the two duplicate sample sets indicates values of 17.4 and 22.2 percent difference. An RPD of less than 50 percent is considered acceptable given the heterogeneous nature of the poorly sorted alluvial sediments (Chishti 2005).

Analytical results of the flood plain bedrock and background bedrock samples have been tabulated and are presented in Table 3-5. Three different bedrock formations are present in the flood plain area and the analytical results are separated accordingly.

Table 3-5
Flood Plain Bedrock and Background Bedrock Analytical Results

Formation	Flood Plain Bedrock Uranium (mg/kg)	Background (Outcrop) Bedrock Uranium (mg/kg)
Laramie	Test Pit 8 0.41	0.100
Fox Hills Sandstone	Test Pit 4 2.0	0.430
Pierre Shale	Test Pit 2 2.4 Test Pit 3 7.7 Test Pit 6 2.0	1.2

mg/kg - milligrams per kilogram

Because of the small data set for each of the formations and varying bedrock lithologies between the test pit sample and the available outcrop samples, a meaningful statistical comparison between flood plain bedrock and ambient bedrock cannot be established. In the case of the Laramie Formation, coal was encountered in CLT-8, but a coal outcrop was not located. Additionally, the Pierre Shale samples collected from the test pits were collected in competent bedrock while the Pierre Shale sample from the outcrop appeared to be weathered and coarser grained and also in closer proximity to the contact with the overlying Fox Hills Sandstone.

Based on the results of the analyses and statistical evaluation of ambient alluvial soil collected upstream of the Site in a similar depositional environment, a mean uranium value of 3.05 mg/kg (ppm) with two standard deviations of 1.7 mg/kg (ppm) yields an ambient uranium value for this work of 6.45 mg/kg (ppm) and was proposed for ambient alluvial soil. Log transformation of the sample data results in an ambient uranium concentration (mean + two standard deviations) of 7.2 mg/kg for soil in the flood plain.

3.3.3 Geochemical Modeling for Site-Specific Cleanup Level

Stoller retained Whetstone Associates, an experienced geochemical modeling firm, to oversee the geochemical laboratory testing and integrate the Site-specific field and laboratory data into the geochemical modeling to help determine a Site-specific soil cleanup level for uranium.

EPA guidance presents two methods for determining soil screening levels (SSLs) for radionuclides. The first method uses a generalized soil/water partition equation (SWPE). The SWPE method tends to overestimate leaching to groundwater because it assumes an infinite contaminant source.

The second method uses the mass-limit equation procedure (MLEP). The mass-limit model calculates a soil concentration that corresponds to the release of all radionuclides present within the source, at a constant health-based concentration, over the duration of exposure. These concentrations form the limits that are used as a minimum concentration for each SSL. Below this concentration, a receptor point concentration time-averaged over the exposure period cannot exceed the health-based concentration on which it is based (EPA 2000).

In addition to the calculation of soil partition coefficients and SSLs for uranium, Whetstone performed geochemical modeling of the leachate. The modeling used the program PHREEQC to speciate the uranium in solution and evaluate potential precipitation and sorption mechanisms that may attenuate uranium concentrations along the groundwater flow path.

Phase I testing of flood plain soils consisted of a series of eight 24-hour bottle roll tests for each soil sample using eight solid:solution ratios ranging from 1:4 to 1:500. The resultant solutions from the testing were decanted; filtered (0.45µ); preserved; and analyzed for pH, electrical conductivity, and dissolved uranium. The batch adsorption tests were then evaluated by plotting Phase I concentrations against the amount of solute adsorbed per unit mass of adsorbent and regressing a line through the data. The equation of the line was then used to calculate the distribution coefficient (K_d). Freundlich isotherms or Langmuir isotherms were then used to describe absorption in solid-liquid systems. The resulting soil partition coefficient (K_ds) was then used to calculate SSLs using the generalized SWPE equation procedure (MLEP).

Phase II testing consisted of a series of four bottle roll tests for select samples with fixed solid:solution ratios and durations of 1, 24, 48, and 72 hours per sample. The Phase II results were used to calculate equilibrium times for uranium sorption on soil with equilibration time being defined as the minimum time at which the change in solute concentration is less than 5 percent during a 24-hour interval.

3.3.3.1 Soil Partition Coefficients and Soil Screening Levels for Uranium

Phase I batch testing indicated that uranium concentrations in the contact solutions for samples from test pits CLT-1, CLT-2, CLT-3, and CLT-8 generally increased and that the samples acted as additional sources of uranium rather than as adsorbents. These samples were not selected to derive K_ds because of the uranium-releasing potential from the associated soil samples.

Soil samples from test pits CLT-4 and CLT-7 displayed mixed results with adsorption occurring at higher solid:solution ratios and release occurring at lower solid:solution ratios. However the CLT-7 results showed a clearer trend of increasing adsorption with increasing solids at higher soil:solution ratios than CLT-4 and the data were deemed usable. Results from test pit CLT-6 showed that the differences between the head solution and the supernatant solutions are generally less than the likely error associated with analytical precision. Accordingly, the batch roll test results from CLT-4 and CLT-6 were not carried forward for the preliminary soil partitioning calculations.

Whetstone identified the samples from test pit CLT-5 as the most consistent sorption behavior across the range of tested soil:solution ratios and was used with CLT-7 data to calculate adsorption isotherms and soil partitioning coefficients.

Regression analyses of the CLT-5 and CLT-7 data indicate distribution coefficients of 0.01 and 0.19 L/kg, respectively, using the Freundlich isotherm equation. Using default values in the EPA SWPE equation resulted in an SSL of 0.348 mg/kg (ppm), an SSL of 0.114 using K_d data derived from test pit CLT-5, and an SSL of 0.219 using K_d data from test pit CLT-7.

Using the highest SSL of 0.219 mg/kg (ppm), a soil uranium concentration that has the potential to exceed the groundwater standard of 30 µg/L (ppb), and extrapolating the SSL to the ambient uranium concentration determined for the Site results in a groundwater uranium concentration of 410 µg/L (ppb). This value is well in excess of the MCL of 30 ppb. Thus, the conservative nature of the modeling proved to be too conservative and unrealistic to determine a uranium soil cleanup standard for the flood plain.

3.3.3.2 Results of Geochemical Modeling using PHREEQC

The groundwater sample collected from monitor well CSMRI-8 during the pump test was submitted to ACZ Laboratories, Inc. of Steamboat Springs, Colorado for total and dissolved metals, anions, cations, and general wet chemistry. Whetstone then entered the analytical results into the geochemical modeling software PHREEQC to evaluate aqueous speciation and mineral saturation indices for uranium.

The results of the modeling effort indicated uranal carbonate complexes are the dominant uranium species present in solution and account for approximately 99.6 percent of dissolved uranium in the groundwater samples. Uranium exists predominately as hexavalent species U^{+6} with very little reduced and less mobile forms such as U^{+5}, U^{+4}, and U^{+3}.

Saturation indices for iron and aluminum hydroxides indicate that gibbsite and ferrihydrite are slightly oversaturated in groundwater. These minerals are favorable substrates for uranium adsorption. Uranium minerals are under saturated in groundwater, and no precipitates were identified that could potentially attenuate uranium concentrations under the observed redox and pH conditions. Thus, this approach was not feasible to determine a flood plain soil cleanup standard for uranium.

3.4 Establishment of Tentative Site Cleanup Goals

Tentative cleanup goals for the Site were originally presented in the *CSMRI Creekside Site Final Site Characterization Work Plan* (Stoller 2006b), which was the guiding document for the investigation of the upper terrace and was approved by CDPHE. The tentative cleanup goals for this Site characterization were adopted from the upper terrace work and are presented in Table 3-6. Because this investigation stems from a persistent dissolved uranium plume, uranium was added to the list of COCs and a tentative cleanup goal established.

Table 3-6
Tentative Site Cleanup Goals and
Established Background Levels

Constituent	Tentative Site Cleanup Goal	Site Background Levels
Metals	mg/kg	mg/kg
Arsenic	39	38
Barium	5,277	370
Cadmium	76.1	1.5
Chromium	223	16
Lead	400	86
Mercury (total)	23	0.63
Molybdenum	390	6.1
Selenium	380	1.7
Silver	380	0.12
Uranium*	14	6.45
Vanadium	78	44
Zinc	22,825	250
Radioisotopes	picoCuries/gram	picoCuries/gram
Radium 226	4.14	2.7
Radium 228	4.6	2.4

Table 3-6
Tentative Site Cleanup Goals and Established Background Levels

Constituent	Tentative Site Cleanup Goal	Site Background Levels
Thorium 228	6.47	2.7
Thorium 230	11.53	1.7
Thorium 232	3.88	2.4
Uranium 234	254.9	1.9
Uranium 235	4.97	0.098
Uranium 238	21.8	1.6

mg/kg - milligrams per kilogram
Site background levels taken from New Horizons RI/FS dated Jan. 24, 2004
*Ambient Level taken from S. M. Stoller Final Work Plan – Environmental Assessment and Characterization – CSMRI Site Flood Plain Area dated August 2010

The tentative cleanup goal of 14 ppm for uranium was determined by evaluating (1) the ambient concentration of uranium from the background study, (2) the results of geochemical modeling, (3) field screening instrument sensitivity, (4) published risk-based soil standards for uranium from EPA Region 3, and (5) Site data. Each of these items is discussed in more detail below:

- The background study undertaken determined that the ambient uranium concentration from a nearby analogous depositional environment upstream of the Site is 6.45 micrograms per kilogram (mg/kg). This value was statistically derived by using the mean uranium value of the sample population 3.05 ppm plus two standard deviations of 1.7 ppm.

- Geochemical evaluation of groundwater was performed to determine a Site-specific soil partitioning coefficient (K_d) and calculate a SSL. The evaluation involved batch adsorption testing of soil and groundwater samples collected from the flood plain. The results of this testing found K_d values 0.01 to 0.19 L/kg resulting in SSL calculated values of 0.114 to 0.219 ppm. Geochemical modeling of the leachate was performed using PHREEQCi to speciate the solution and evaluate potential precipitation and sorption mechanisms that may attenuate uranium concentrations along the groundwater flow path. The geochemistry determined that virtually all uranium present in Site groundwater was in the soluble form U^{+6} present as carbonate. Given these results, ambient uranium in soil could result in groundwater uranium concentrations as high as 400 ppb. However, this was determined using an EPA test method that is considered to be very aggressive and provides a partitioning coefficient that can be considered to be a conservative value for the Site.

- The field screening instrument that is critical for the success of this investigation is the x-ray fluorescence (XRF) instrument. Real-time analysis of COC concentrations is the key to being able to perform the characterization of soil from beneath the water table without handling and treating groundwater, which is technically challenging and very expensive. The XRF has a limit of detection of 7 ppm for uranium using a 2-minute count time and assuming less than 3 percent total metals in the sample (high metals concentrations shield the soil response, which elevates the detection limit). A tentative cleanup goal for uranium that can be achieved with a degree of certainty using the field instrumentation is two times the limit of detection or 14 ppm.

- The tentative cleanup goal of 14 ppm is consistent with Regional Screening Level Summary Table (June 2011) presented in the EPA Region 3 Mid-Atlantic Human Health Risk Assessment (2011). This assessment assumes what little source of uranium exists in the groundwater would never communicate in the bedrock formations to a receptor; this assumption is consistent with known Site conditions. The human health-based assessment determined that a screening level of 14 ppm for uranium in soil is protective of groundwater at the 30 μg/l (ppb) maximum contaminant level (MCL).

- Uranium concentrations in soil are pervasive across the flood plain. The majority of the Site has uranium concentrations at less than twice ambient levels with the exception of the west end where concentrations are higher. Dissolved uranium in groundwater is present across the Site in decreasing concentrations toward the east indicating a likely contaminant source for groundwater in the vicinity of well CSMRI-8. Soil uranium concentration values determined from test pits indicate that using a tentative Site cleanup goal of 14 mg/kg (ppm) will eliminate this source material from the Site. Test pit CLT-6, which identified uranium concentrations exceeding the tentative cleanup goal, was installed to determine the geotechnical characteristics of the berm in the event a low-permeable barrier wall was determined to be necessary. The berm is a Site feature that consists of an elevated strip of land immediately adjacent to Clear Creek. Because of the risks that characterization activities have of impacting the Creek, a 5- to 10-foot setback from the Creek has been established for this work. This may result in elevated uranium being left in place within the berm, but would be minimal amounts.

The ambient uranium concentration for soil in Clear Creek Alluvium is 6.45 mg/kg as determined from sampling and analysis. The proposed soil cleanup goal of 14 mg/kg (ppm) for uranium is inclusive of the ambient concentration.

Additionally, the CDPHE requested that 78 ppm for vanadium be used as a tentative cleanup goal rather that the previously used goal of 550 ppm. The concentrations in Table 3-6 were derived by combining background levels with the DCGL to arrive at the tentative cleanup goal. Based on previous sampling efforts on the upper terrace portion of the Site, five of the metals listed above (arsenic, lead, mercury, molybdenum, and vanadium) were present at levels above these tentative DCGLs; therefore, these metals were considered COCs. Uranium was also added to the COC list. Levels of the other metals onsite were already below the tentative DCGLs and no further analysis was conducted. The listed radioisotopes were also considered COCs.

3.5 Flood Plain Soil Investigation

After the test pit preliminary investigation concluded, additional and more intensive flood plain soil investigation work was performed and completed in the fall of 2010. This investigation used the data generated during the previous EPA and Stoller work to guide further data collection and determine nature and extent of contamination. This was accomplished only after detailed planning and analysis. A re-examination of Site data and the mechanisms of contaminant placement and regulatory framework was completed to evaluate the possible investigation options. Due to the heterogeneous nature of Site contaminants generated by the numerous research projects conducted at this Site, which is unlike many other sites contaminated with radionuclides and metals, additional data were required to accurately determine the nature and extent of contamination within a reasonable confidence range. The additional data are necessary to enable remedial cost estimates to be developed within the +50 percent to -30 percent range in the RI/FS stage and +15 percent to -10 percent range for the remedial design and implementation stage of the remedial action. Estimating a volume of impacted soil based on the data in the EPA Closure report, the 2006 Stoller work, and the test pit, characterization was not possible with the requisite degree of confidence.

Therefore, the question became what method to use for additional Site characterization. To attempt to determine the volume of impacted material onsite using traditional methods of boreholes investigation would have been comparable in cost to the technique selected but would have provided significantly less certainty in volume estimates. Additionally, the data confirmed the need to take action. Any remedial action would include excavation of soils impacted by past Site activities above cleanup goals.

The investigative method selected was to excavate the impacted soil and stockpile it onsite to determine the nature and extent of contamination. This excavation method is analogous to the method used by EPA to address the former settling pond at the Site and used by Stoller in 2007 to characterize the upper terrace. EPA had excavated the former settling pond down to the UMTRA cleanup goals for Ra-226 of 5 pCi/g for soil from the ground surface to 0.5 ft bgs and 15 pCi/g for soil depths greater than 0.5 ft. EPA-excavated soils were stockpiled at another location on the Site for further characterization work for disposal purposes.

Further, the characterization by excavation implemented on the flood plain was appropriate in that the no-action alternative would be rejected based on the following reasoning.

CDPHE notified the School in a letter, dated September 18, 2009 of the following:

> “Specific actions should be proposed to bring the ground water contamination noted in wells CSMRI-4, CSMRI-8 and CSMRI-9 into compliance. Ground water contamination remains un-resolved at the Site. A specific remediation plan and schedule, which can include ground-water monitoring, is needed. An environmental covenant is not an appropriate remedial action at the Site unless future studies determine that it remains the only option.”

The School had sufficient well monitoring data to confirm the presence of a uranium plume as identified by the CDPHE and agreed that a better understanding of the geology, hydrology, and contaminant distribution on the flood plain was necessary. As part of the preparation of a work plan to complete a flood plain characterization, a preliminary characterization was conducted as described in Section 3.3. The results delineated exceedances of Site cleanup goals for several metals in soil from two test pits on the western portion of the flood plain, specifically around monitoring well CSMRI-8. The presence of these exceedances further supports the rejection of the no-action alternative. It was clear that a source of contamination was in the soil that needed to be addressed in some proactive manner. The only reasonable remedial action alternative that did not involve excavation was capping the floodplain, but that was easily screened out because the source material would continue to contaminate the groundwater due to the fact that the contamination was in contact with groundwater including creek water that was entering the subsurface at the floodplain.

Rejection of the no-action alternative was confirmed by data recovered from the soil excavated from the flood plain and stockpiled on the upper terrace for eventual dispositioning. Samples from this soil contained levels of Ra-226 far exceeding the cleanup goals as described in Section 4 of this document.

Furthermore, the estimated cost of using this excavation investigative method was comparable to the cost for using the traditional method of borehole site investigation to complete the subsurface site investigation. In addition, the excavation method simultaneously performs the likely inevitable task of soil excavation and guarantees the requisite degree of confidence to determine the nature and extent of the contamination to reliably estimate the cost of remediation alternatives, unlike the traditional investigation method of boreholes. The excavation investigative method was as cost effective as the traditional method, but it was expected to produce more reliable results than the traditional method.

To maintain fiscal responsibility and attain the requisite degree of confidence to estimate nature and extent of contamination, the Site characterization technique of excavating and stockpiling impacted material was adopted. Field screening tools were used to guide excavation. Laboratory analyses were used to confirm that tentative cleanup goals were met and to determine the lateral and vertical extent of contamination.

This RI/FS report describes the flood plain investigation conducted during 2010 on the western portion of the flood plain, excluding other areas that formerly comprised the CSMRI Site. The extent of impacts to Site soils was successfully determined during this investigation. This investigation was conducted in accordance with the approved Site Characterization Work Plan (Stoller 2010a).
Tasks completed as part of the Site investigation included:

- Site preparation
- Instrument bias/correlation
- Iterative lateral and vertical extent determination and excavation
- Confirmatory sampling
- Site reclamation

The highly heterogeneous nature of contamination at the Site complicated efforts to derive a strong correlation between field screening data and laboratory data. However, the use of reasonably accurate correlations allowed for the use of field screening methods and instrumentation that were critical to allow timely determination of excavation end points. The co-location of many of the COCs along with overlapping use of the different field instruments helped to ensure that the correlations used were effective in achieving the project goals.

3.5.1 Site Preparation

Several tasks required completion prior to initiating soil characterization activities. These tasks included evaluating the responsiveness of the field instruments to Site conditions and preparing the Site for characterization activities.

3.5.2 Instrument Bias/Correlation

During Site characterization activities, field and laboratory screening instruments along with visual observations were used to guide excavations. These instruments included a field XRF spectrometer, a microR meter, and a hand-held sodium iodide (NaI) gamma scintillator. To quantify the relative effectiveness of the XRF spectrometer for detecting contaminants above the tentative cleanup goals but still very near the instrument's limit of detection, samples were taken for metals analyses and sent to an approved offsite laboratory. Data generated using different field techniques were cross-correlated, as well as compared to laboratory data. After the initial data were compiled, a thorough data review and comparison were made to determine if any biases exist and, if so, whether there was a correlation between the different measurement results. The basis for determining the correction factors was documented in laboratory and field logs, as applicable for the instrument. The initial correction factors were refined and adjusted as necessary based on additional data collected during the ongoing characterization activities. Results of this study indicated the screening instruments allowed semi-quantitative assessment of contaminant levels.

3.5.2.1 Gamma Detection Instruments

Site characterization activities included the segregation of soils emitting gamma radiation above two times background. A non-impacted soil location on the site was selected and agreed upon with the CDPHE for gamma background determination. Background levels established daily averaged 19 microR/hr using a Ludlum Model 19 microR meter and 16,250 counts per minute (cpm) using a Ludlum Model 2350-1 meter connected with a Ludlum Model 44-10 NaI scintillation detector.

3.5.2.2 XRF Bias Determination

In-situ metals analyses were performed using a field portable XRF spectrometer. *In-situ* XRF measurements may differ from, but have the ability to be directly correlated to, laboratory results. The magnitude of this bias was dependent on Site and sample conditions. To quantify this bias for the materials on this Site, soil was evaluated by the field XRF and also submitted to an offsite laboratory for metals analyses. Twenty sampling locations representing a range of field readings were selected based on historical data and field XRF readings. After the laboratory data were obtained, a correlation curve was generated for each element in question. A correction factor for the XRF was then calculated based on the correlation curve for each element. This correction factor was entered into the XRF, allowing it to automatically account for bias. If the correlation was not well defined, a conservative correction factor was used.

The metals and radionuclides were not always co-located, making the use of one as a surrogate for the other impractical in some instances. The uranium correlation was determined to be less than optimum at soil concentrations approaching the instrument's level of detection. Therefore, as the characterization progressed, the percentage of QA/QC samples sent to the laboratory was increased from the 10 percent specified in the work plan to 15 percent. As additional soil sample results were received from the offsite laboratory, these additional results were used to confirm that the correct limits of excavation had been reached and were also used to further evaluate the instrument's correlation. The result was a correlation that degraded as the project progressed because the XRF has poor precision at the instrument's limit of detection, which was very close to the action level and the concentration Stoller measured at the majority of the sampling locations. Field procedures were then modified to further evaluate uranium concentration in field screening samples where *in-situ* uranium concentrations were between 10 ppm and 12 ppm. In addition the work plan was modified so that the soil at any location with an *in-situ* XRF reading above 13 ppm was excavated while readings between 10 and 12 ppm were reevaluated using the XRF (i.e., re-shot *in situ* and/or bagged and sieved). This revised approach allowed an increased level of certainty in the decision to characterize the soil as either exceeding the tentative cleanup standards or not.

The XRF was only used as a qualitative assessment of metals in soils; extent and final confirmatory determinations were based on laboratory data.

3.5.3 Iterative Lateral and Vertical Extent Determination and Excavation

Extent determination commenced only after necessary adjustments to field operations and field screening instruments were made, based upon data collected during the instrument bias/ correlation phase of the project.

3.5.3.1 Soil Sampling Protocol

Each sample location was marked with a pin flag that was labeled with the sample number. XRF readings and global positioning system (GPS) readings were taken at each sample location, and the results were recorded in the instrument data loggers. Field gamma and microR readings were also taken at each sample location and were recorded on the sample log sheet.

Soil was collected in a stainless steel bowl using a stainless steel scoop, both of which were decontaminated between sample locations. Large rocks and vegetation were excavated. Soil samples were sieved to screen out objects larger than 0.25 inches. Duplicate and composite samples were well mixed in the bowl prior to filling the individual 8-oz plastic sample containers. After each jar was filled with soil, an additional XRF reading was taken prior to sealing the jar for comparison to the *in-situ* reading and the offsite laboratory result. The sample numbers were written on the container lids with permanent marker. Duplicate samples were given consecutive sample numbers and identified as such on the sample log sheet. Containers were then swiped for contamination, and the swipes were counted in the onsite laboratory for removable alpha and beta contamination. After containers were verified to be free of contamination on the exteriors, labels were applied to each container. Labels contained the following information:

- Date
- Time
- Sample number
- Name of sampler
- Required analysis
- Required preservative (if any)

3.5.3.2 Radiological Screening

Screening for gamma radiation levels was performed in conjunction with the *in-situ* XRF readings. Both the microR meter and the hand-held NaI scintillation detector were used to identify gamma radiation levels that were greater than two times background. Soils exhibiting levels greater than two times background were targeted for excavation.

3.5.3.3 Initial Metals Sampling

After the site work area was cleared and grubbed, a 10-foot by 10-foot grid was established in the work area using the GPS. Each point on this grid was sampled following the required sampling procedures (Photograph 3.1 in Appendix A). If an area required excavation due to XRF readings that exceeded the Site action levels, or due to field gamma detector readings that exceeded twice the background level, that area was excavated up to the next adjacent “clean” grid point in a 1-foot lift (Photograph 3.2 Appendix A). The excavation process was repeated, starting with a new 10-foot by 10-foot grid and continued laterally and/or vertically until all sample locations were considered “clean,” bedrock was encountered, or some other barrier was encountered (e.g., water lines or the river). Whenever artificial fill material was observed within the characterization excavation, it was excavated and transported to the stockpile. Confirmatory laboratory samples were collected from at least 10 percent of all XRF samples.

3.5.3.4 Continuing Metals Sampling

Based on XRF results from the initial metals sampling, soil exceeding tentative Site DCGLs for any of the six metals of concern was excavated to the stockpile in approximately 1-foot lifts. Each area was then resampled on an approximately 10-foot by 10-foot grid. This procedure was repeated until XRF readings were below the Site tentative DCGLs for all six metals.

3.5.3.5 Final Metals Sampling

A total of 54 confirmation samples were sent to the offsite laboratory for metals analysis. Of these 54 confirmation samples, 18 samples were from locations that were not excavated and remained in place following characterization.

3.5.3.6 Stockpile Sampling

The excavated soil was stored into one stockpile on the upper terrace, just above the flood plain. The stockpile contains approximately 1,400 cubic yards. Ten samples and one duplicate sample were collected, for a total of 11 stockpile samples. Each stockpile sample was a composite of five aliquots taken from an area of approximately 100 square feet. The ten stockpile sample locations were randomly generated across the surface of the stockpile in order to collect representative samples. All stockpile samples were submitted to the offsite laboratory for metals and radionuclide analyses. XRF and GPS readings were not taken for stockpile samples. Results of the stockpile sampling are summarized in Section 4.

3.5.4 Confirmation Sampling

After contaminated soils were excavated and placed in the stockpile, *in-situ* soils remaining at the Site were sampled to confirm attainment of cleanup goals (i.e., nature and extent determination) and serve as the final status survey.

Eighteen of the 54 confirmation samples that were submitted to the offsite laboratory represent *in-situ* soil samples that remained following excavation. These 18 samples were also used as post-characterization samples and were submitted for metals and radionuclide analysis.

3.6 Air Monitoring

Two air monitoring stations were used during the characterization activities (Photograph 3.3 Appendix A). Both monitoring stations were placed downwind of the project Site based on prevailing wind direction. The monitors were placed to perform air monitoring between active work areas and the nearby neighborhood and the School's athletic fields. One monitoring station was located on the flood plain east of the characterization work area, and the other station was located on the upper terrace east of the soil stockpile. Airborne radioactivity samples were obtained on 47-millimeter diameter glass fiber filters at a sampling rate of 60 liters per minute. Samplers were run continuously during the characterization field work. Operational hours of the samplers were recorded for use in calculating air volume. Filters were changed and analyzed on a weekly basis during the time when active soil sampling/excavation was being conducted.

Samples were counted for gross alpha activity using a Ludlum Model 2929 alpha/beta scaler with a Model 43-10-1 detector in accordance with procedure SOP-RAD-031, *Counting Systems Operation*. Measured count rates (cpm) were converted to disintegrations per minute (dpm) using the efficiency of the detector. The measured dpm values were converted to microcuries and divided by the total volume of air sampled in milliliters for comparison to the effluent air concentration standard. Table 3-7 shows the Colorado effluent concentration limits for the radionuclides of concern on the Site. The chemical form of the radionuclides on the Site is unknown; therefore, the limits for Class W compounds, which are the most restrictive, are shown in Table 3-7.

Table 3-7
Effluent Concentration Standards[1]

Isotope (Class W)	Concentration (microcuries per milliliter)
Ra-226	9 E-13
Ra-228	2 E-12
Th-228	3 E-14
Th-230	2 E-14
Th-232	4 E-15
U-234	1 E-12
U-235	1 E-12
U-238	1 E-12

[1] 6 CCR 1007-1 Part 4, Appendix 4B, Standards for Protection Against Radiation

Samples were held for a minimum of 72 hours prior to counting to allow the radon and progeny to decay. All air sample results were generally an order of magnitude beneath the limits; however, per the work plan all of the flood plain air samples were submitted to the laboratory for isotopic analyses. Three of the six air filters collected from the upper terrace were submitted to the laboratory as well. Filters from the upper terrace not submitted have been saved in the event future laboratory sampling is deemed necessary. A summary of final air sample results as reported by the laboratory are presented in Table 3-8. Detailed air sample results are presented in Appendix B.

Table 3-8
Air Monitoring Summary CSMRI Creekside Site Characterization
October – November 2010

	Ra-226 (µCi/ml)	Ra-228 (µCi/ml)	Th-228 (µCi/ml)	Th-230 (µCi/ml)	Th-232 (µCi/ml)	U-234 (µCi/ml)	U-235 (µCi/ml)	U-238 (µCi/ml)
Air sampler flood plain 10/6/10 - 10/8/10	9.1E-15	9.0E-15	2.2E-15	-1.6E-15	1.3E-15	1.8E-15	0.0E-16	1.3E-15
Air sampler terrace 10/6/10 - 10/8/10	1.9E-15	1.1E-14	-8.0E-16	-1.7E-15	2.8E-16	8.9E-16	9.0E-17	8.0E-16
Air sampler flood plain 10/11/10 - 10/15/10	2.2E-15	1.3E-14	1.7E-15	0.0E-15	8.6E-16	9.6E-16	7.0E-17	5.1E-16
Air sampler flood plain 10/18/10 -10/22/10	9.0E-16	1.3E-14	1.0E-16	2.3E-15	1.5E-15	6.5E-16	4.4E-16	1.1E-15
Air sampler terrace 10/18/10 - 10/22/10	9.0E-16	1.1E-14	-1.8E-15	-4.0E-16	1.5E-15	1.1E-15	1.6E-16	4.0E-16
Air sampler flood plain 10/25/10 - 10/29/10	1.5E-15	5.0E-15	-1.0E-16	1.4E-15	6.4E-16	1.9E-15	2.8E-16	1.0E-15
Air sampler flood plain 11/1/10 - 11/5/10	1.8E-15	-3.0E-15	1.0E-16	5.0E-16	1.3E-15	7.2E-16	1.5E-16	3.8E-16
Air sampler terrace 11/1/10 - 11/5/10	6.0E-16	1.4E-14	2.0E-15	9.0E-16	9.3E-16	7.0E-16	5.0E-17	7.0E-16
Air sampler flood plain 11/8/10 - 11/10/10	5.0E-15	7.0E-15	7.0E-16	2.4E-15	1.5E-15	2.0E-15	5.3E-16	1.0E-15

µCi/ml – microCuries per milliliter

3.7 Groundwater Investigation

Groundwater will be discussed in detail in an RI/FS for the groundwater operable unit (OU 2) at a later date. This document addresses the soil operable unit (OU1) and presents a summary of groundwater conditions in the text that follows.

Groundwater occurs under unconfined conditions in the alluvium/colluvium of the Site. Depth to the water table ranges from about 3 to 30 feet bgs, which is strongly dependent on vertical distance above the creek and/or depth to bedrock. Based on surface and bedrock topography, groundwater generally flows to the northeast toward Clear Creek. The alluvial/colluvial deposits are mainly recharged by infiltration of precipitation and to a limited extent by Clear Creek during periods of high flow. The alluvial/colluvial system naturally discharges to Clear Creek.

Five groundwater monitoring wells were initially installed at the Site in the 1990s. During the 2004 RI, two additional monitoring wells were installed using two of the borings drilled during the subsurface investigation. The purpose of the installation was to provide additional groundwater (upgradient and downgradient) data for the Site. Wells have been sampled on a monthly basis, with quarterly monitoring reports being provided and submitted to CDPHE. The upgradient well (CSMRI-6) location was positioned along the north-south boundary with the baseball field. The downgradient well (CSMRI-7) was positioned north of the former Building

101N foundation and above the former settling pond. CSMRI-6 was 43.5 feet deep and CSMRI-7 was 20 feet deep. These two wells were later abandoned and then replaced.

Groundwater in the shallow alluvium/colluvium has been shown to contain elevated levels of uranium, a COC that occurs naturally in the bedrock formations and in the surficial deposits that comprise the Site. The elevated groundwater concentrations in question have been attributed to migration of radionuclides from materials that were formerly located on the Site and are now residing in the lined stockpile.

In February 2007, Stoller installed seven additional groundwater wells to track the effectiveness of uncontained source remediation in addressing elevated uranium concentrations in groundwater beneath the Site, augment the characterization data, and provide a better understanding of the geohydrologic conditions in the alluvial/colluvial aquifer at the Site. These wells were installed in accordance with the approved work plan, *Groundwater Monitoring Well Installation Work Plan, CSMRI Site* (Stoller 2006d).

As part of this RI, three new wells were installed and will be reported on in the Groundwater RI/FS under separate cover.

4. Nature and Extent of Affected Materials 4-1
4.1 Summary of Previous Flood Plain Soil Characterization 4-1
4.2 Applicable Regulatory Classification 4-1
4.3 Flood Plain Site Soil (OU1) Characterization Results 4-1
4.3.1 Structures Encountered during Characterization 4-2
4.3.2 Nature and Extent of Impacted Soil 4-4
4.3.2.1 Metals 4-4
4.3.2.2 Radionuclides 4-8
4.3.2.3 Exceptions to Nature and Extent 4-9
4.3.2.4 Nature and Extent Conclusions 4-10
4.3.2.5 Stockpile Sampling Results 4-10
4.4 Groundwater (OU2) Characterization 4-12

List of Tables

Table 4-1 Laboratory Metals and Ra-226 Results (mg/kg) of Soil Sample Collected in Concrete Tunnel 4-3
Table 4-2 Laboratory Metals Results Excavated Material 4-5
Table 4-3 Final Metals Confirmatory Sample Results and Summary Statistics 4-7
Table 4-4 Laboratory Radionuclides Results Excavated Material 4-8
Table 4-5 Final Radionuclide Confirmatory Sample Results and Summary Statistics 4-9
Table 4-6 Exceptions to Confirmatory Data Set for Extent 4-10
Table 4-7 Stockpile Laboratory Metals Results 4-11
Table 4-8 Stockpile Laboratory TCLP Results 4-11
Table 4-9 Stockpile Laboratory Radionuclide Results 4-12

List of Figures

Figure 4-1 Location of Entrance to Concrete Water Tunnel
Figure 4-2 Final Uranium Confirmatory Sample Results
Figure 4-3 Final Lead Confirmatory Sample Results
Figure 4-4 Final Arsenic Confirmatory Sample Results

4. Nature and Extent of Affected Materials

Section 4 characterizes the nature and extent of waste and contaminated soil on the CSMRI flood plain site. COCs include:

- Metals – arsenic, lead, mercury, molybdenum, uranium, and vanadium
- Radionuclides – radium, thorium, and uranium

4.1 Summary of Previous Flood Plain Soil Characterization

The results of the EPA emergency removal action for the former settling pond were presented in the EPA Closure Report and are incorporated by reference. As described in Section 3.1, these data provided little information on remaining concentrations of Site COCs. The other two characterization efforts, conducted by Stoller in 2007 and 2010 and summarized in Sections 3.2 and 3.3 of this RI/FS, increased the understanding of the impacts to the flood plain as well as provided valuable information about the subsurface stratigraphy. Based on site knowledge supported by data, the west end of the flood plain contained soils that were acting as a source for groundwater contamination.

4.2 Applicable Regulatory Classification

The regulatory classification of Site contaminated soils was presented in Section 4.1.11 of the 2004 RI/FS and Section 4.2 of the 2007 RI/FS, which are hereby incorporated by reference. The conclusion of these sections was that the soil is "solid waste" that may be disposed of at a solid waste disposal facility that can demonstrate the ability to safely accept and dispose of the soil. Because the data recovered from the flood plain site are similar to that recovered during the 2004 and 2007 RI/FS, the conclusion that the contaminated soil is solid waste remains the same in this RI/FS for the 1,400 yards of flood plain soil now stockpiled on the upper terrace. The solid waste landfills considered for disposal have agreed to accept the stockpile.

4.3 Flood Plain Site Soil (OU1) Characterization Results

As described in Section 3, characterization activities identified soil with radionuclides and/or metals above tentative Site action levels on the flood plain. These soils were excavated in incremental layers and placed in the onsite stockpile. At the conclusion of characterization activities, the majority of contaminated soil had been excavated and located in the stockpile, and the majority of unexcavated material remaining on the Site was below the tentative cleanup action levels. This approach allowed determination of the nature of the material (based on *in-situ* and stockpile sampling) and extent of material (based on excavated or stockpile volume and confirmatory sampling showing the Site now meets tentative Site action levels).

The one area containing soil above the tentative cleanup goals that was not excavated was adjacent to the City water main. Stoller was directed by the City of Golden that further excavation of soil posed an unacceptable risk to the structural integrity of the potable water main and that soil excavation should stop. Specifically, the thrust block installed to protect the tee, where two water mains intersected, was not anchored in bedrock, and additional excavation of alluvium could cause the integrity of these water pipes to be compromised. CDPHE concurred to leave the small amounts of soil. Therefore, a limited quantity of soil above the tentative cleanup levels, located approximately 10 feet on either side of the water main, was left in place. (Photograph 4.1 Appendix A)

The primary purpose of the flood plain characterization was to identify material in soil that might be acting as a source of dissolved uranium groundwater contamination beneath the Site. Material identified by field screening as impacted or visually observed as containing artificial fill was excavated and placed in the stockpile located on top of the terrace. The one exception, the contaminated soil near the City of Golden water main, is explained above.

Conservative groundwater modeling demonstrated that under the existing Site conditions and water chemistry even a small amount of source material could have significant impacts on groundwater quality. Field screening of the overburden soil determined that although contaminant levels were below the tentative cleanup goal for the flood plain soil, small concentrations above background but below cleanup goals of contaminants remained in this soil. For this reason, the “clean” soil that was excavated as overburden during clearing and grubbing operations was excavated and managed on the upper terrace. No material excavated from the flood plain was returned to the flood plain.

Monitoring well CSMRI-8, which has historically contained the highest concentrations of dissolved uranium, was abandoned and surrounding soil included for excavation as part of the characterization effort.

4.3.1 Structures Encountered during Characterization

During abandonment of groundwater well CSMRI-8, it was apparent that the well was completed in fill material, as large timbers and debris were observed in the immediate area of the well. As the excavation proceeded to bedrock (per the work plan), the top of a steel tank that was buried in the weathered Pierre Shale was encountered. This tank was excavated and determined to be a water/sand filter. It had been used to filter water being supplied to research operations at the Site. Two soil samples, one from outside the tank and one from the sand inside the tank, were collected and screened for COCs using the XRF. While the soil sample from the outside the tank measured uranium at 77 mg/kg, the concentration of uranium from the sand inside of the tank was below the instrument’s level of detection (7 ppm).

When the tank was excavated, it exposed the opening of a 4 foot wide by 6 foot high concrete water supply tunnel. The tunnel was embedded in competent Pierre Shale bedrock, with the entrance nearly filled to the top with soil and debris. Upon revealing the entrance, water initially flowed out of the tunnel at a rate estimated to be a few gallons per minute and shortly thereafter slowed to a trickle. The entrance of the tunnel was located directly beneath a City of Golden 20-inch water main. The tunnel trended due south into the steep terrace slope beneath the 12-inch raw water line with no observable change in grade (Figure 4-1). (Photograph 4.2 Appendix A)

Information was gathered about the tunnel to determine the best course of action. Soil near the entrance was excavated and sloped back to allow for access, and a hydrovac unit was used to vacuum as much of the soil and debris as possible out of the tunnel.

Water appeared to be flowing out of the tunnel; however, it was not possible to determine if the groundwater had flowed into the tunnel from the surrounding alluvium prior to opening the entrance to the tunnel or if the water was emanating from a source within the tunnel. A sample was collected of the water flowing from the tunnel for analytical laboratory analysis. The water sample collected from the tunnel had a dissolved uranium concentration of 360 µg/L. This concentration is consistent with that observed in the west seep during the September 2010 sampling event, which also measured dissolved uranium concentrations of 360 µg/L. In addition, a sample of sediment was collected from 15 feet inside the entrance of the tunnel and sent for analytical laboratory analysis of metal COCs and Ra-226. The laboratory results from the sediment sample and a duplicate sample are presented in Table 4-1 and show uranium, lead, arsenic, and Ra-226 concentrations above the tentative cleanup goals. Material was vacuumed from the tunnel using the hydrovac to a distance about 20 feet inside the entrance where vacuuming was no longer effective. A 40-foot-long string of 1-inch PVC pipe was then pushed along the top of the remaining soil and debris into the back of the tunnel without refusal, confirming the tunnel penetrated at least 40 feet into the terrace.

Table 4-1
Laboratory Metals and Ra-226 Results (mg/kg) of
Soil Sample Collected in Concrete Tunnel

Sample ID	Uranium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Molybdenum (mg/kg)	Mercury (mg/kg)	Vanadium (mg/kg)	Ra-226 (pCi/g)
00404-03	30	410	65	120	2.5	26	5.5
00404-03 (duplicate)	31	359	119	121	na	31.9	8.5
Tentative Cleanup Goal	14	400	39	390	23	78	4.14

mg/kg - milligrams per kilogram
pCi/g - picoCuries per gram

After withdrawing all material from the tunnel that could be accomplished using the hydrovac and consulting with CDPHE, a 3/8-inch-thick steel plate was placed in front of the entrance of the tunnel, and 108 sacks of bentonite chips (total of 5,400 lbs) were opened and hand placed behind the plate to create an impermeable plug approximately 3 feet thick. The excavation was then backfilled with clean imported 6-inch minus alluvium. Special care was taken to ensure the steel plate did not shift during backfill activities. (Photograph 4.3 Appendix A)

A subsequent search of historic documents from the School's library found the following reference in the *Quarterly of the School of Mines* vol. 7, July 1912.

> "A concrete-lined well, 5 ft in diameter and 25 ft deep, has been sunk near the bank of Clear Creek. A 4 by 6-ft tunnel, 120 ft long, extends from the bottom of the well to a stratum of gravel under the bed of the creek. The well and tunnel have a storage capacity of 20,000 gal. The pumping outfit consists of an automatic motor-driven, submerged-type, two-stage centrifugal pump. This has a capacity of 100 gal per minute against 50-lb pressure, pumping into pressure storage tanks of 2,500-gal capacity. An ample supply of clear water is thus assured for all operations."

Thus, the tunnel and well were constructed to provide water for research at the Site.

Laboratory results from the groundwater sample collected from naturally occurring seeps along the toe of the terrace slope found dissolved uranium concentration consistent with water found inside the tunnel. It cannot, therefore, be determined with a sufficient degree of certainty if contaminated water is originating from a source within the tunnel or if impacted groundwater is flowing into and being stored in void spaces inside the tunnel. The sediment sample collected from the tunnel detected elevated concentrations of COCs. However, these COC concentrations are consistent with soil COC concentrations observed throughout the Site during the Site characterization. Although some contribution is likely, the tunnel sediments do not appear to be the single source, or even a primary source, of contamination in the flood plain. Whatever the contribution of sediment inside the tunnel to overall groundwater quality may have been, it has been reduced by minimizing the flow of groundwater into the north entrance of the tunnel by installation of the impermeable bentonite plug.

4.3.2 Nature and Extent of Impacted Soil

This section presents the laboratory results of soil samples collected for nature and extent determination, including samples that were taken from *in situ* material prior to excavation that was ultimately excavated and transported to the stockpile (nature) and confirmatory samples that were below the tentative action levels (extent). Composite samples taken from the stockpile for landfill waste acceptance and remedial action analysis are summarized in Section 4.4. They are included in this analysis to demonstrate the nature of the radioisotopes and to evaluate remedial alternatives.

The flood plain site characterization was conducted using a combination of visual observations and field screening instrumentation. This process identified soils containing characteristic CSMRI wastes (crucibles, bricks, soil with purplish discoloration), elevated concentrations of metals, and/or gamma activity above the tentative Site action levels (Photographs 4.4 and 4.5 Appendix A). These contaminated materials were transported to the onsite soil stockpile. The field screening instruments were correlated to and backed up by laboratory data. This characterization effort was an iterative process where each surface following excavation of a lift was re-screened until the tentative action levels were achieved.

The extent of impacted soils was physically constrained on three sides by Clear Creek to the north and west, and to the south by the boundary limits of the 2007 remedial action on the upper terrace.

The data sets are presented below, first for the nature and extent of metal compounds, followed by the nature and extent of radioisotopes. Appendix C includes offsite analytical laboratory sample and data validation summary reports for the laboratory data packages.

4.3.2.1 Metals

During this characterization effort, COCs included those assessed during characterization work on the upper terrace (lead, arsenic, mercury, molybdenum, and vanadium as well as uranium). Uranium was added because this characterization effort was designed to target soils acting as a source for a dissolved uranium plume in the flood plain groundwater. The nature of the metals contamination is represented by the data set that includes the samples taken from soil that was determined to exceed tentative Site action levels and was excavated and placed in the stockpile

(Table 4-2). Extent of the metals is defined by the sampling locations of the confirmatory data set and is equal to the volume of soil in the stockpile. For this characterization effort, the soil stockpile was comprised of 1,400 cubic yards of contaminated soil.

4.3.2.1.1 Metals Nature

A total of 54 soil samples were sent to the offsite laboratory for metals analysis. These samples represent contaminated soils that were excavated and placed in the stockpile. These samples include field sampling duplicates but do not include QA/QC laboratory duplicates or stockpile samples. Laboratory analytical results for metal COCs are presented in Table 4-2.

Table 4-2
Laboratory Metals Results Excavated Material

Sample ID	Uranium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Molybdenum (mg/kg)	Mercury (mg/kg)	Vanadium (mg/kg)
00057-03	6.8	46	7.6	1.7	0.68	19
00073-03	17	55	11	3.4	3.1	21
00075-03	18	48	8.1	3.4	0.33	20
00084-03	4.1	36	5.3	1.3	0.15	17
00091-03	25	69	17	5.8	2.6	23
00092-03	13	48	8	2.8	0.56	21
00102-03	9.7	51	10	3.3	0.79	24
00106-03	16	200	28	22	3	30
00109-03	22	200	17	25	2.4	29
00112-03	19	220	20	29	3.3	54
00116-03	36	280	65	38	13	37
00117-03	11	82	12	8.4	1.3	20
00124-03	20	120	15	26	2.5	54
00141-03	21	200	27	22	1.9	23
00144-03	19	79	14	16	1	16
00148-03	26	140	29	14	0.7	16
00152-03	25	200	33	21	3.1	27
00163-03	9.4	86	23	8.2	2.7	20
00165-03	20	160	30	16	4	26
00185-03	75	7100	780	210	420	120
00195-03	16	520	150	25	290	46
00196-03	12	130	27	13	230	40
00200-03	14	270	56	36	76	49
00202-03	36	170	42	10	11	28
00205-03	11	50	13	3.7	4.1	22
00214-03	15	42	6.8	2.1	0.34	24
00231-03	16	100	28	11	2.6	28
00232-03	16	150	30	14	3	27
00236-03	25	68	14	5.3	0.84	27
00237-03	15	60	15	4.2	1.2	23
00257-03	5.2	19	3.3	1.2	0.29	14
00259-03	11	51	11	3.2	0.89	29
00267-03	8.4	160	14	5.2	12	31
00268-03	23	890	34	47	3.5	48
00279-03	3.1	87	17	2.2	1.2	25
00286-03	24	110	19	6.1	1.5	28
00288-03	26	95	16	4.9	1.8	26

Sample ID	Uranium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Molybdenum (mg/kg)	Mercury (mg/kg)	Vanadium (mg/kg)
00305-03	13	68	11	4.1	0.84	25
00321-03	15	190	16	6.5	1.6	30
00325-03	15	150	23	10	0.96	29
00336-03	19	650	27	14	14	29
00352-03	21	440	33	4.7	0.46	38
00353-03	3.3	26	15	1.6	0.03	36
00354-03	4.5	29	10	0.53	0.094	34
00355-03	2.6	66	8	4.1	1.5	36
00357-03	2.6	28	3.1	0.83	0.024	19
00374-03	3.3	61	4.8	5.1	0.44	32
00375-03	4.9	170	24	1.7	14	27
00381-03	11	41	5	1.8	0.26	19
00384-03	6.7	95	9.3	3.8	1.2	25
00386-03	2.7	13	1.8	0.38	0.025	12
00387-03	5.5	220	22	6.5	16	25
00388-03	3.1	40	6.1	2.6	0.35	29
00422-03	2.9	60	8.3	8.4	0.48	54
Mean	15.29	272.94	34.66	14.08	21.47	30.20
Std Dev	11.82	959.94	105.67	29.10	74.67	15.96
Geo Mean	11.61	103.99	15.39	6.64	1.72	27.70
Tentative Goal	14	400	39	390	23	78

mg/kg - milligrams per kilogram

As shown in Table 4-2, uranium is the only metal COC for which the mean value exceeds the tentative cleanup goal. The mean values for mercury and arsenic are close to the cleanup goal. Very little molybdenum or vanadium was detected in flood plain soils, and lead showed a mean concentration well below the cleanup goal. The high standard deviation of all COCs indicates the highly variable nature of the contamination.

4.3.2.1.2 Metals Extent

The concentration of metals exceeded the Site tentative cleanup goal in soil for only three of the seven metal COCs, including uranium, lead, and arsenic. The metals extent for these metals is shown on Figure 4-2, final uranium confirmatory sample results; Figure 4-3, final lead confirmatory sample results; and Figure 4-4, final arsenic confirmatory sample results.

The extent of contamination was defined by the locations of the confirmatory data set, which indicated the excavation had reached soils below the tentative cleanup goals. This data set (Table 4-3) consists of 18 soil samples that were sent to the offsite analytical laboratory (ALS Paragon Laboratories) for analysis. These samples were collected from sample locations on the outer walls and bottom of the excavation, and thus form the confirmatory data set and the basis for the final status survey. The data set in Table 4-3 provides the analytical results for the confirmation soil samples. Visual Sampling Plan (VSP) software program was used to verify that the number of final survey samples used to define the extent of contamination was sufficient (VSP Reports are located in Appendix D).

Table 4-3
Final Metals Confirmatory Sample Results and Summary Statistics

Location	Uranium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Molybdenum (mg/kg)	Mercury (mg/kg)	Vanadium (mg/kg)
00163	9.4	86	23	8.2	2.7	20
00257	5.2	19	3.3	1.2	0.29	14
00259	11	51	11	3.2	0.89	29
00267	8.4	160	14	5.2	12	31
00279	3.1	87	17	2.2	1.2	25
00305	13	68	11	4.1	0.84	25
00353	3.3	26	15	1.6	0.03	36
00354	4.5	29	10	0.53	0.094	34
00355	2.6	66	8	4.1	1.5	36
00357	2.6	28	3.1	0.83	0.024	19
00374	3.3	61	4.8	5.1	0.44	32
00375	4.9	170	24	1.7	14	27
00381	11	41	1.8	5	0.26	19
00384	6.7	95	3.8	9.3	1.2	25
00388	3.1	40	2.6	6.1	0.35	29
00422	2.9	60	8.4	8.3	0.48	54
mean	5.94	67.94	10.05	4.17	2.27	28.44
Std dev	3.51	44.34	7.04	2.79	4.26	9.36
geo mean	5.08	56.46	7.66	3.13	0.60	27.10
Tentative Goal	14	400	39	390	23	78

mg/kg - milligrams per kilogram

The data set was evaluated using EPA's *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media* (EPA 1989). *A s*tatistical analysis was performed in accordance with Chapter 6, *Determining Whether the Mean Concentration of the Site is Less Than a Cleanup Standard*. Using Equation 6.8, *Computing the Upper One-sided Confidence Limit*:

$$\mu_{U\alpha} = \bar{x} + t_{1-\alpha,df} \frac{s}{\sqrt{n}}$$

Where: $\mu_{U\alpha}$ = Upper One-Sided Confidence Limit

$\bar{x}$ = mean level of contamination

s = standard deviation

α = desired false positive rate (the probability that the sample area will be declared to be clean when it is actually dirty), set at 0.05

df = degrees of freedom, equal to n-1

n = final sample size (i.e., the number of data values available for statistical analysis)

$t_{1-\alpha,df}$ = value from Appendix A in referenced EPA document, Table A-1 of t for selected alpha and degrees of freedom

Table 4-3 shows the results of this statistical test performed on the confirmatory soil samples for the metals of concern at the Site. All computed values are below the tentative Site action levels. Thus, the soil remaining in the flood plain area after excavation meets the soil cleanup standards for metals based on the offsite analytical laboratory results.

4.3.2.2 Radionuclides

The primary driver for this characterization effort was the presence of uranium contamination in soil that was a source for groundwater contamination. Based on the findings of previous investigations, CDPHE requested a tentative screening standard for radionuclides of two times the Site background gamma activity be included in the work plan. Qualitative screening instruments (MicroR and NaI detector) were used in the field to measure *in situ* gamma activity and assisted in guiding the segregation of soil. Representative samples were then collected from the stockpile and from *in situ* soils for laboratory analysis. The radionuclides were handled similarly to the metals; those samples representing soil placed in the stockpile portray the nature of the radionuclide contamination. The locations of confirmatory samples representing soil from locations on the periphery of the excavation define the extent of radionuclide impacts. Both the nature and extent are discussed below.

4.3.2.2.1 Radionuclide Nature

The nature of the radionuclide impacts identified on the flood plain site is described by the data set representing soil that was excavated. This data set is presented in Table 4-4.

Table 4-4
Laboratory Radionuclides Results Excavated Material

Sample ID	Ra-226 (pCi/g)	Ra-228 (pCi/g)	Th-228 (pCi/g)	Th-230 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
00430-03	15.9	2.31	2.13	14	2.01	5.1	0.2	5.14
00431-03	92	2.36	1.98	21.2	2.04	8.7	0.49	9.5
00432-03	16.4	2.05	2.41	10.2	2.24	5.84	0.268	6
00433-03	7.5	1.96	1.85	7.5	1.68	4.81	0.179	5.02
00434-03	12	1.77	2.18	12.2	1.93	6.3	0.29	6.5
00435-03	18.1	1.98	2.16	13.8	2.02	6	0.31	6.2
00436-03	9.6	1.86	2.3	8.5	2.39	4.29	0.29	4.51
00437-03	15.7	2.22	2.23	10.9	2.01	7.6	0.39	7.4
00438-03	6.32	2.09	1.9	5.57	1.75	4.07	0.204	4.06
00439-03	12.1	1.96	1.91	9.4	2.02	5.7	0.32	5.9
Mean*	20.56	2.06	2.11	11.33	2.01	5.84	0.29	6.02
Std. Dev.	25.41	0.19	0.19	4.38	0.21	1.44	0.09	1.57
Geo Mean	14.63	2.05	2.10	10.64	2.00	5.69	0.28	5.86
Tentative Goal	4.14	4.6	6.47	11.53	3.88	254.9	4.97	21.8

* arithmetic mean
pCi/g - picoCuries per gram

4.3.2.2.2 Radionuclide Extent

After soils that exceeded tentative Site action levels were excavated, final confirmatory sampling was completed following the guidelines in Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) and using the guidance of the VSP software. Eighteen of the CSMRI soil samples sent to the offsite laboratory were collected from sample locations that were not excavated, and thus form part of the basis for the final status survey. The data set was evaluated using EPA's *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media* (EPA 1989). A statistical analysis was performed in accordance with Chapter 6, *Determining Whether the Mean Concentration of the Site is Less Than a Cleanup Standard*. Using Equation 6.8, *Computing the Upper One-sided Confidence Limit:*

$$\mu_{U\alpha} = \bar{x} + t_{1-\alpha,df} \frac{s}{\sqrt{n}}$$

Where: $\mu_{U\alpha}$ = Upper One-Sided Confidence Limit

$\bar{x}$ = mean level of contamination

s = standard deviation

α = desired false positive rate (the probability that the sample area will be declared to be clean when it is actually dirty), set at 0.05 for CSMRI

df = degrees of freedom, equal to n-1

n = final sample size (i.e., the number of data values available for statistical analysis)

$t_{1-\alpha,df}$ = value from Appendix A in referenced EPA document, Table A-1 of t for selected alpha and degrees of freedom

Table 4-5 shows the results of this statistical test for the radioisotopes of concern at the Site. All computed statistical values are below the tentative Site action levels. Thus, the data confirm that the flood plain soil remaining at the Site after excavation now meets the soil cleanup standards for radionuclides based on the offsite analytical laboratory results.

Table 4-5
Final Radionuclide Confirmatory Sample Results and Summary Statistics

Sample ID	Ra-226 (pCi/g)	Ra-228 (pCi/g)	Th-228 (pCi/g)	Th-230 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
00163	11.1	2.91	2.05	10.4	1.76	4.35	0.197	4.21
00257	3.93	2.02	2.15	2.49	1.75	2.27	0.121	2.14
00259	5.22	2.67	2.41	6.7	1.96	4.22	0.252	4.07
00267	4.29	2.31	2.55	6.2	1.92	4.46	0.245	4.52
00279	1.92	1.98	2.27	1.73	2.04	1.82	0.108	1.85
00305	4.67	2.27	2.06	4.65	1.84	4.28	0.242	4.28
00353	1.94	1.72	2.35	1.19	1.8	1.48	0.091	1.48
00354	1.91	1.93	2.3	1.11	1.72	2.28	0.106	2.31
00355	2.47	2.29	2.97	2.82	2.93	1.69	0.074	1.9
00357	1.38	1.7	1.96	0.73	1.65	1.31	0.064	1.15
00374	4.19	3.49	2.86	2.79	2.73	1.41	0.066	1.29
00375	2.62	3.34	2.99	1.85	2.57	2.11	0.088	1.99
00381	2.38	2.25	2.41	1.46	2.01	3.72	0.146	3.88
00384	6.41	2.57	2.09	4.66	1.76	2.83	0.123	2.57
00388	2.41	3.07	2.02	1.31	1.69	1.79	0.086	1.74
00422	4.23	1.84	1.8	3.54	1.55	1.46	0.074	1.58
mean	3.82	2.40	2.33	3.35	1.98	2.59	0.13	2.56
Std dev	2.41	0.56	0.36	2.62	0.41	1.20	0.07	1.20
geo mean	3.29	2.34	2.30	2.58	1.95	2.35	0.12	2.32
Tentative goal	4.14	4.6	6.47	11.53	3.88	254.9	4.97	21.8

pCi/g - picoCuries per gram

4.3.2.3 Exceptions to Nature and Extent

The CDPHE-approved project characterization work plan was followed whenever possible to guide the investigation throughout the characterization of flood plain soils. In some isolated cases, COCs determined to be above the tentative cleanup goals, based on laboratory confirmatory samples, were left in place and not excavated. Table 4-6 summarizes these data points, lists the COC concentration, and gives the rationale used for their exclusion from the confirmatory data set. The two data points represent a volume of approximately 20 cubic yards of soil left in place that exceeded the cleanup standards.

Table 4-6
Exceptions to Confirmatory Data Set for Extent

Sample ID	Ra-226 Laboratory Result (pCi/g)	Tentative Cleanup Goal (pCi/g)	Uranium Laboratory Result (mg/kg)	Tentative Cleanup Goal (mg/kg)	Rationale
00236	6.66	4.14	25	14	Directed by City of Golden to not dig any closer to water main. CDPHE concurred.
00237	8.7	4.14	15	14	Directed by City of Golden to not dig any closer to water main. CDPHE concurred.

Note: Field screening data were not included in the final survey data set for the statistical evaluation, only laboratory confirmatory data were used.
mg/kg - milligrams per kilogram
pCi/g - picoCuries per gram

4.3.2.4 Nature and Extent Conclusions

The characterization effort achieved the goal of determining the nature and extent of contamination by metal and radionuclide COCs on the flood plain. The nature of contamination by the COCs is described in Tables 4-2 and 4-4. The extent of the contamination of the COCs was defined and determined to be 1,400 cubic yards of soil.

4.3.2.5 Stockpile Sampling Results

One soil stockpile was established for excavated materials. The stockpile contains material excavated from locations identified as exceeding the tentative cleanup levels for the metals of concern, soils with gamma activity greater than two times ambient levels, artificial fill, and soil excavated from beneath the water table where field screening directly above the saturated zone identified COC exceedances. The stockpile contains approximately 1,400 cubic yards of material (Photograph 4.6 Appendix A).

The stockpile was sampled after excavation was complete. These soil samples were analyzed for all COCs. In anticipation of a need to evaluate remedial alternatives, the samples were also tested for landfill waste acceptance criteria with the Toxicity Characteristic Leaching Procedure (TCLP). Tables 4-7 and 4-8 show the analytical results for metals and TCLP testing performed by the offsite analytical laboratory. The TCLP results confirm that the stockpiled material is not a characteristic hazardous waste. Ten stockpile samples and one duplicate sample were collected, for a total of eleven samples. Each stockpile sample was a composite of five aliquots taken within an area of approximately 100 square feet. The ten stockpile sample locations were randomly selected across the surface of the pile to ensure results were representative and unbiased. Table 4-9 provides a summary of offsite laboratory radionuclide results for the soil stockpile.

Table 4-7
Stockpile Laboratory Metals Results

Sample ID	Uranium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Molybdenum (mg/kg)	Mercury (mg/kg)	Vanadium (mg/kg)
00430-03	14	440	25	7.4	6.1	51
00431-03	21	630	40	16	9.9	45
00432-03	15	370	23	9.2	4.2	45
00433-03	15	150	22	11	4.4	35
00434-03	19	820	39	8.7	1.8	36
00435-03	14	450	26	9.2	2.8	41
00436-03	12	310	17	6.6	1.3	35
00437-03	13	370	23	6.4	1.8	42
00438-03	14	120	17	7.5	3.2	29
00439-03	13	450	23	7.2	2.6	38
Mean	15.00	411.00	25.50	8.92	3.81	39.70
Std. Dev.	2.83	206.96	7.95	2.86	2.58	6.38
Geo Mean	14.79	358.60	24.52	8.59	3.19	39.23

mg/kg - milligrams per kilogram

Table 4-8
Stockpile Laboratory TCLP Results

Sample ID	Mercury (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Lead (mg/L)	Selenium (mg/L)	Silver (mg/L)
00430-03	0.00037	0.039	0.88	0.024	0.0051	0.48	0.029	0.011
00431-03	0.00029	0.039	0.81	0.034	0.0051	1.7	0.028	0.011
00432-03	0.00031	0.039	0.88	0.032	0.0051	0.5	0.03	0.011
00433-03	0.00034	0.039	0.97	0.018	0.0051	0.12	0.053	0.011
00434-03	0.00034	0.039	0.95	0.028	0.0051	0.16	0.027	0.011
00435-03	0.00032	0.039	0.85	0.029	0.0051	0.5	0.027	0.011
00436-03	0.00032	0.039	1.1	0.023	0.0051	0.24	0.041	0.011
00437-03	0.00035	0.039	0.77	0.022	0.0051	0.37	0.027	0.011
00438-03	0.00037	0.039	0.87	0.016	0.0051	0.23	0.027	0.011
00439-03	0.00034	0.039	0.89	0.029	0.0051	0.24	0.027	0.011
Mean	0.00	0.04	0.90	0.03	0.01	0.45	0.03	0.01
Std. Dev.	0.00	0.00	0.09	0.01	0.00	0.46	0.01	0.00
Geo Mean	0.00	0.04	0.89	0.02	0.01	0.34	0.03	0.01
Haz Class Limit	0.2	5.0	100	1.0	5.0	5.0	1.0	5.0

mg/L - milligrams per liter

Table 4-9
Stockpile Laboratory Radionuclide Results

Sample ID	Th-228 (pCi/g)	Th-230 (pCi/g)	Th-232 (pCi/g)	U-234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)	Ra-226 (pCi/g)	Ra-228 (pCi/g)
00430-03	2.13	14	2.01	5.1	0.2	5.14	15.9	2.31
00431-03	1.98	21.2	2.04	8.7	0.49	9.5	92	2.36
00432-03	2.41	10.2	2.24	5.84	0.268	6	16.4	2.05
00433-03	1.85	7.5	1.68	4.81	0.179	5.02	7.5	1.96
00434-03	2.18	12.2	1.93	6.3	0.29	6.5	12	1.77
00435-03	2.16	13.8	2.02	6	0.31	6.2	18.1	1.98
00436-03	2.3	8.5	2.39	4.29	0.29	4.51	9.6	1.86
00437-03	2.23	10.9	2.01	7.6	0.39	7.4	15.7	2.22
00438-03	1.9	5.57	1.75	4.07	0.204	4.06	6.32	2.09
00439-03	1.91	9.4	2.02	5.7	0.32	5.9	12.1	1.96
Mean	2.11	11.33	2.01	5.84	0.29	6.02	20.56	2.06
Std. Dev.	0.19	4.38	0.21	1.44	0.09	1.57	25.41	0.19
Geo Mean	2.10	10.64	2.00	5.69	0.28	5.86	14.63	2.05

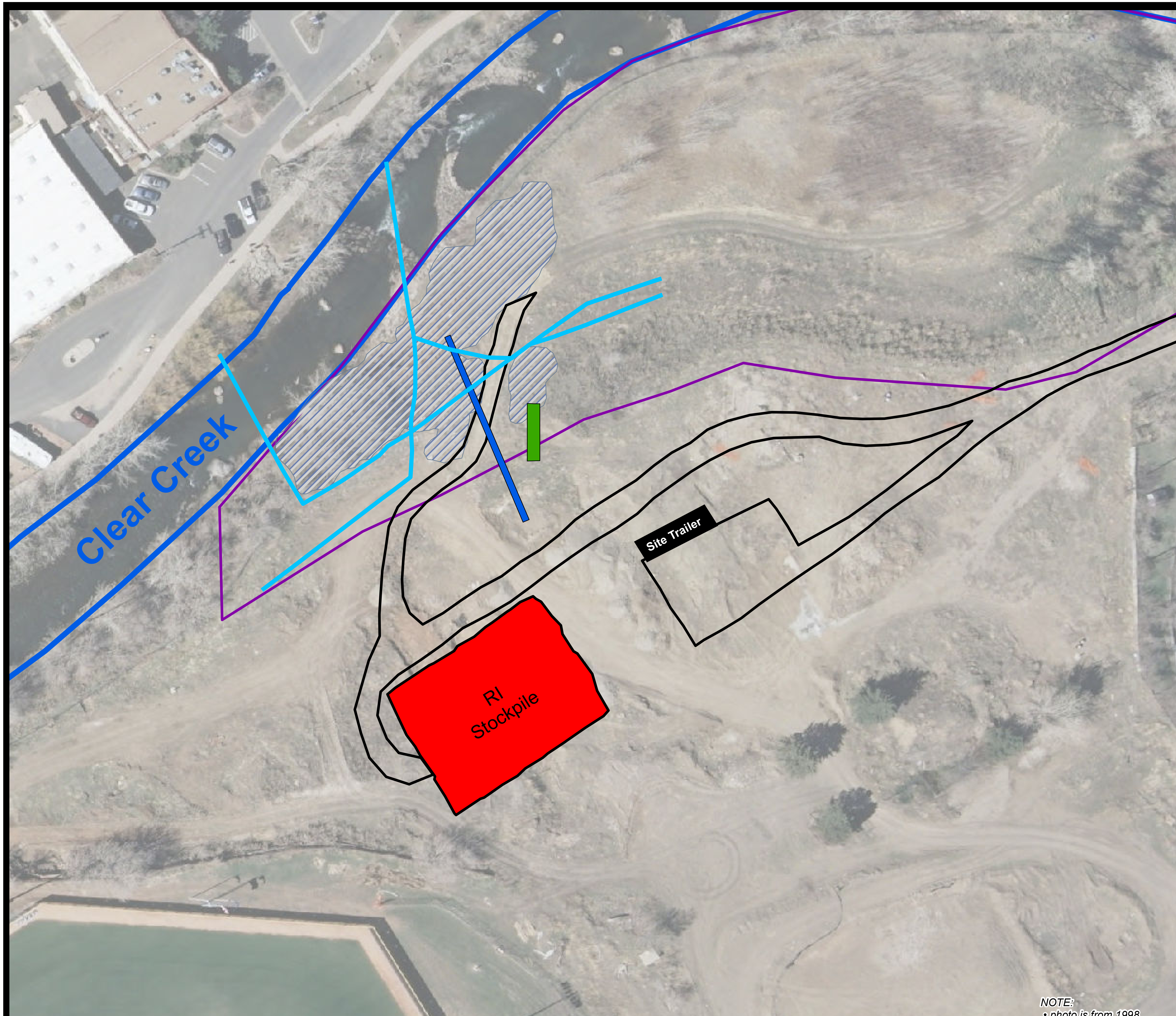
pCi/g - picoCuries per gram

4.4 Groundwater (OU2) Characterization

Groundwater is currently being evaluated for the post-excavation impact of the soil characterization activities described herein. After the water quality stabilizes, a separate groundwater RI/FS will be prepared that describes the current understanding of groundwater quality, physical nature, and associated risks to the public and the environment. Quarterly monitoring and sampling of the existing 14 monitoring wells will continue as will the associated quarterly reports.

Figure 4-1

Location of Water Supply Tunnel
Site Characterization
Colorado School of Mines Research Institute
(CSMRI), Golden, Colorado



Explanation

- 6FT Diameter Concrete Culvert
- CSMRI Water Supply Tunnel
- Extent of COC's
- Site Boundary
- City of Golden Water Lines
- Temporary Access Road

N

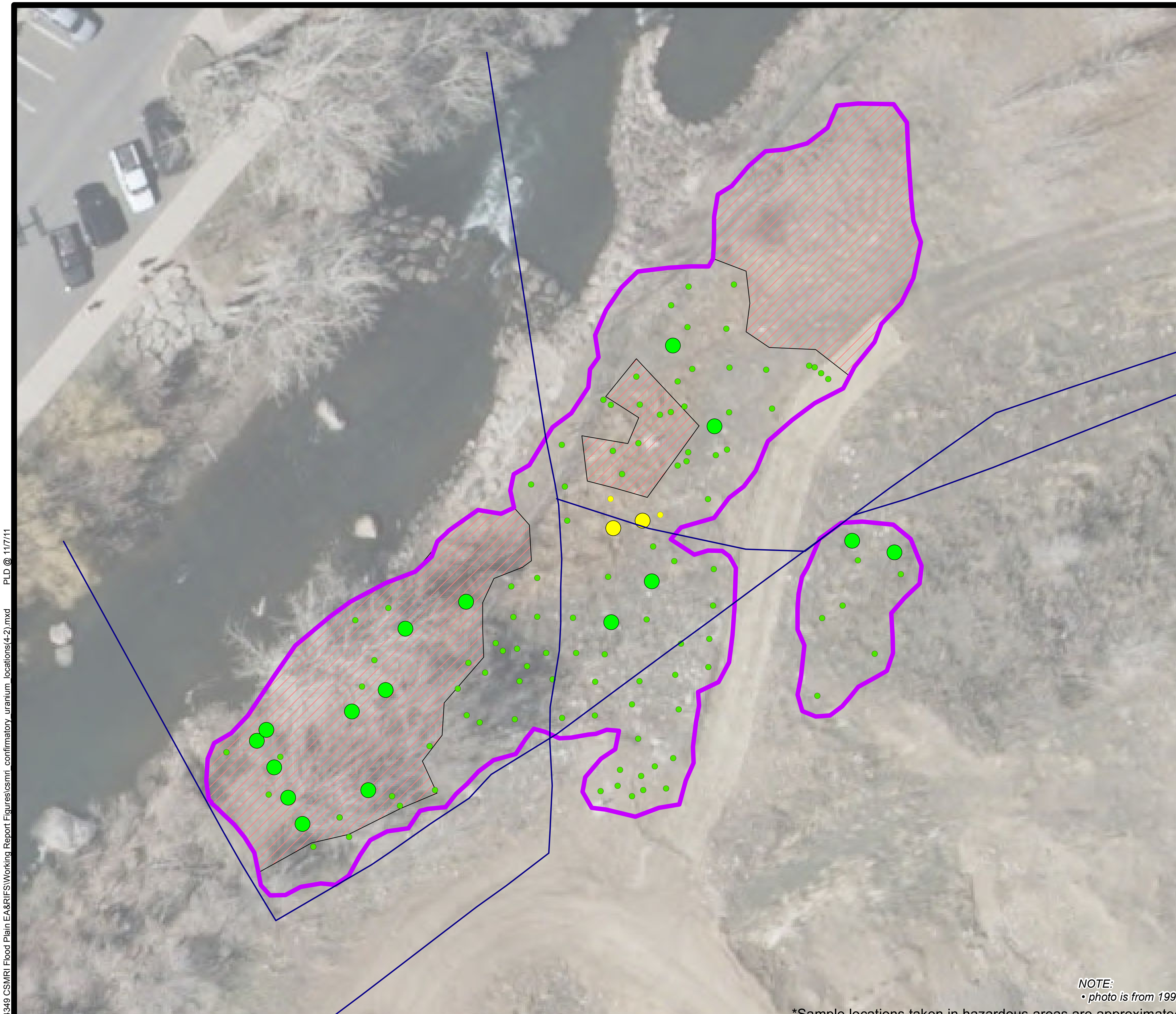
100 50 0 100 Feet

CSMRI Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

Figure 4-2

Confirmatory Uranium Sample Locations
Flood Plain
Site Characterization
Colorado School of Mines Research Institute
(CSMRI); Golden, Colorado



Explanation

- City of Golden Water Lines
- Laboratory Analytical Result: Uranium Below 14 ppm
- Laboratory Analytical Result: Uranium Above 14 ppm
- XRF Field Screening Result: Uranium Below 14 ppm
- XRF Field Screening Result: Uranium Above 14 ppm
- Extent of COC's
- Excavation to Bedrock (Pierre Shale)

N

30 15 0 30 Feet

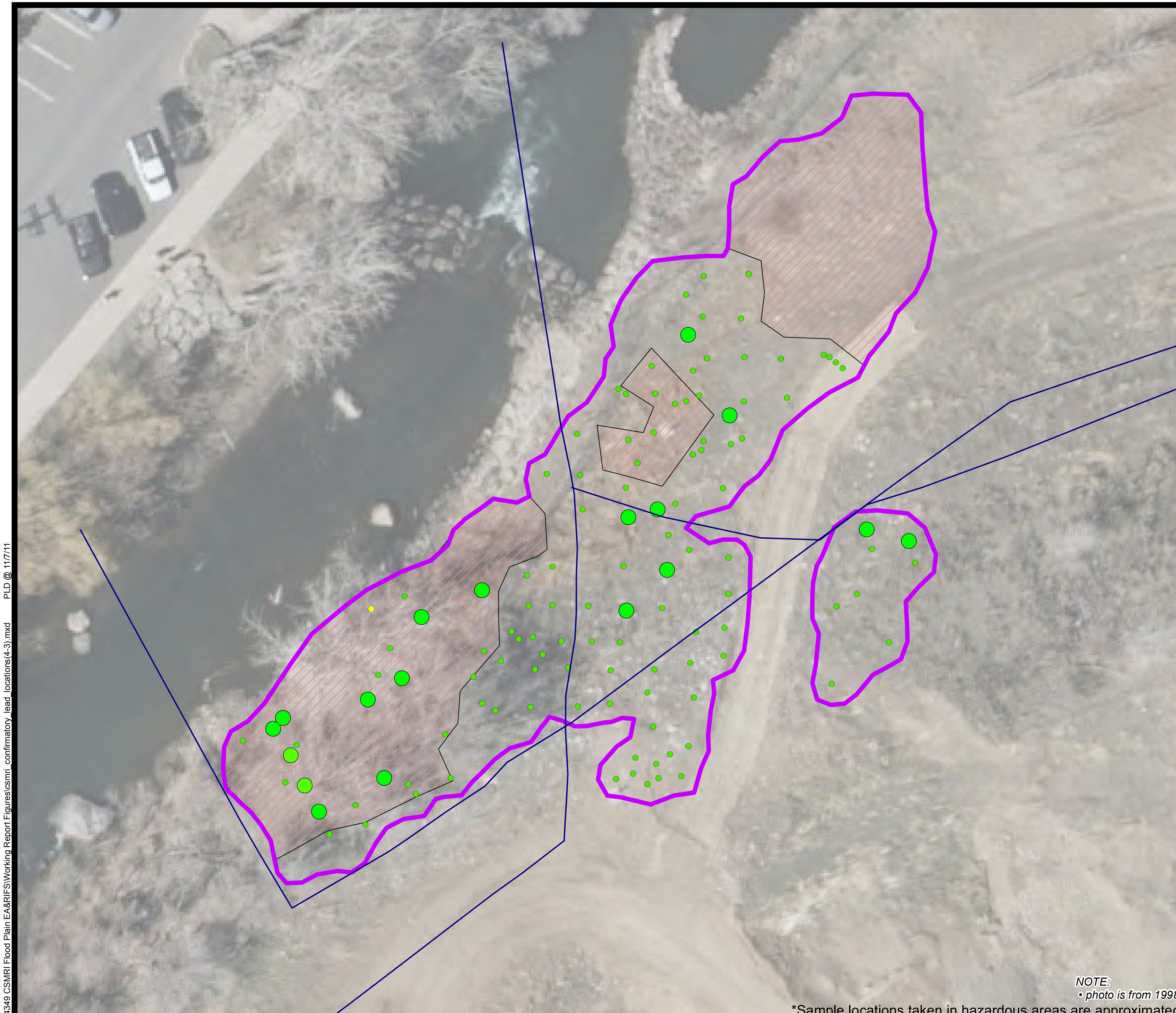
CSMRI Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\csmri_confirmatory_uranium_locations(4-2).mxd PLD @ 11/7/11

Figure 4-3

Confirmatory Lead Sample Locations
Flood Plain
Site Characterization
Colorado School of Mines Research Institute
(CSMRI); Golden, Colorado



Explanation

- City of Golden Water Lines
- Laboratory Analytical Result: Lead Below 400 ppm
- Laboratory Analytical Result: Lead Above 400 ppm
- XRF Field Screening Result: Lead Below 400 ppm
- XRF Field Screening Result: Lead Above 400 ppm
- Extent of COC's
- Excavation to Bedrock (Pierre Shale)

N

40 20 0 40 Feet

CSMRI Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\csmri_confirmatory_lead_locations(4-3).mxd PLD @ 11/7/11

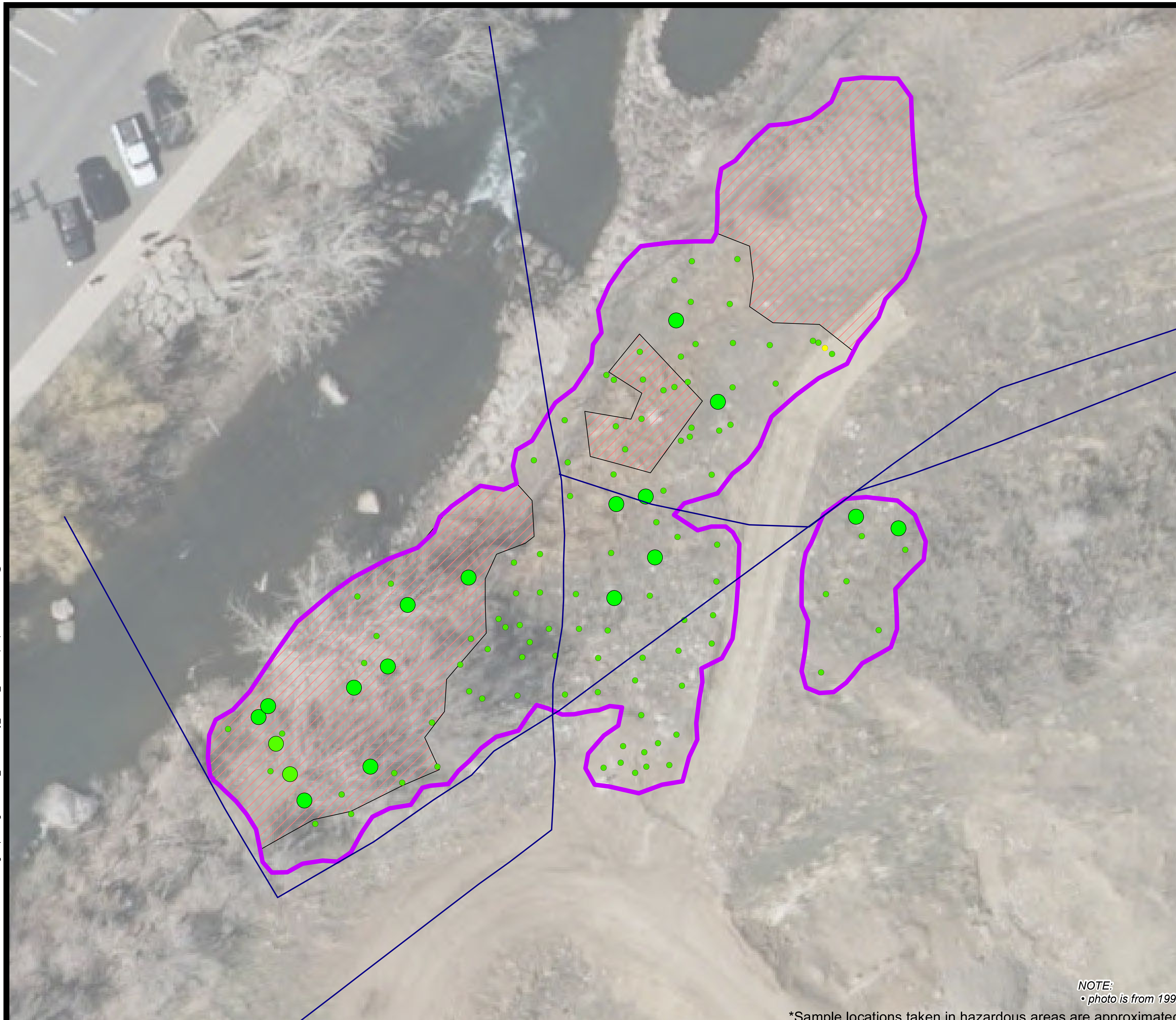


Figure 4-4

Confirmatory Arsenic Sample Locations
Flood Plain
Site Characterization
Colorado School of Mines Research Institute
(CSMRI); Golden, Colorado

Explanation

- City of Golden Water Lines
- Laboratory Analytical Result: Arsenic Below 39 ppm
- Laboratory Analytical Result: Arsenic Above 39 ppm
- XRF Field Screening Result: Arsenic Below 39 ppm
- XRF Field Screening Result: Arsenic Above 39 ppm
- Extent of COC's
- Excavation to Bedrock (Pierre Shale)

N

40 20 0 40 Feet

CSMRI Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\csmri_confirmatory_arsenic_locations(4-4).mxd
PLD @ 11/7/11

Table of Contents for Section 5

5. Contaminant Fate and Transport 5-1
5.1 Potential Routes of Migration 5-1
5.2 Contaminant Persistence 5-1
5.3 Contaminant Migration 5-1
5.3.1 Material Migration to Groundwater 5-2
5.3.2 Factors Affecting Migration 5-2
5.3.3 Geochemical Modeling of Uranium 5-2

5. Contaminant Fate and Transport

This characterization effort was designed to characterize the contaminated soil acting as source material for groundwater uranium contamination and identify other risks to human health or the environment. The only constituent impacting groundwater is uranium, but all constituents of concern will be evaluated for offsite migration.

5.1 Potential Routes of Migration

The potential routes of migration associated with the flood plain site prior to soil segregation activities included:

- Wind erosion, moving material primarily to the east (prevailing winds are from the west),
- Water erosion, transferring material into Clear Creek,
- Windborne diffusion, moving radon and radon decay products offsite (again driven by prevailing west winds),
- Plant material transport, moving material taken up by plants as wind or waterborne plant debris,
- Particle transfer, moving material via attachment to personnel and/or vehicle, and
- Solute and particle transport, transferring material into the underlying groundwater through percolation and preferential pathways.

Mitigation of these mechanisms included the following: wind and water erosion was controlled on the Site by stormwater best management practices. Vegetation growing on the Site was removed and disposed of at the local sanitary landfill during Site preparation activities. Particle transport was controlled by Site-specific safety requirements. Radon diffusion and solute transport were not controlled at that time.

Soil segregation activities resulted in the elimination of many of the above-described transport mechanisms by way of placing the impacted soil in a lined stockpile. Following the soil segregation activities, only two transport mechanisms remain potentially active for the Site on a short-term, temporary basis: wind erosion, moving material primarily to the east; and windborne diffusion, moving radon and radon decay products offsite. Mitigation of the wind erosion transport mechanism was addressed through the application of a soil tackifier to the soil stockpile upon completion of segregation activities.

5.2 Contaminant Persistence

The primary COCs on the Site are metals and radionuclides. These materials are very persistent in the environment, and remedial techniques typically focus on stabilization, removal, or containment through the use of a cap. In this instance, where much of the contamination was below the water table, a cap would not be effective and stabilization would require the materials first be relocated to above the water table.

5.3 Contaminant Migration

During the flood plain site characterization activities, contaminant migration was controlled through best management practices for runon/runoff control. Wind erosion was controlled through daily water application, and personnel and equipment were surveyed prior to exiting the Site. Air monitoring stations did not detect any airborne migration, and no fixed or removable contamination was detected on any person or equipment leaving the Site.

5.3.1 Material Migration to Groundwater

Prior to the flood plain RI activities, the metal uranium, present in Site soils, provided a continuing source of contaminants to the underlying groundwater. No other COCs were present in Site groundwater at concentrations above State regulatory limits. Geochemical modeling was completed in an effort to better understand the relationship between soil uranium concentrations and their potential to impact Site groundwater.

5.3.2 Factors Affecting Migration

Factors that affect the migration of COCs—particularly uranium—from the Site, include erosion, plant uptake, and material solubility. Wind and water erosion can be controlled using vegetation, cover material, engineered controls, or an impermeable barrier. Erosion/sediment controls include silt fencing, trenching, erosion control mats, and temporary vegetation. Solubility is a function of precipitation, the parent material, and soil properties such as conductivity and pH. Solubility can be controlled primarily through limiting the movement of water through the material.

Soil amendments and physically or chemically changing material properties also have been used to control solubility, but these methods are typically expensive and of varying success. No solubility controls are currently in place. Radon generated by the natural decay of the radionuclides diffuses through the soil and migrates to the atmosphere. Radon is typically a problem when a building foundation is in contact with the affected soil and the radon is trapped inside the building. No buildings are located on the Site at this time but they are reasonably foreseeable in the future. Radon released to the atmosphere diffuses to the point that human health risk is negligible.

5.3.3 Geochemical Modeling of Uranium

Geochemical modeling was performed to better understand how the uranium concentrations found in the soil may be causing the uranium concentrations found in the groundwater and to determine Site soil screening levels for uranium. The methods used to calculate soil partition coefficients and the results of the geochemical modeling effort are described in Section 3.3.3. The completion of the geochemical modeling work greatly improved the understanding of uranium fate and transport and the physical, chemical, and hydrological nature of the flood plain portion of the CSMRI Site. The main conclusions drawn from this work are presented below.

- Dissolved uranium in groundwater is present across the Site in decreasing concentrations toward the east indicating a likely contaminant source for groundwater west of well CSMRI-8. Essentially all dissolved uranium occurs as a carbonate complex, and the Site-specific partitioning coefficient for uranium is very low at less than 0.2 L/kg.
- The results of the roll tests indicate very little soil adsorption of uranium occurs across the Site. The shape of the dissolved uranium plume, with highest values centered within the Site and decreasing concentrations toward the east, appears to indicate that the plume is impacted by dilution from upper terrace waters and water from Clear Creek.

- The ambient concentration of uranium in soils is 6.45 mg/kg (mean plus 2 standard deviations), elevated from background by mining activities in this area and up Clear Creek.
- Geochemical modeling determined that ambient uranium in soil could result in groundwater uranium concentrations as high as 400 ppb based on the Site-specific partitioning coefficient. However, this was determined using an EPA test method that is considered to be very aggressive, is a screening level standard, and provides a partitioning coefficient that can be considered to be a conservative value for the Site.

6. Risk Assessment 6-1
6.1 Human Health Evaluation 6-2
6.2 Exposure Assessment 6-2
6.3 Soil Radionuclide Risk Characterization 6-3
6.3.1 RESRAD Model Description 6-4
6.3.2 Microshield Model Description 6-4
6.3.3 Drinking Water Pathway 6-5
6.3.4 Receptor Dose/Risk Assessment 6-6
6.3.5 Results of Radionuclide Assessment 6-7
6.4 Soil Metals Risk and Toxicity Assessment 6-9
6.4.1 Arsenic Assessment 6-10
6.4.2 Lead 6-14
6.4.3 Molybdenum 6-15
6.4.4 Mercury 6-15
6.4.5 Vanadium 6-15
6.5 Risk Assessment Summary 6-16

List of Tables

Table 6-1 Radionuclide Exposure Scenarios 6-3
Table 6-2 Uranium Concentrations in Surface Water Samples Collected on Clear Creek 6-5
Table 6-3 Effective Diffusion Coefficient (De) for Radon in Concrete 6-6
Table 6-4 Stockpile Dimensions 6-7
Table 6-5 Doses and Risks Associated with Radionuclides 6-8
Table 6-6 Summary of Metal Results (mg/kg) Above Action Levels and Background 6-9
Table 6-7 Final Metals Confirmatory Sample Results and Summary Statistics 6-9
Table 6-8 Soil Consumption Arsenic Risk: Gardener/Groundskeeper 6-12
Table 6-9 Soil Consumption Arsenic Risk: Residential 6-13
Table 6-10 Lead Risk Urban Residential (Child) 6-14
Table 6-11 Cumulative Total Lifetime Risk from Radionuclides and Arsenic 6-16

List of Figures

Figure 6-1. Flood Plain Characterization Area Showing Locations of Test Pits and Characterization Area Confirmatory Samples.
Figure 6-2. Areas Evaluated in the Current Risk Assessment.

6. Risk Assessment

The current risk assessment examined both carcinogenic risks and systemic toxicants associated with the pre-investigated flood plain area, the post-investigated flood plain area, and the excavated material, which has been placed in a stockpile managed on the upper terrace. Characterization of the investigated flood plain was accomplished in two separate sampling campaigns: the test pit study, which focused the remaining characterization to the western portion of the flood plain, and the second phase of the investigation. The second phase included samples of contaminated material that was removed to the stockpile and confirmatory samples from the flood plain characterization area (Figure 6-1). The risk assessment included data from both phases of the investigation as summarized below. The stockpiled material was sampled and analyzed separately for waste characterization only and not as part of the risk assessment. For this risk assessment, three potential land use areas were assessed:

1. The post-characterization flood plain, which consists of the western sampled area and the eastern sampled area (Figure 6-2). The western portion is represented by data from the confirmatory samples collected in the characterization, and the eastern portion is represented by test pit data (test pits 3, 4, 5, 7, and 8) collected during the first phase of the characterization. The investigated flood plain area is also referred to as the post-characterization area in this section of the report. This area was assessed to confirm that contaminated soils were excavated and the remaining alluvial soil does not require further action and to identify potential land use restrictions for the remaining soil, if any.
2. The stockpile, which is the alluvial material excavated from the characterized flood plain. It is located south of the flood plain on the upper terrace (Figure 6-2). The purpose of assessing the risk of the stockpiled material is to evaluate the need to remediate it or leave it in place without further action.
3. The pre-characterization flood plain, which is the post-excavation flood plain with the stockpiled material hypothetically spread back over it, including data from all test pits. This is also referred to as the pre-characterization flood plain in this report. The purpose of assessing the risk of the flood plain with the stockpiled material on it is to confirm the necessity of excavating the material as part of a remediation.

Potential land use scenarios for each of the areas above were evaluated for the near-term and the long-term foreseeable future. Near-term land use scenarios evaluated included:

1. recreational use, such as picnicking, by the general public;
2. recreational use, such as soccer or Frisbee throwing, by a student; and
3. maintenance by a groundskeeper.

Future potential land use scenarios were also evaluated because of the persistence of metals and the longevity of the radionuclides involved (Ra-226 has a half-life of 1.6×10^3 years, Th-230 has a half-life of 7.6×10^4 years, and U-238 has a half-life of 4.5×10^9 years). The requirements of 40 CFR §192.02 necessitate that remedies for sites with similar radionuclide contaminants provide up to 1,000 years of protection to human health and the environment (at least 200 years). The long-term land use scenario evaluated was residential use, student housing, or an urban resident. An urban resident was assumed to live in a 2,000 square-foot home.

The current flood plain assessment area includes a western portion, which encompasses test pits CL-1, -2, and -6, and the characterization area, and an eastern portion, which incorporates test pits CL-3, -4, -5, -7, and -8. The stockpile is located south of the flood plain. The previous assessment area is not included in the risk evaluation. Calculations made for human health risk determination are in Appendix E.

6.1 Human Health Evaluation

Acceptable exposures to known or suspected carcinogens are generally those that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} to 10^{-6}. EPA uses the 10^{-6} risk level as the point of departure for determining remediation goals for the National Priority List (NPL) sites. However, the upper boundary of the risk range is not a discrete line at 1×10^{-6}. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions (EPA 1991). EPA references site-specific acceptable risks in the range of 3×10^{-4}, but risks may become unacceptable in the range of 6×10^{-4} (EPA 1997a).

Numerous tools were used for this risk assessment. Radionuclide doses and risks were estimated using the RESRAD (version 6.5) model developed by the Environmental Assessment Division of Argonne National Laboratory for the DOE and the NRC (Yu *et al.* 2001). RESRAD used the current slope factors referenced in the Health Effects Assessment Summary Tables (HEAST). RESRAD calculations were supplemented, in most cases, with calculations of external exposure using MicroShield 7.0 (Grove Software 2005). MicroShield was used for external gamma dose calculations because it more accurately models the geometry of the source, shields, and location of the receptor and uses an extensive library of data (radionuclides, attenuation, buildup, and dose conversion) which reflect standard data from the Radiation Safety Information Computational Center (RSICC), American Nuclear Society (ANS), and International Commission on Radiological Protection (ICRP).

Health hazards were evaluated using the Risk Assessment Information System (RAIS) developed by Bechtel Jacobs Company LLC and the University of Tennessee for the DOE, Office of Environmental Management (http://rais.ornl.gov/).

6.2 Exposure Assessment

For the risk assessment, the exposure scenarios examined include an urban resident, a recreational user, a student athlete, and a groundskeeper for each of the potential land use areas described previously (i.e., the characterized flood plain, the pre-characterized flood plain, and the stockpile). The urban resident assumed a 2,000 square foot house similar to neighborhood housing, but drinking water would come from city water mains and minimal consumption of fruits and vegetables raised in a backyard garden. The recreational receptor assumed regular use by a nearby resident who would use the area to picnic on during summer months. The student athlete also assumed regular use of the land for athletics such as running or playing Frisbee. The groundskeeper assumed a worker who is actively involved in landscaping and thus working in the soil. Exposure pathways for each scenario are summarized in Table 6-1.

Table 6-1
Radionuclide Exposure Scenarios

Scenario	Exposure Pathways
Resident	
Receptor:	Adult living at home
Pathways:	Radon inhalation and external exposure
Duration of exposure:	30 years
Recreational Receptor	
Receptor:	Picnicker
Pathways:	Inhalation and external exposure
Duration of exposure:	4 hr/wk for 16 weeks
Student Athlete	
Receptor:	Student who runs or plays Frisbee
Pathways:	Inhalation[a] and external exposure
Duration of exposure:	6 mos/yr, 4 hr/da
Groundskeeper	
Receptor:	Groundskeeper
Pathways:	Inhalation[b], soil ingestion, and external exposure
Duration of exposure:	8 hr/wk, 5 da/wk for 20 yr

a. The maximum inhalation rate available in RESRAD was selected for the student athlete.
b. The active breathing rate for a 71kg adult in EPA (1989) was used.

6.3 Soil Radionuclide Risk Characterization

Doses and risks from exposure to radionuclides in soil were calculated using results of analyses of soil samples collected from locations shown in Figure 6-2 and from the stockpile. Radionuclide results were reported for Ra-226, Ra-228, Th-228, Th-230, Th-232, U-234, U-235, and U-238. The radionuclides which exceeded background levels in at least one sample were Ra-226, Th-230, and U-238. The background levels were obtained from the New Horizons 2004 RI/FS (New Horizons, 2004).

A screening analysis was first performed on the radionuclides to help focus the risk assessment. The maximum result for each radionuclide was multiplied by the EPA radionuclide cancer morbidity slope factors [(risk/pCi for water, food, soil, and inhalation pathways and risk per pCi/g for the external exposure pathway) (http://epa.gov/superfund/health/contaminants/radiation/pdfs/tbd-part-2-clean.pdf).] The top two results for the water, food, soil, and inhalation pathways were Ra-226,and U-238, in that order. Inhalation dominated these pathways in every case. The top two results for external exposure pathway were Ra-226 and U-238, in that order. The remaining six radionuclides (Ra-228, Th-228, Th-230, Th-232, U-234, and U-235) were far below these results and therefore were not considered further. The results were analyzed statistically using STATISTICA 10 (http://www.statsoft.com) were found to have no discernible distribution across the flood plain or within the stockpile. For this reason, the median soil concentration values were used as a measure of central tendency for the resident, recreational, student athlete, and groundskeeper scenarios. These individuals were assumed to use the entire areas encountered.

The radiological doses and risks were calculated for Ra-226 and U-238 using the scenarios presented in Table 6-1. Ra-226 and U-238 were detected above background in both the characterized flood plain and the stockpile. Because of this, the scenarios were evaluated using these radionuclides for the characterized flood plain, the stockpile, and the flood plain with stockpile material spread on it.

In general, RESRAD was used for the food ingestion, radon, inhalation and, soil ingestion calculations and Microshield for the external exposure analyses. An exception is that for the residential scenario, which involves the receptor living and receiving a dose entirely indoors, the external exposure pathway was evaluated using RESRAD.

6.3.1 RESRAD Model Description

The RESRAD computer program is a pathway analysis model designed to evaluate the potential radiological dose incurred by an individual who occupies land containing residual radioactive material (Yu *et al*. 2001). Version 6.5 of RESRAD was used for this analysis. That version has the capabilities of performing both deterministic and probabilistic dose assessments, as well as risk calculations using EPA HEAST.

The two primary exposure pathways considered by the RESRAD model for these assessments include:

1. Internal dose from inhalation of airborne radionuclides, including radon progeny, and
2. Internal dose from ingestion of radionuclides, which includes ingestion of:
    - Plant foods grown in the contaminated soil, and
    - Contaminated soil.

RESRAD has been widely accepted and has a large user base. According to the RESRAD website (http://web.ead.anl.gov/resrad/home2/), it has been applied to over 300 sites in the U.S. and other countries. It is the only code designated by DOE for the evaluation of radioactively contaminated sites. NRC has approved the use of RESRAD for dose evaluation by licensees involved in decommissioning, NRC staff evaluation of waste disposal requests, and dose evaluation of sites being reviewed by NRC staff. The EPA Science Advisory Board reviewed the RESRAD model. EPA used RESRAD in its rulemaking on radiation site cleanup regulations. RESRAD code has been verified and has undergone several benchmarking analyses,and has been included in the IAEA's VAMP and BIOMOVS II projects to compare environmental transport models. In addition, the software has been verified and validated (Yu 1999; NRC 1998).

6.3.2 Microshield Model Description

Microshield (http://www.radiationsoftware.com/mshield.html) is a comprehensive photon/gamma ray shielding and dose assessment program that is widely used for evaluating radiation designing shields estimating source strength from radiation measurements. The features that make it useful to this assessment are:

1. It models 16 geometries that accommodate offset dose points. (RESRAD, on the other hand treats each source as an infinite slab, which tends to result in higher results.)

2. Library data (radionuclides, attenuation, buildup, and dose conversion) reflect standard data from RSICC, ANS, and ICRP.
3. Buildup and uncollided results are both automatically and simultaneously calculated. (RESRAD does not estimate buildup in source or shielding material.)
4. Provides the ability to design and save up to eight custom materials for any case to add to the 12 built-in materials. This is useful for simulating unique materials, such as different kinds of soil.
5. Source decay can be calculated with daughter products generated.
6. As many as 25 energy groups (with an energy range of 15 keV to 10 MeV) may be used; input may be concentration or totals.
7. Sensitivity of exposure rate to time, source dimension, shield thickness, or distance can be investigated. Integration conversion verification can be conducted with sensitivity to quadrature order.
8. Provides the ability to define multiple (up to six) dose points for a case for almost all geometries.

6.3.3 Drinking Water Pathway

Measurements of uranium in Clear Creek upstream and downstream water samples taken since 2005 show no difference between the two locations, indicating no detectable contamination of the stream (Table 6-2.) A paired t-test of the data confirmed this statistically. No impact to downstream water users was detected.

Table 6-2
Uranium Concentrations in Surface Water Samples Collected on Clear Creek

Date	Uranium Concentration[a]	
	SW-1 (upstream)	SW-2 (downstream)
2/25/2005	1.97	1.29
9/7/2005	1.04	1.62
12/20/2005	2.11	1.5
3/15/2006	1.59	1.52
6/14/2006	0.61	1.44
9/13/2006	1	0.89
3/1/2007	1.7	1.7
6/27/2007	0.6	0.57
9/11/2007	0.94	0.97
11/27/2007	1.8	1.7
2/27/2008	2	2
4/18/2008	1.9	1.8
9/25/2008	1.1	0.99
12/3/2008	1.6	1.5
3/16/2009	1.9	1.9
6/24/2009	0.55	0.059
9/24/2009	1.1	1.1
12/17/2009	1.7	1.9
3/9/2010	2	2

Table 6-2
Uranium Concentrations in Surface Water Samples Collected on Clear Creek

Date	Uranium Concentration[a] SW-1 (upstream)	SW-2 (downstream)
6/7/2010	0.46	0.52
9/7/2010	1	1
12/7/2010	1.6	1.7
3/3/2011	2	2.1
6/8/2011	0.63	0.75
9/22/2011	0.88	0.87
Mean:	1.35	1.33

a. μg/L

6.3.4 Receptor Dose/Risk Assessment

RESRAD has default values to describe the different pathway parameters, but site-specific data are normally used to refine the model for the actual site and receptor. Some of the factors are more sensitive to change than others, such as the time of exposure to external gamma (fraction of time spent outdoors), permeability/porosity of the contaminated material (for radon), and soil ingestion (children typically ingest more soil). The literature references a wide range of assumptions used for the RESRAD parameters (USACE 2002).

Default values were used, for the most part, in all of the calculations. The biggest exceptions are for the radon dose in the residence scenarios. In this scenario, the residence has:

- A building foundation thickness of 0.2032 m (8 inches)
- A building foundation of 0.2032 m (8 inches) below surface
- A building foundation radon diffusion coefficient of 3.4 E-08 m-2/s and porosity of 0.11 as shown in Table 6-3.

Table 6-3
Effective Diffusion Coefficient (De) for Radon in Concrete

D_e (m^2s^{-1})	Total porosity (p_t)	Total porosity (p_t)
1.10E-07 to 4.00E-07	0.11 to 0.13	Poffijn et al. (1988)
1.20E-08	0.25	Culot et al. (1976)
3.40E-08	0.05	Culot et al. (1976)
3.40E-08	0.068	Zapalac (1983)
8.00E-09 to 8.40E-08		Stranden (1988)
Median 3.40E-08	0.11	

(from Table 7.1 of Yu et al 1993)

The other exceptions were the contaminated area dimensions discussed previously and the breathing rates assumed for the active receptors. The Microshield calculations were made using cylinder geometry for the source:

When the entire flood plain or stockpile was assessed, the dimensions listed in Table 6-4 were used.

Table 6-4
Stockpile Dimensions

Stockpile						
Radius	**Height**	**Unit**	**Area**	**Unit**	**Volume**	**Unit**
56.35	12.00	Ft	9976.00	ft^2	119712.00	ft^3
18.78	1.27	Yd	1108.44	yd^2	4433.78	yd^3
17.18	3.66	M	926.80	m^2	11121.61	m^3
Stockpile on Flood Plain (prior to removal)						
Radius	**Height**	**Unit**	**Area**	**Unit**	**Volume**	**Unit**
79.79	5.99	ft	20000.00	ft^2	119712.00	ft^3
26.60	2.00	yd	2222.22	yd^2	4433.78	yd^3
24.32	1.82	m	1858.06	m^2	11121.61	m^3

The density of the characterized flood plain was assumed to be 1.5 g/cc. The density of the stockpile was assumed to be 1.04 g/cc.

The two radionuclides of interest (Ra-226 and U-238) were first evaluated separately as unit concentrations (pCi/g). This exercise determined Ra-226 dominates the external exposure calculations. For this reason, only Ra-226 was modeled in subsequent calculations.

The subsurface concentrations of radionuclides measured in the test pits were overwhelmed by the external exposure associated with the contaminated surface soils. Because of this, only surface soils were used in the Microshield calculations.

6.3.5 Results of Radionuclide Assessment

A summary of the dose and risk predictions for the various scenarios is provided in Table 6-5. The data indicate that prior to characterization activities action was required on the flood plain area because the total annual human exposure to radiation exceeded 25 mrem or 100 if controls fail. This exposure was primarily from radon. Following characterization activities, the human exposure dropped to 16 mrem/per year. The existing stockpile could, if left in place, result in human exposure of 133 mrem/year.

Table 6-5
Doses and Risks Associated with Radionuclides

			Dose (mrem/y)				Risk (lifetime risk per million)			
Area	**Scenario**	**Concentration Values[a]**	**RESRAD**	**Microshield**	**Drinking water**	**Total**	**RESRAD**	**External[b]**	**Drinking water[c]**	**Total**
Flood Plain (Post-characterization)	Residence (radon)	Maximum	16.1	NE[d]	NE	16.1	1.35	Included in the RESRAD calculation	NE	1.35
	Recreational (picnic)	Maximum	0.000893	0.000850	NE	0.00174	0.0882	0.00168	NE	0.0899
	Student athlete	Median	0.00193	0.0225	NE	0.0244	0.00511	0.000806	NE	0.00592
	Groundskeeper	Median	0.0226	0.00802	NE	0.0315	5.65	0.00232E-09	NE	5.65
Flood Plain (Pre-characterization)	Residence (radon)	Maximum	133	NE	NE	133	97.7	Included in the RESRAD calculation	NE	97.7
	Recreational (picnic)	Maximum	0.003	0.00701	NE	0.010	0.839	0.0143	NE	0.853
	Student athlete	Median	0.0194	0.0224	NE	0.666	3.38	0.0238	NE	3.41
	Groundskeeper	Median	0.657	0.00880	NE	0.661	5.65	0.0685	NE	5.72
Stockpile	Residence (radon)	Maximum	133	NE	NE	133	97.3	Included in the RESRAD calculation	NE	97.3
	Recreational (picnic)	Maximum	0.00288	0.00702	NE	0.00991	97.3	0.0143	NE	0.113
	Student athlete	Median	0.0185	0.0221	NE	0.0406	0.446	0.0238	NE	0.470
	Groundskeeper	Median	3.14	0.00876	NE	3.15	4.30	0.0685	NE	4.37

a. Concentrations minus background concentrations.
b. Based on the FGR 13 slope factor used in RESRAD of 2.29E-08 (risk/yr per pCi/g) for Ra-226.
c. Based on the FGR 13 slope factor used in RESRAD of 6.4E-11 (risk per pCi ingested) for U-238 in water.
d. NE = Not evaluated. Drinking water assumed to be from City, not groundwater wells.

6.4 Soil Metals Risk and Toxicity Assessment

This section describes the methods used to evaluate the non-cancer systemic risks and toxicity associated with metals detected in soils collected from the evaluation area.

Table 6-6 summarizes the results of sample analyses of surface soils that contained exceedances collected on the characterized flood plain and the stockpile. Most of the results of laboratory analysis were below background and action levels. Some were above background but below action levels. A few were above both the action level and background values. These are shown in Table 6-6. All of the Table 6-6 results, with the exception of the sample collected at location 268, were collected from the stockpiled material. The latter location was determined to be too risky to excavate due to close proximity to a large City of Golden water line and was left in place.

Table 6-6
Summary of Metal Results (mg/kg) Above Action Levels and Background

Sample ID	Lead	Molybdenum	Arsenic	Mercury	Vanadium
Action Level[a]	400	39	39	23	78
Background[b]	86	6.1	38	0.63	44
116	<[e]	<	65	<	<
185[c]	7100	210	780	420	120
195[c]	520	<	150	290	<
196[c]	<	<	<	230	<
200[c]	<	<	<	76	<
268[d]	890	<	<	<	<
336	650	<	<	<	<
352	440	<	<	<	<

a. Tentative site cleanup goals agreed upon with the State of Colorado.
b. Data from New Horizons 2004 RI/FS, with the exception of arsenic.
c. Sample collected from the stockpile
d. Sample collected within characterization area
e. < = result is less than the action level and background

Table 6-7 presents the concentrations of metal COCs remaining in the flood plain. The summary values presented in this table are used to demonstrate that the post-characterized soil remaining on the flood plain no longer requires action.

Table 6-7
Final Metals Confirmatory Sample Results and Summary Statistics

Location	Uranium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Molybdenum (mg/kg)	Mercury (mg/kg)	Vanadium (mg/kg)
00163	9.4	86	23	8.2	2.7	20
00257	5.2	19	3.3	1.2	0.29	14
00259	11	51	11	3.2	0.89	29
00267	8.4	160	14	5.2	12	31
00279	3.1	87	17	2.2	1.2	25

Location	Uranium (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Molybdenum (mg/kg)	Mercury (mg/kg)	Vanadium (mg/kg)
00305	13	68	11	4.1	0.84	25
00353	3.3	26	15	1.6	0.03	36
00354	4.5	29	10	0.53	0.094	34
00355	2.6	66	8	4.1	1.5	36
00357	2.6	28	3.1	0.83	0.024	19
00374	3.3	61	4.8	5.1	0.44	32
00375	4.9	170	24	1.7	14	27
00381	11	41	1.8	5	0.26	19
00384	6.7	95	3.8	9.3	1.2	25
00388	3.1	40	2.6	6.1	0.35	29
00422	2.9	60	8.4	8.3	0.48	54
mean	5.94	67.94	10.05	4.17	2.27	28.44
Std dev	3.51	44.34	7.04	2.79	4.26	9.36
geo mean	5.08	56.46	7.66	3.13	0.60	27.10
Tentative Goal	14	400	39	390	23	78

mg/kg - milligrams per kilogram

The Risk Assessment Information System (RAIS) (http://rais.ornl.gov/) was consulted to evaluate the metals. Typically risks are expressed in terms of carcinogenicity. Only arsenic is listed as a human carcinogen. The potential risk to an individual who accesses arsenic in the stockpile is assessed in Section 6.4.1. The potential consequences of a human being exposed to the other metals are discussed following the arsenic assessment.

6.4.1 Arsenic Assessment

Arsenic risk was determined for both the soil stockpile and the flood plain after soil excavation. The most conservative exposure scenario for someone who intrudes into the stockpile would be digging and ingestion of arsenic in the contaminated soil. A groundskeeper who gardens during spring and summer months on the stockpiled material could be exposed to arsenic in soil via ingestion of soil. Also evaluated is the urban resident scenario. The risk (linear, low-dose cancer) from this exposure pathway was calculated using the formula from EPA (1989):

Risk = CDI X SF

where:

Risk = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer;

CDI = chronic daily intake averaged over 70 years (mg/kg-day);

And SF = slope factor, expressed in $(\text{mg/kg-day})^{-1}$.

The following assumptions were used to calculate the risk to a groundskeeper/gardener:

- The groundskeeper gardens 5 days/week, 26 weeks of year (May-October).
- He or she spends 5 years as a gardener (entry-level position).

- An adult gardener consumes soil at a rate of 2 mg/day (EPA 1997).
- Body weight is 70 kg (EPA 2005).
- Averaging time is 70 years (EPA 2005).
- The approved cleanup level for arsenic is 39 mg/kg.
- The concentration of arsenic in the stockpile is 780 mg/kg of soil.
- The highest concentration of arsenic on the flood plain is 24 mg/kg.
- The background concentration of arsenic is 38 mg/kg of soil.
- The flood plain average concentration after soil characterization is 10 mg/kg.
- From the above information, at the soil stockpile maximum, the chronic daily intake is 5.7 × 10-6 mg/kg/da.
- The slope factor for inorganic arsenic is 1.5 (mg/kg/da)-1 (EPA IRIS).

The assumptions used for the residential scenario are the same, except for the following (from EPA 1996):

- The resident lives at the same location for 70 years (from childhood through adulthood.)
- He or she is exposed to the contaminated soil 350 days/year.
- The weighted soil consumption rate from childhood through adulthood is 114 mg/day.

The calculation spreadsheet for the resident scenario was validated by comparing the soil screening level estimated by EPA (2011) that is estimated to approximate a risk of 1E-6. They estimated that a soil concentration of 0.43 ppm is equivalent to this risk. The spreadsheet used for the CSMRI estimated a risk of 1 E-06 for this soil concentration, thus confirming that the calculation is correctly applied.

Table 6-8 contains the results for the stockpile, and Table 6-9 contains the results for the flood plain for the concentrations listed and referenced above.

Table 6-8
Soil Consumption Arsenic Risk: Gardener/Groundskeeper

COC	$Conc_{soil}$ [a]	Consumption Rate[b]	Expos freq[c]	Expos dur[d]	Body wt[e]	Averaging time[f]	Slope factor[g]	Chronic Daily Intake[h]	Lifetime Risk[i] (per million)
As	mg/kg	kg/da	days/yr	years	kg	days	mg/kg/da^{-1}	mg/kg/da	(cancer)
STOCKPILE MAXIMUM CONCENTRATIONS									
	780	0.00002	130	5	70	25550	1.5	0.0000056695	8.5
FLOOD PLAIN MAXIMUM CONCENTRATION (post-excavation)									
	24	0.00002	130	5	70	25550	1.5	0.00000017445	0.262
FLOOD PLAIN AVERAGE CONCENTRATION (post-excavation)									
	10	0.00002	130	5	70	25550	1.5	0.000000072687	0.11
BACKGROUND LEVELS									
	38	0.00002	130	5	70	25550	1.5	0.00000027621	0.41
REFERENCE LEVELS									
	1	0.00002	130	5	70	25550	1.5	0.000000007268	0.011
	0.43	0.00002	130	5	70	25550	1.5	0.000000003125	0.0047

a. Measured value for As in metals data. The remaining are action levels.
b. Adult gardening. EPA, 1997. Exposure Factors Handbook, Vol. 1, EPA/600/P-95/002Fa, August 1997. p 4-16
c. Assume gardens 5 days/week, 26 weeks of year (May-October)
d. Assume he spends 5 years as a gardener (entry level position).
e. Adult. EPA, 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. EPA530-R-05-006, Sept. 2005.
f. 70 years. EPA 2005.
g. EPA Integrated Risk Information System (IRIS). http://www.epa.gov/iris. Arsenic, inorganic (CASRN 7440-38-2)
h. 70 years (EPA 2005)
i. Risk = CDI * SF. EPA, 1989

Table 6-9
Soil Consumption Arsenic Risk: Residential

COC	$Conc_{soil}$	Consumption Rate[a]	Expos freq[b]	Expos dur[b]	Body wt[b]	Averaging time	Slope factor[c]	Chronic Daily Intake	Lifetime Risk[d] (per million)
As	mg/kg	kg/da	days/yr	years	kg	days	mg/kg/da^{-1}	mg/kg/da	(cancer)
STOCKPILE MAXIMUM MEASUREMENT									
	780	0.000114	350	70	70	24500	1.5	0.00127	1910
FLOOD PLAIN MAXIMUM LEVEL (post-excavation)									
	24	0.000114	350	70	70	24500	1.5	0.0000391	58.6
FLOOD PLAIN AVERAGE LEVEL (post-excavation)									
	10*	0.000114	350	70	70	24500	1.5	0.0000163	24.4
BACKGROUND LEVELS									
	38*	0.000114	350	70	70	24500	1.5	0.0000619	92.8
REFERENCE LEVELS									
[e]	1	0.000114	350	70	70	24500	1.5	0.00000163	10.5
[f]	0.43	0.000114	350	70	70	24500	1.5	0.0000007	2.44

* Post-investigation Flood Plain arsenic levels were reduced to 74% below the Site-approved background level.
a. Age-adjusted soil ingestion factor from EPA Risk Assessment Guidance for Superfund, Vol 1(Publication 540/1-89/002, December 1989) http:// www.epa.gov/oswer/riskassessment/ragsa/index.htm
b. Factors from EPA Risk Assessment Guidance for Superfund, Vol. 1, Human Health Evaluation Manual, interim final, December 1989
c. EPA Integrated Risk Information System (IRIS). http://www.epa.gov/iris. Arsenic, inorganic (CASRN 7440-38-2)
d. Risk = CDI * SF.
e. DCGL
f. The Arsenic soil concentration estimated to be equivalent to 1E-06.From the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" website. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/

6.4.2 Lead

RAIS does not provide a reference dose or slope factor for lead. Although there is a strong correlation between exposure to lead-contaminated soils and blood lead concentration, numerous factors make a direct prediction of blood lead concentrations difficult. Soil particle size, lead species, bioavailability, and health of the exposed individual affect the uptake of lead. Alternative exposure paths such as lead paint and lead pipes in older buildings also influence blood lead concentrations. According to the IRIS website, "It appears that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold. The Agency's RfD Work Group discussed inorganic lead (and lead compounds) at two meetings (07/08/1985 and 07/22/1985) and considered it inappropriate to develop an RfD for inorganic lead." Often lead is regulated by the use of the soil standards; however, there is significant disagreement about the appropriate concentration. A paper published by the Agency for Toxic Substances and Disease Registry (ATSDR) lists recommended lead soil standards ranging from <100 mg/kg to 1,000 mg/kg (HHS 1992). The current proposed Tier 2 soil standard listed by CDPHE is 400 mg/kg. The Tier 2 table value for lead is based on current EPA guidance (EPA 1994).

The highest measured lead concentration in the stockpile is 7,100 mg/kg (Table 6-6). The concentration is well above the proposed CDPHE soil cleanup standard of 400 mg/kg for unrestricted land use and 2920 mg/kg for commercial use (CDHPE 1997), as well as the ATSDR recommended range of soil standards. This indicates the need to restrict access to the stockpile, or remediate it so that no one ingests the contaminated soil.

The maximum concentration of lead measured in confirmatory samples collected from the characterized flood plain is 170 mg/kg with an average concentration of 68 mg/kg. If the maximum concentration is corrected for background (86 mg/kg) the resulting concentration above background is 84 mg/kg using the EPA IEUBK model (EPA 1994) (www.epa.gov.gov/superfund/lead/products.htm). The estimated maximum blood level that could be received by an infant (1-2 years old) consuming soil containing these values is well below the values summarized in Table 6-10. The CDC has identified a blood lead concentration level of 10 mg/dL as the level of concern above which significant health risks occur.

Table 6-10
Lead Risk Urban Residential (Child)

Scenario	Soil Value	Blood Pb Concentration
Flood Plain Maximum Concentration.	170 ppm	4.1 µg/dL
Background Concentration	BKG = 86 ppm	2.1 µg/dL
Above Background Concentration	170 ppm – BKG (86 ppm) = 84 ppm	2.0 µg/dL
Flood Plain Average Concentration	68 ppm	1.8 µg/dL

6.4.3 Molybdenum

Molybdenum is considered an essential trace element. Molybdenum is placed in EPA Group D, not classifiable as to carcinogenicity in humans, and calculation of slope factors is not possible.

Data documenting molybdenum toxicity to humans are limited. Factors such as the physical and chemical state, route of exposure, and dietary deficiencies of copper and sulfur may affect toxicity. There is, however, no information available on the acute or sub-chronic oral toxicity of molybdenum in humans.

The provisional recommended dietary intake is 75 to 250 µg/day for adults and older children (NRC 1989). Molybdenum in excess of the action level and background was determined in one sample in the stockpile (210 mg/kg, as shown in Table 6-6). Assuming that an individual accessing the stockpile (such as the groundskeeper in Section 6.4.1) consumes 2 mg/da of soil, he or she could ingest approximately 0.42 µg/day of the metal per day. This is well below the NRC provisional recommendation and the U.S. Food and Drug Administration current Daily Value of 75 micrograms recommended for molybdenum.
Http://www.fda.gov/Food/LabelingNutrition/FoodLabeling
GuidanceRegulatoryInformation/RegulationsFederalRegisterDocument/ucm073531.htm

6.4.4 Mercury

Mercury is a naturally occurring element that exists in multiple forms and various oxidation states. Exposure to mercury in the natural environment typically involves dietary intake (ATSDR 1989). Absorption, distribution, metabolism, and excretion of the element depend on its form and oxidation states (ATSDR 1989). Ingestion of mercury metal is usually without effect (RAIS). Ingestion of inorganic salts may cause severe gastrointestinal irritation, renal failure, and death with acute lethal doses in humans ranging from 1 to 4 g (ATSDR 1989). Organic mercury, especially methyl mercury, rapidly enters the central nervous system resulting in behavioral and neuromotor disorders (ASDTR 1989). An oral RfD_c of 0.1 µg/kg/da has been established for methyl mercury (EPA 1996).

No data are available regarding carcinogenicity of mercury in humans or animals. Measurements of mercury in the stockpile exceeded background and the action limit in four samples. The highest result was 420 mg/kg. These results also exceed the maximum CDPHE soil cleanup standard for commercial land use (176.53 mg/kg). A groundskeeper could potentially ingest up to 0.84 µg of mercury a day through ingestion of soil while working. The consequence of consuming this depends on the form of mercury in the soil, and past speciation of mercury has indicated the predominant form is in metal and not organic (Stoller 2007), indicating low risk.

6.4.5 Vanadium

Vanadium is a metallic element that occurs in six oxidation states and numerous inorganic compounds (RAIS). Vanadium compounds are poorly absorbed through the gastrointestinal system but slightly more readily absorbed through the lungs (ICRP 1960).

There is little evidence that vanadium or its compounds are carcinogenic.

The toxicity of vanadium depends on its physic-chemical state. The elemental metallic form is considered to be non-toxic (RAIS).

Measurements of vanadium in the stockpile exceeded background and the action limit in one sample (120 mg/kg). A groundskeeper could potentially ingest up to 0.24 µg of vanadium a day through ingestion of soil while working. The health impact of consuming this depends on the form of vanadium in the stockpile. However, previous risk indicators had concluded that the stockpile is a health risk, so the exact nature of vanadium is purely academic. The vanadium on the flood plain is below cleanup standard, thus below the risk threshold.

6.5 Risk Assessment Summary

In conclusion, the flood plain pre-characterization soils presented an unacceptable risk to human health and the environment. The residual risk for soils remaining on the flood plain post-characterization will require an environmental covenant to be protective of human health because of the potential for radon exposure. Although the radionuclide exposure post-characterization has been reduced to 16 mrem/yr, less than the TEDE of 25 mrem/yr, the CERCLA risk goal is 15 mrem/yr. The existing stockpile if left in place could result in unacceptable human exposure of 133 mrem/yr for an urban resident.

In addition to radionuclides, the lifetime risk for arsenic was calculated for post-characterization and stockpile soil for the two scenarios that posed the greatest risk (groundskeeper and resident). Risk on the flood plain site predominantly results from the presence of the radionuclides and arsenic. Both radionuclides and arsenic add human health risk in the post-characterization flood plain soil. Other COCs such as lead, mercury, molybdenum, and vanadium do add some risk, but the value is sufficiently low so as to not change the risk numbers reported below. The cumulative total risk from radionuclides and arsenic are presented in Table 6-11. For the stockpile to be protective of human health, additional action will be required.

Table 6-11
Cumulative Total Lifetime Risk from Radionuclides and Arsenic

Area	Scenario	Total Radionuclide Risk (lifetime risk per million)	Arsenic Risk (lifetime risk per million)	Cumulative Total Risk (lifetime risk per million)
Flood Plain (Post-characterization)	Residence	1.35	58.6	59.95
	Groundskeeper	5.65	0.262	5.91
Flood Plain (Pre-characterization)	Residence	97.7	1910	2007.7
	Groundskeeper	5.72	8.5	14.22
Stockpile	Residence	97.3	1910	2007.3
	Groundskeeper	4.37	8.5	12.87

Figure 6-1

Test Pit and Confirmatory Sample Locations in Characterization Area

Explanation

Comfirmatory Sample

CLT locations - June 2010

Flood Plain Characterization Area

Extent of COC's

Stockpile

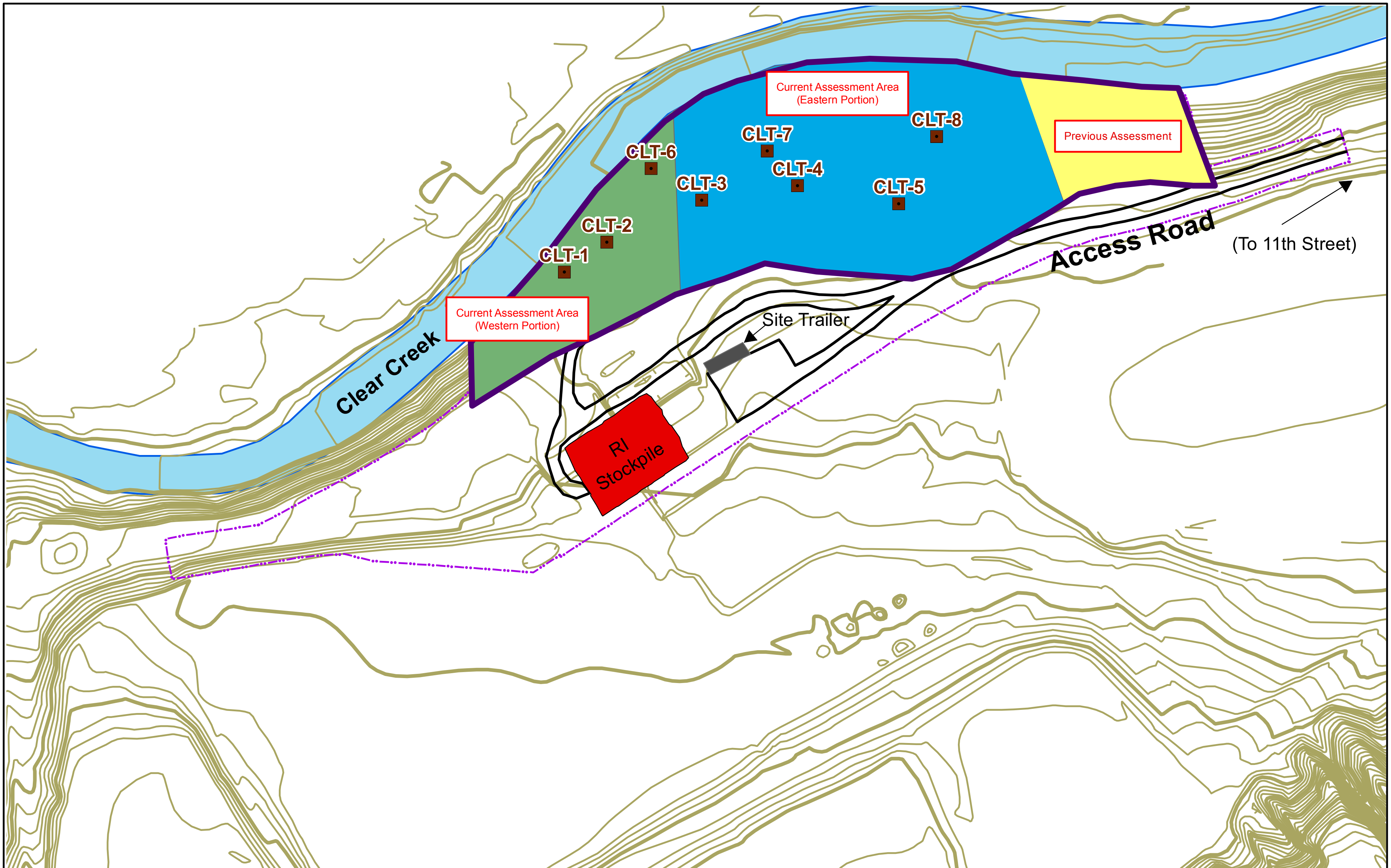
N
W E
S

0 25 50 100 Feet

CSMRI
Flood Plain
Remedial Investigation /
Feasability Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\rifs_figure_(6-1).mxd PLD @ 11/7/11



Explanation

- CLT locations - June 2010
- CSMRI Flood Plain Site
- Stockpile
- Temporary Access Road
- Fences
- Topography (2Ft Intervals)
- Topography (10Ft Intervals)

Figure 6-2

CSMRI Flood Plain
Risk Assessment Areas

CSMRI
Flood Plain
Remedial Investigation /
Feasibility Study

Stoller

S:\4349 CSMRI Flood Plain EA&RIFS\Working Report Figures\rifs_figure(6-2).mxd PLD @ 11/7/11

Table of Contents for Section 7

7. Development and Screening of Alternatives 7-1
7.1 Identification of Remedial Action Objectives (RAOs).................... 7-3
7.2 Identification of Treatment, Recovery, or Containment Options 7-5
7.2.1 Baseline Risk Assessment Impact on Available Options 7-5
7.2.2 Available Options 7-7
7.2.3 Remaining Action Groups 7-7
7.3 Evaluation of Technologies 7-8
7.4 Generation of Alternatives.................... 7-10
7.4.1 Remedial Action Alternative Screening 7-11
7.4.2 Common Alternative Elements.................... 7-12
7.4.3 Alternatives 1a, 1b and 1c – No Action.................... 7-14
7.4.4 Alternative 2 – Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility 7-15
7.4.5 Alternative 3 – Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository 7-15
7.4.6 Alternative 4 – Onsite Solidification and Placement into an Above-Grade Repository 7-16
7.4.7 Disposal Facility Options.................... 7-17

List of Tables

Table 7-1 Site DCGLs and Cleanup Levels.................... 7-4
Table 7-2 Remedial Action Alternatives 7-11
Table 7-3 Remedial Action Objectives.................... 7-12
Table 7-4 CSMRI Site Disposal Options Summary 7-17

7. Development and Screening of Alternatives

This RI/FS includes an environmental covenant requiring installation of a radon mitigation system for any structure built on the floodplain site to meet ARARs and as a best management practice. With the exception of the No Further Action alternative (Alternative 1), this covenant applies to all of the remedial alternatives due to residual impacted soils remaining after excavation and to the relatively high concentration of background Ra-226.

The first six sections of this RI/FS described the remedial investigation. The RI was completed through two field programs. The first phase provided valuable data with respect to the geology and hydrology of the flood plain, the presence of contaminants and complexity of their distribution, and the nature of the subsurface sediments on the flood plain. The data were used to refine the approach to determining the source area and the nature and extent of contamination. The second phase implemented a program to complete source area determination and nature and extent investigation using the data recovered during the first phase.

The remainder of this RI/FS document focuses on the FS, which develops, screens, and evaluates alternatives for remedial actions. The FS presents the remedial action alternatives to be evaluated by decision makers and aids in the selection of the appropriate remedy. The primary requirement of the selected alternative is to be protective of human health and the environment by eliminating, reducing, and/or controlling risks posed through each Site pathway.

The purpose of this section is to explain the processes used to identify possible alternatives and screen out alternatives that may be impractical, unworkable, or not protective of health and environment at the Site. Development of the alternatives requires the following actions:

- Identification of remedial action objectives (RAOs),
- Identification of potential treatment, resource recovery, and containment technologies that will satisfy the objectives,
- Evaluation of technologies based on effectiveness, implementability, and cost,
- Screening out of potential alternatives that do not meet the objectives, and
- Generation of alternatives to be evaluated further by detailing the technologies and their associated containment or disposal requirements.

The volume of impacted material requiring management under each alternative is 1,100 in-place cubic yards. The 1,100 in-place yards expanded to an actual volume of 1,400 cubic yards in the stockpile. The stockpile volume is the volume that will require remediation.

The previous FS completed by Stoller for the upper terrace of the flood plain in 2007 eliminated the no-further action alternative and indicated that leaving the impacted soil in place was not an acceptable option. Further, the selected remedial action alternative was excavation and offsite disposal of impacted soils above the DCGLs.

Earlier characterization efforts identified the complexity and heterogeneous nature of the distribution of impacted Site soils. The investigation strategy achieved characterization through the excavation of successive 1-foot-thick soil layers.[1] Material determined by field screening to exceed tentative cleanup levels for metal COCs and radionuclide activity was segregated from clean Site soils. After each 1-foot layer was excavated, the underlying surface was tested, and additional contaminated material was then segregated if necessary. This continued until material below the DCGLs was encountered across the entire site or until bedrock was reached.

This procedure guided the flood plain characterization because the no further action alternative was not deemed viable due to the ongoing impacts to the groundwater from an unknown source. Two significant differences were designed to ensure all impacted material was excavated in cases where field screening may be inadequate: (1) when the water table was encountered if the soil immediately above the water was impacted, all soil was excavated to bedrock and; (2) if artificial fill material was observed it was excavated. In both cases, all material was handled as impacted and segregated into the stockpile.

Excavated materials, which exceeded the cleanup goals for metal COCs (including uranium above 14 ppm) and/or soils with gamma activity more than two times Site background, were placed in a stockpile. In addition, material identified as artificial fill and/or excavated from beneath the water table during the investigation was placed in this stockpile.

Any soil excavated during the characterization effort that was determined to be below the Site cleanup action levels based on field screening was managed on the upper terrace in an area separate from the stockpile. This material was mostly limited to topsoil and vegetation excavated during the initial clearing and grubbing of the characterization footprint.

Characterizing the Site soils in this way saved costs by excavating soil that would have required excavation eventually during the implementation of remedial options. The investigation approach was adopted after determining that the no-action alternative was not a viable alternative. In 2004, the nature and extent of contamination was far greater than that estimated in the RI/FS which had used a grid and borehole investigation method. It was clear then that the no-action alternative and the *in-situ* alternatives will not be reasonable alternatives and extensive excavation of Site soils was still required. The approach used in the 2007 RI/FS and adopted for this RI/FS demonstrated that characterizing Site soils in the traditional manner of drilling numerous boreholes across the entire Site used in 2004 did not work given the degree of heterogeneity and complexity. The borehole approach would have cost an amount that was comparable to the excavation and segregation method used in this RI/FS and would not have achieved the needed volume accuracy and increased the risk of overlooking impacted material. Prior investigation and cleanup experience at this Site, the relatively high concentrations of uranium in CSMRI-8 compared to other wells at the Site, and the results of the first phase of this investigation in the flood plain area using test pits demonstrated that remedial action was necessary and the no-action alternative was not a viable alternative.

The characterization was successful and determined remaining Site soils are below the tentative cleanup action levels.

[1] This investigation strategy was developed and successfully implemented during the 2007 RI because conventional borehole sampling on a grid proved to be an ineffective method at a site like the CSMRI Site.

After development of potential alternatives, options not meeting the objectives are screened out from further evaluation. The screening process evaluates alternatives with respect to their effectiveness, implementability, and cost.

7.1 Identification of Remedial Action Objectives (RAOs)

The RI identified elevated concentrations of radionuclides and metals. RAOs for the Site are designed to prevent or mitigate further release of affected materials to the surrounding environment and to eliminate or minimize risk to human health and the environment. Based on existing information, site-specific RAOs were developed. The RAOs specify the materials and media of concern, the exposure routes and receptors, and an acceptable concentration or dose for the materials of concern level or range of levels for each exposure route (i.e., preliminary remediation goals).

The affected material was the surface and subsurface soil located on the terrace slope and flood plain adjacent to Clear Creek that could be acting as a continuing source of elevated uranium concentrations in Site groundwater monitoring wells and other risks. After placement in the soil stockpile, the segregated, affected material is located above the 500-year flood contour just above the terrace slope. The stockpile is in a stable configuration within geomembrane-lined containment and has been armored with a soil tackifier to temporarily prevent airborne dust and minimize erosion.

Potential receptor pathways include direct radiation, inhalation, and ingestion of plants and soil. Another potential exposure pathway is the migration of the affected material to groundwater and subsequent groundwater ingestion. The following objectives, originally established for the Site prior to soil segregation activities, remain valid:

- Eliminate or minimize the pathway for dermal contact, inhalation, and ingestion of site-specific radionuclides to human receptors to achieve a level of protection in compliance with the NCP levels of acceptable cancer risk (10^{-4} to 10^{-6}).
- Develop receptor-specific DCGLs to limit unacceptable radiation doses (TEDE to less than 25 mrem/yr and 15 mrem/yr, distinguishable from background; and less than 100 mrem/yr above background if institutional controls fail for onsite restricted-use remedies) for the radionuclides found in the affected material (i.e., soil). Radium-226, total uranium and thorium-230 are present onsite at activities above tentative DCGLs.
- Prevent exposure to indoor air concentrations of radon gas and radon decay products greater than 4 picocuries per liter (pCi/L) and 0.02 working level (WL), respectively. Exposure to 4 pCi/L of air for radon corresponds to an approximate annual average exposure of 0.02 WL for radon decay products, when assuming residential land use.
- Prevent long-term dermal, inhalation, and ingestion exposures to metal-affected materials with concentrations greater than the CDPHE proposed Residential/Unrestricted Land-Use Standards or that generate hazard indexes greater than 1. The primary metals of concern are arsenic, lead, and uranium.
- Address specific issues associated with the hazards associated with soil containing elevated concentrations of lead (possible access issues with neighborhood children).
- Implement remedial measures that comply with Colorado standards for the protection of groundwater and limit groundwater and surface-water concentrations to the MCLs at the

points of compliance and to non-zero maximum contaminant level goals (MCLGs), established under the Safe Drinking Water Act and under Colorado law. Although the affected groundwater is not a current drinking water supply, it eventually enters Clear Creek, which is used by downstream users for drinking water. Uranium is the primary groundwater COC.

- Prevent offsite migration of affected material that could result in the exposures described above. This includes the groundwater pathway.
- Implement remedial actions that reduce exposures from ionizing radiation to levels that are as low as reasonably achievable (ALARA).
- Comply with soil-, location- and action-specific applicable or relevant and appropriate requirements (ARARs) (Section 8.1 and Appendix F).

Table 7-1 presents the Site action levels agreed to in the CDPHE-approved 2010 Site Characterization Work Plan. These DCGLs, originally developed prior to the 2004 RI/FS, have been considered tentative for all Site work and documentation during the investigation phases of the work. The tentative DCGLs and Site Action Levels were agreed to by the School and CDPHE in 2004 and have only been modified for arsenic (2006), total uranium (2010), and vanadium (2010) since that time. These DCGLs, in combination with the environmental covenant, allow the School to comply with all ARARs and allow for future beneficial use of the Site. For the feasibility phase of the work, DCGLs are no longer referred to as "tentative." They are considered final DCGLs.

Table 7-1
Site DCGLs and Cleanup Levels

Metal	DCGL (mg/kg)	Site Action Level (inclusive of background) (mg/kg)
Arsenic	1.0	39
Lead	NA	400*
Mercury (elemental)	1.1	1.1
Mercury (compounds)	NA	23
Molybdenum	NA	390
Uranium	NA	14
Vanadium	NA	78
Radioisotope	**DCGL (pCi/g)**	**Site Action Level (pCi/g)**
Radium 226	1.44	4.14
Radium 228	2.20	4.6
Thorium 228	3.77	6.47
Thorium 230	9.83	11.53
Thorium 232	1.48	3.88
Uranium 234	253	254.9
Uranium 235	4.88	4.97
Uranium 238	20.2	21.8

[1] NA – Not applicable
mg/kg – milligrams per kilogram
pCi/g – picocuries per gram
* DCGLs not calculated for some metals. Site action levels use ARARs for cleanup goals.

Receptor definition is important for the determination of risks and hazards. Exposure times and multiple pathways place the urban resident at greater risk than an occasional recreational user. The persistence of the affected material will place receptors at risk for over 1,000 years, and land use could change significantly in that amount of time. The urban resident, student athlete, groundskeeper, and recreational user were evaluated for each scenario because of the reasonably foreseeable future land uses by the School or other future owners of the Site. Additionally, exposures resulting from each alternative must comply with a 1997 NRC rule (10 CFR Part 20, Subpart E), which has been adopted by Colorado (6 CCR 1007-1 4.61.3) and establishes a dose criterion for decommissioning a site. This rule includes a provision that permits decommissioning under restricted release conditions, such as those proposed herein. Under a restricted release (a release including an environmental covenant), the dose to the average member of the critical group must not exceed 25 mrem/yr with the restrictions in place, and, if the restrictions were to fail, the dose due to residual radioactivity must not exceed 100 mrem/yr.

7.2 Identification of Treatment, Recovery, or Containment Options

The NCP, at 40 CFR 300.430(e)(ii) and (iii), requires the identification and evaluation of potentially suitable technologies to comply with ARARs and the assembly of suitable technologies into alternative remedial actions.

The initial step of the NCP process is to identify the general action groups. 40 CFR 300.430(e) requires the evaluation of a range of alternatives including:

- No action – may involve no-further action if some removal or remedial action has already occurred at the Site.
- No treatment – involves little or no treatment but provides protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants. This may be accomplished through engineering controls such as containment, and, as necessary, institutional controls to protect human health and the environment and to assure continued effectiveness of the response action. Treatment – identifies treatment(s) that reduces the toxicity, mobility, or volume of the hazardous substances, pollutants, or contaminants. Innovative treatments are to be considered.
- Removal – involves removal of affected material to an offsite landfill or equivalent location designed to contain such material.

The results of the baseline risk assessment presented in Section 6 impact the suitability of the transport, recovery or containment options as described below.

7.2.1 Baseline Risk Assessment Impact on Available Options

The baseline risk assessment evaluated three Site scenarios: (1) the pre-excavation flood plain area (Site Condition 1) and (2) the Site as it exists today which includes both (2a) the post-characterization flood plain soil and (2b) the impacted soil excavated during the characterization that is currently managed in a stockpile on the upper terrace. The post-characterization floodplain soil and stockpile although evaluated for human health risk as separate scenarios in Section 6 are discussed as Site Condition 2 when evaluating the no action alternative because together they represent the current Site configuration. The baseline risk assessment provides the basis of determining whether further action for these Site conditions is warranted or whether the no-action alternative considered in the FS is viable. The results of the baseline risk assessment confirmed the validity of eliminating the no further action alternative for the pre- and post-characterization Site conditions discussed below.

Site Condition 1 (pre-characterization flood plain soil)
The risk assessment evaluated the flood plain soils prior to characterization to determine if they posed an acceptable risk to human health if no further actions were undertaken and the soils remained in place. The preliminary characterization results from soil samples collected from exploratory test pits in June 2010 detected metals (As, Pb, V, and U) and total radium above the tentative cleanup goals, which are based on either human health risk standards or background concentrations. When the characterization began, environmental impacts were evidenced by elevated concentrations of dissolved uranium in the groundwater. No further action is unacceptable because Site Condition 1 is neither protective of human health as described in Section 6 nor is it protective of the environment.

Site Condition 2 (current Site status)
The risk assessment evaluated the entire Site in its current configuration which includes the soils remaining on the flood plain post-characterization and the stockpile managed on the upper terrace to determine if they posed an acceptable risk to human health.

The risk analysis presented in Section 6 for the soil remaining on the flood plain determined that soil no longer presents significant human health risk. The residual risk remaining at the flood plain warrants only an environmental covenant requiring radon mitigation systems for all future structures because of background concentrations of radium in area soils and a 16 mrem/yr dose due to radon (the CERCLA risk goal is 15 mrem/yr). Two sample locations with elevated total radium, one of which detected uranium and lead above the tentative cleanup goals, could not be excavated due to their close proximity to municipal water lines. No further action is a viable alternative for the flood plain, and further action is not warranted for the soil. However, it is important to note that this RI/FS deals only with the soil operable unit. Quarterly monitoring of groundwater wells since impacted soils were excavated has determined there is a decreasing trend, but elevated concentrations of dissolved uranium continue above the ground water standard. Groundwater (OU1) will be addressed in a separate RI/FS for that operable unit after monitoring continues for another five quarters and the data analyzed to determine next steps.

The soil stockpile was evaluated to determine if it poses an acceptable risk to human health. The risk analysis presented in Section 6 determined this soil presents an unacceptable human health risk for the urban residence scenario. In addition, although measures have been taken to stabilized the stockpile while alternatives are evaluated, over the long-term without further action these measures will not be protective of the environment because the uranium concentrations exceed the cleanup goal established to protect ground water quality. Therefore, no further action is unacceptable, and further action is warranted because the stockpile is not protective of human health or the environment.

In conclusion, the flood plain pre-characterization soils presented an unacceptable risk to human health and the environment and further actions were warranted. Although, soils remaining on the flood plain post-excavation pose a very small human health risk, this alternatives analysis must evaluate the current Site conditions as a whole which includes the stockpile thereby eliminating the no further action alternative. For the Site in its current condition to be protective of human health and the environment further action will be necessary with respect to the stockpile and an appropriate environmental use covenant requiring the use of radon mitigation systems in structures.

Institutional controls are evaluated to determine if environmental covenants alone without other action or treatment are a feasible alternative. This alternative would prescribe no further actions for the three Site conditions described above other than institutional controls. This option is not acceptable because neither the soil *in situ* prior to excavation nor the soil in the stockpile reduces the threat to human health or the environment to an acceptable risk. Future indoor radon exposures from the soil in situ prior to excavation or in the stockpile could have exceeded 100 mrem per year. The sole use of environmental covenants to control that level of risk is unacceptable.

7.2.2 Available Options

On the basis of the information described above, the no-action alternative is unacceptable and the other remedies considered in the FS include environmental covenants for portions of the flood plain. These restrictions may include requirements such as radon mitigation, subgrade structures, and use of groundwater for future property uses and are discussed in Section 7.4.2.4.

7.2.3 Remaining Action Groups

As a result of the elimination of the no action/no treatment as viable alternatives, the remaining action groups need to be evaluated to determine what remedial action is appropriate. A number of guidance documents and methodologies are available to assist with this process. The following primary sources of information were used for this portion of the FS:

- Remediation Screening Matrix (http://www.frtr.gov/matrix2/top_page.html) prepared for the U.S. Department of Defense and other federal agencies participating in the Federal Remediation Technology Roundtable
- Presumptive Remedy for Metals-in-Soil Sites (EPA 1999). Developed in a joint effort between the EPA and the DOE
- Contaminants and Remedial Options at Selected Metal-Contaminated Sites (EPA 1995)
- Rules of Thumb for Superfund Remedy Selection (EPA 1997b)

According to the program expectations listed in 40 CFR 300.430(a)(1)(iii)(A-F), EPA generally has the following expectations when appropriate remedial alternatives are developed:

- Use of treatment to address the principal threats posed by a site, wherever practicable.
- Use of engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.
- Use of a combination of methods, as appropriate, to achieve protection of human health and the environment.

- Use of institutional controls, such as water use and deed restrictions, to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants.
- Consideration of innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.
- Return of usable groundwaters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site.

Because of the persistent nature of metals and radionuclides, remediation options are typically limited. Current potentially applicable technologies include immobilization, reclamation and recovery, containment, institutional controls, other onsite treatment, and offsite disposal (EPA 1999). The concentrations of the COCs are too low to warrant reclamation and recovery; thereby, reducing the list to the remaining five options.

7.3 Evaluation of Technologies

Immobilization includes processes that change the physical or chemical properties to reduce the leaching characteristics of a treated waste or decrease its bioavailability and concentration. This treatment locks metals within a solidified matrix (solidification) and/or converts the waste constituent into a more immobile form, usually by chemical reaction (e.g., stabilization, reducing available oxygen). The process involves mixing a reagent (usually cement kiln dust, proprietary agents, cement, fly ash, blast furnace slag, bitumen) and generally solidifying the material with the contaminated soil. Reagents are selected based on soil characteristics and the specific metal contaminants present. The treatment must be performed *ex-situ* in either onsite or offsite units. The addition of the stabilization reagents does not achieve waste minimization. The literature suggests the more volatile metals (arsenic and mercury, which are methylated by bacteria and fungi) may continue to migrate out of the completed matrix, albeit at a slower rate than the untreated soil.

Vitrification is another immobilization method that uses an electric current to melt soil at extremely high temperatures to solidify the soil/metals mixture. Vitrification is an expensive process and can potentially transfer the more volatile metals (arsenic and mercury) to the atmosphere.

Mechanical soil mixing, using large augers to mix reagent with impacted soil, also has been used but typically requires additional solidification materials and makes verification of cleanup levels more difficult. Immobilized materials generally are managed in a landfill with the associated containment barriers (e.g., caps). These methods require some type of institutional control to prevent construction or earthwork that could damage the matrix. The institutional controls will involve long-term operation and maintenance costs.

Containment of wastes in place includes vertical and horizontal barriers. This remedial technology can provide sustained isolation of contaminants and can prevent mobilization of soluble compounds over long periods of time. It also reduces surface water infiltration, provides a stable surface over wastes, limits direct contact, and improves aesthetics. Containment is typically handled with the construction of an engineered onsite waste repository. Onsite materials are consolidated and placed in the cell that includes a clay or synthetic liner. The area is then capped to prevent the migration of precipitation into the cell. Institutional controls are used to prevent damage to the cap. Groundwater monitoring and periodic physical inspection of the cell are often required to ensure the ongoing integrity of the cap and liner systems. Long-term operation and maintenance costs are associated with this option, which may include the capture and treatment of leachate from the cell itself.

In addition to the stabilization option, a number of onsite treatment technologies are available for removing metals from soils. Soil acid washing, phytoremediation, and electrokinetic separation have been used with varying degrees of success to remove metals from soils.

Acid extraction involves adding an acid and water mixture to the affected soil. This technique is typically performed in an onsite treatment cell to prevent the migration of material to groundwater. In this process, soils are first screened to remove coarse solids. Hydrochloric acid is then introduced into the soil in the extraction unit. The residence time in the unit varies depending on the soil type, contaminants, and contaminant concentrations but generally ranges between 10 to 40 minutes. The soil-leachate mixture is continuously pumped out of the mixing tank, and the soil and leachate are separated using hydrocyclones. The technique is based on the idea that most metals are cations adsorbed to soil particles (primarily clay) and adding the acid increases the mobility of the metals. The leachate from the process is collected and the metals are extracted. However, the technique is often problematic for metal mixtures that exhibit a variety of solubility behaviors in response to pH (e.g., some forms of arsenic are more mobile at high pH). The treatment cell construction in combination with consumable costs makes this option relatively expensive. Hazards associated with the onsite handling of acids also make this option less attractive. If successful, onsite soils can be cleaned to regulatory requirements, allowing unrestricted use of the property.

Phytoremediation uses vegetation to extract metals from the soils. The vegetation is then harvested and disposed at an approved landfill. The technique has shown promise for several metals, but as with the acid washing technique, varying metal solubilities make the extraction process difficult to predict. Sites have tried using chelating agents such as EDTA to improve metal solubilities only to drive the metals to groundwater. The technique also requires a number of growing seasons before significant decreases in metal concentrations can be observed. While initial costs for this option are relatively low, the long-term nature of the process can be costly. Institutional controls will be needed to limit access to the Site for the duration of the process. The vegetation also can be an ecological risk to local wildlife. The technique provides no initial control of the groundwater pathway and may accelerate the metals migration if the selected vegetation requires irrigation.

Electrokinetic separation relies upon application of a low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. The current creates an acid front at the anode and a base front at the cathode.

The acid or base front may help to mobilize sorbed metal contaminants for transport to the collection system at the cathode. Limitations of electrokinetic separation include (1) the requirement of soil moisture contents in excess of 10 percent (can be problematic in a semiarid climate), (2) the presence of buried metallic or insulating material can induce variability in the electrical conductivity making the technique ineffective, (3) the heterogeneity of the soil can be problematic – the technique is most effective in clays, and (4) the oxidation/reduction reactions can produce undesirable products such as chlorine gas. Engineering, equipment, and operational costs make this option relatively expensive. Again the technique provides no initial control of the groundwater pathway. If successful, onsite soils potentially can be cleaned to regulatory requirements, allowing unrestricted use of the property.

Offsite disposal involves the excavation, transportation, and disposal of the affected material to an offsite landfill. The material is placed in a licensed landfill that can accept the materials contained in the soil. Factors to consider for this option include the risks and costs associated with the transportation of the material. Movement of the material through adjacent neighborhoods can sometimes make community acceptance more difficult. Determining the feasibility of offsite disposal requires knowledge of land disposal restrictions and other regulations developed by state governments. Transportation costs will increase if specialized landfills are required because they are located farther away than ordinary landfills. Because the impacted soils are already excavated and stockpiled, offsite disposal costs are reduced.

7.4 Generation of Alternatives

After reviewing the remedial action alternatives, a number of technologies were eliminated in the earlier FS because of questionable effectiveness and/or implementability or excessive cost. These are listed below:

- Vitrification was eliminated because of cost and the potential to off-gas volatile metals.
- Acid extraction was dismissed because of cost and the uncertainty associated with the technique. Movement and use of large quantities of acid in such close proximity to Clear Creek creates additional risk.
- Phytoremediation was dismissed because of the long-term requirements of the technology and the continued lack of groundwater protection.
- Electrokinetic separation was eliminated because of cost and the technique uncertainty. Onsite soils are highly heterogeneous, and soil moisture is highly variable due to seasonal fluctuations throughout the year.

Similar to the materials at issue in the 2007 RI/FS, the impacted Site soils reside in a lined stockpile. The basis for eliminating alternatives that were eliminated in previous FS efforts remains valid. There is very little difference in the current state of the impacted soils from the state during preparation of the earlier FS efforts. Like in the 2007 RI/FS, the groundwater pathway has been temporarily interrupted and the volume of impacted soils is known. Having the impacted soil in a lined stockpile reduces some costs associated with the above-discussed options. The reduced costs are not, however, sufficient reason to re-evaluate any of the above-discussed options that have been screened out.

The 2010 Site characterization activities were successful, and the impacted Site soils were placed in a lined/stabilized stockpile. Remedial action alternatives evaluated for this FS are summarized in Table 7-2.

Table 7-2
Remedial Action Alternatives

Alternative	Description	Is Excavation Included as Part of Remedy?	Are Institutional Controls Included as Part of Remedy?
1	No Action	No	No
2	Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	Yes	Yes
3	Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository	Yes	Yes
4	Onsite Solidification and Placement into an Above-Grade Repository	Yes	Yes
5	Place Cap over Stockpile Soil	Yes	Yes

7.4.1 Remedial Action Alternative Screening

Section 8 of this document provides detailed information concerning evaluation of each alternative determined to meet the majority of the remedial objectives. This section further reviews and screens out those alternatives presented in Table 7-2 that do not meet the remedial objectives.

As detailed in Section 7.1, the RAOs can be summarized as being the following.

1. Eliminate or minimize human exposure pathways including
   - Dermal contact
   - Inhalation
   - Ingestion
   - Radiation
2. Reduce potential future radiation exposure to less than 15 mrem/yr and 25 mrem/yr and to less than 100 mrem/yr with the failure of institutional controls
3. Attain 10^{-4} to 10^{-6} acceptable cancer risk level
4. Eliminate or minimize environmental exposure pathways, including
   - Groundwater
   - Surface water
   - Dust
   - Biota uptake

These objectives were evaluated for each of the above alternatives to determine if they can be eliminated from further scrutiny or if they sufficiently meet the objectives to be further considered. Table 7-3 presents this screening summary for the 2010 preliminary alternatives listed above. The table indicates whether the remedial alternative indicated eliminates or minimizes the pathway indicated.

Table 7-3
Remedial Action Objectives

RA	Human Exposure					Environmental Exposure			
	Dermal	Inhalation	Ingestion	Radiation	Radon	Ground water	Surface water	Dust	Biota Uptake
1a	N	N	N	N	N	N	N	N	N
1b	Y	Y	Y	Y	N	Y	Y	Y	Y
1c	N	N	N	N	N	N	N	N	N
2	Y	Y	Y	Y	Y	Y	Y	Y	Y
3	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Y	Y	Y	Y	Y	Y	Y	Y	Y
5	Y	Y	Y	N	N	N	N	Y	Y

Alternatives 1a, 1b, 1c, and 5 do not meet the RAOs, because they fail to provide sufficient reduction of risk from each medium and/or pathway of concern for the Site. Therefore, these alternatives are eliminated from further consideration.

One of the primary criteria for remedy selection under CERCLA is protection of human health and the environment. If this criterion is not met, the alternative(s) will not be retained for further consideration. In the description of the FS screening process in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), it says:

> "Information available at the time of screening should be used primarily to identify and distinguish any differences among the various alternatives and to evaluate each alternative with respect to its effectiveness, implementability, and cost. Only the alternatives judged as the best or most promising on the basis of these evaluation factors should be retained for further consideration and analysis."

Alternative 5 is essentially a variation on Alternative 1 offering only a minimal increase to protection of human health and the environment whereas Alternatives 2, 3, and 4 contain elements that satisfactorily address the protectiveness of human health and the environment. Although the no-action alternative does not meet the RAOs, it is carried through the detailed analysis of alternatives and discussed in Section 8 for comparative purposes. As stated above, Alternative 5 fails to meet RAOs and thus is eliminated from further consideration.

The remaining alternatives (2, 3, and 4) are evaluated further in Section 8. The following sections describe the details of the implementation of each of the remaining options. A detailed analysis of the risks/hazards and compliance with the ARARs is provided in Section 8.

7.4.2 Common Alternative Elements

Elements that are common to all of the remedial action alternatives (except for Alternative 1 – no-further action) are presented below.

7.4.2.1 Work Plan Preparation

After the remedial action is selected, a work plan and/or remedial design will be submitted to the CDPHE to implement the selected alternative. Elements of that work plan will vary with the selected alternative but will, at a minimum, include the following:

- Materials handling and storage, including onsite handling and loading of the elevated materials, equipment to be used, work/staging areas, and equipment and personnel decontamination areas.
- Confirmatory sampling, analysis, and disposal plans for the elevated material, including sampling methodology, air monitoring, radiation monitoring, equipment and personnel decontamination criteria and procedures, analytical procedures, quality assurance/quality control, and data validation.
- Health and safety plan update, including training and medical monitoring requirements for workers, personal protective equipment, evacuation procedures, emergency response, Site security, access, and organization and responsibility.
- Stormwater pollution prevention plan designed to limit erosion and sediment movement, prevent onsite spills of fuel and other hazardous materials, and prevent offsite migration of affected materials.
- Engineering designs, including, at a minimum, specifications, plans, final configuration of the affected areas, dust suppression, erosion control, backfill, and revegetation.
- Transportation approaches, including work force access, deliveries of supplies and materials, and equipment access to and from the Site, including proposed routes, placarding, dust suppression, decontamination procedures, shipment tracking, and permit requirements.
- Reporting requirements, including periodic reports detailing Site activities, project schedule, and summary of materials handled, health and safety activities, injury/accidents on the Site, and a final report providing the details of the remedial action and results of confirmatory samples.

7.4.2.2 Mobilization Activities

Mobilization activities for each alternative will typically include the following:

- Installation of trailers for Site personnel and equipment associated with the remedial action contractor, project management, health and safety, personnel decontamination, and oversight activities,
- Modification of temporary fencing system to accommodate work area needs,
- Installation of temporary utilities such as electricity, telephone, etc., as necessary,
- Submittal of CDOT permit application for use of existing U.S. Highway 6 access lane to/from the Site if appropriate, and
- Construction of a storm-water management system (or repairs/upgrades to the existing storm-water management system), including temporary erosion and sedimentation control measures (silt fences, catch basins, etc.).

7.4.2.3 Dust Suppression/Perimeter Air Monitoring

Regardless of the remedial action alternative selected, dust suppression activities and perimeter air monitoring will be performed. Dust control procedures that will be used during excavation and handling of materials will typically include the following:

- Using water hoses with mist or fog nozzles to spray light applications of water over the work area during excavation/loading activities (water discharge will be carefully controlled to minimize material migration).
- Using water hoses or water trucks to spray areas that are extensively used by equipment and enforcing reduced speed limits for construction equipment.
- Minimizing use of disturbed areas during extended non-operational periods.
- Using storm-water best management practices to control stockpiles and prevent offsite migration.
- Using temporary stabilization best management practices during non-operational periods to prevent wind and water erosion.

Fresh water or water collected during storm-water management will be used for dust control on areas containing contaminated soil. Only fresh water will be used on areas that are uncontaminated.

A perimeter air monitoring system will be designed and installed. With the exception of Alternative 1, the system will require electricity (generators or an electric line) around the perimeter of the Site and will consist of low-volume particulate air samplers to monitor radionuclide particulate emissions. Alternative 1 will use a passive, canister-type air monitoring system for gamma and radon measurement.

7.4.2.4 Institutional Controls

Institutional controls are evaluated to determine if environmental covenants alone are a feasible alternative. This alternative would prescribe no further actions for the three Site conditions described in Section 7.2.1 other than institutional controls. This option is not acceptable for Site Condition 1 or 2 because neither the soil *in situ* prior to excavation nor the soil in the stockpile reduces the threat to human health or the environment to an acceptable risk. Site Condition 2 has not achieved this goal for OU2 soils because of a 16 mrem/yr dose due to radon (the CERCLA risk goal is 15 mrem/yr). Moreover, the owner has determined that an environmental covenant for radon mitigation is warranted due to background radium concentrations in the area. In addition, a persistent dissolved uranium in groundwater plume remains. A groundwater covenant prohibiting the use of groundwater on the flood plain[2] is a part of each remedial alternative and will be addressed in a separate RI/FS.

7.4.3 Alternatives 1a, 1b and 1c – No Action

Alternatives 1a, 1b, and 1c provide a comparative baseline against which other alternatives can be evaluated. Under Alternative 1, three scenarios are analyzed: (1a) pre-excavation flood plain soil, (1b) post-excavation flood plain soil, and (1c) stockpile soil. Under the third scenario, the

[2] Groundwater, and any related covenants, in the flood plain area will be addressed in a separate RI/FS after the two-year monitoring period for groundwater ends and the data are analyzed.

affected soils will remain in the lined stockpile without treatment, additional containment, institutional controls, or mitigating technologies being implemented.

7.4.4 Alternative 2 – Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility

Alternative 2 involves the load-out and transportation of the material in the stockpile to an approved landfill. Landfill acceptance criteria have been met allowing the impacted stockpile to go to a local solid waste landfill. This option will require use of the temporary access road to U.S. Highway 6 or transportation through the City of Golden.

Excavated material has already been stockpiled prior to shipping, which will maximize the efficient use of the trucks (eliminates waiting time for trucks) and minimize the handling required for load-out operations. The stockpiled material will be loaded onto trucks with a front-end loader or an excavator staged on the existing stockpile. Following loading, each truck will be inspected, scanned, and dry decontaminated as required prior to travel to the appropriate landfill. Each truck will have a capacity of 20 to 25 tons or approximately 14 cubic yards, assuming a weight of 1.5 ± 0.3 tons per cubic yard for affected material. Alternative 2 will require about 100 truckloads (1,400 cubic yards/14 cubic yards/truck) to transport the material to the landfill.

Estimated transport times were determined assuming the closest solid waste landfill and based on our past experience shipping material from the Site. Foothills Landfill on Colorado Highway 93 is approximately 8 miles north of the Site. Transportation times will increase several fold if other facilities are selected. The various disposal facilities considered for this material are summarized in Table 7-4.

During soil shipping in 2007, Stoller loaded, inspected, and decontaminated each truck in less than 10 minutes, and each truck made about five round trips per day, taking 60 to 80 minutes on each round trip.

We assume it will take 10 minutes to load each truck, and depending on delays at the facility, about six truckloads could be transported by each truck during an eight-hour shift. Shipments will be scheduled so that on average, a loaded truck will leave the Site every 20 minutes, and an empty truck will enter the Site. Using eight to ten trucks, the stockpile will be shipped in two to three days. Additional time will be required for Site preparation, mobilization, excavation, and demobilization activities.

Upon completion of the offsite disposal and implementation of the environmental covenant, the property should be released for all uses (recreational, residential, and other beneficial use). Minimal backfill material may be required to bring the Site to a useable elevation to make it safe and for storm-water control.

7.4.5 Alternative 3 – Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository

Alternative 3 requires the construction of an engineered disposal cell without solidification. An area above groundwater fluctuations will be selected for construction of the cell. Allowing a material depth of 5 feet and a 4:1 slope into the cell to allow for equipment movement, the footprint of the cell will be about 0.5 acres. Geotechnical testing will be required to verify proper placement of the cell, and a clay sub-liner will be installed. A geosynthetic liner will be installed over the clay to ensure containment. The affected material will then be moved from the stockpile(s) and placed in the cell. When all material is relocated to the cell, an engineered clay cap (3 feet deep) will be installed over the material. Institutional controls will be required for the cell to ensure the integrity of the cap and to monitor groundwater in the vicinity of the cell. The area around the 0.5 acre footprint will be available for unrestricted use. Limited groundwater monitoring may be required to monitor the natural attenuation of current metal concentrations and radionuclide activities. Backfill will be required to bring the Site to a useable elevation and to provide storm-water control.

7.4.6 Alternative 4 – Onsite Solidification and Placement into an Above-Grade Repository

Alternative 4 requires soil to be solidified and capped. Alternative 4 involves the consolidation and stabilization of onsite soils using concrete, fly ash, or other reagent. Alternative 4 assumes that the affected onsite material (1,400 cubic yards) will be solidified, placed onsite, and capped. Confirmation sampling has already confirmed all soil above action levels is in the stockpile, and limited additional sampling will be performed to ensure both metal and radionuclide limits are achieved beneath the stockpile.

Alternative 4 will require a bench test to determine the appropriate mixture of concrete, fly ash, and soil. Additional soil tests, including particle size, Atterberg limits, moisture content, sulfate content, organic content, density, permeability, unconfined compressive strength, leachability, pH, and microstructure analysis will be required to determine the proper mixture. Leachability testing will be performed to determine the degree of contaminant immobilization. No treatability or leachability studies have been completed because it was not cost-effective at this time due to this alternative being eliminated during the previous RI/FS.

After the proper mixture is determined, stockpiled materials will require segregation by soil type. Some crushing or removal of large of cobbles may be required. An area at a high enough elevation to remain above groundwater fluctuations will be selected for the final placement of the solidified material. Operational reagent will be stockpiled onsite, and a batch processor will be brought in to mix the materials. A water supply also will be required. Batches of material will be placed in lifts, and solidification will be verified with test cores.

After the solidification of the structure has been confirmed, an engineered clay cap (depth of 3 feet) will be constructed over the structure to limit leaching effects. Assuming a structure depth of 5 feet, a square structure will be about 100 feet on a side. The structure and cap footprint will require institutional controls on about 0.5 acre of land if one assumes 2:1 slope from the top of the cap. Long-term cap maintenance in the vicinity of the solidified matrix will be required. The remaining property will be available for unrestricted use although a limited groundwater monitoring program currently ongoing will continue to monitor the metal concentrations and radionuclide activities. Some backfill will be required to bring the Site to a useable elevation and to provide storm-water control.

Alternative 4, solidification and/or containment of the material, allows for residential and other use of the majority of the property because a limited acreage is needed to implement the remedies.

7.4.7 Disposal Facility Options

Table 7-4 summarizes the various disposal facilities and the associated cost per ton.

Table 7-4
CSMRI Site Disposal Options Summary

Disposal Facility	Transportation Cost (Hours/RT)	Tipping Fee	Total Cost/ton (extended cost 2200 ton)	Comments
Allied Waste – Foothills Landfill Golden, CO	$8.95/ton (1)	$25.39/ton	$34.34/ton ($80,724)	Transportation cost assumes 0.75 hour/load = $100/load + $50/liner = $150/load. Assumes 22 tons/load
Waste Management – Denver Arapahoe Disposal Site	NA	NA	NA	WM declined to bid for DADS and provided CSI quote only
Clean Harbors – Deer Trail Facility Last Chance, CO	$30.00/ton (5)	$150/ton	$180.00/ton ($396,000)	Transportation cost = $650/load (includes $68/liner). Assumes 14 cy/load, 1.5 tons/cy. Adams County and Clean Harbors continue to file suit against each other creating uncertainty as to the ultimate fate of waste shipments to the facility. Ra-226 cutoff 2.22 pCi/g
Waste Management – CSI Facility, Bennett, CO	15.74/ton (2)	61.67/ton	$77.41/ton ($170,302)	Includes fuel surcharge
US Ecology – Grand View Facility Grand View, ID	$153/ton (26)	$175/ton	$328/ton ($721,600)	Transport $132/ton + 16% surcharge ($153.12)
Energy Solutions Clive, Utah	$150/ton (20)	$2,340/ton	$2,490/ton ($5,478,000)	130 per sq ft = 3510 per yard, 1.5 tons per yd = 2,340 per ton.
Waste Control Specialist – WCS Facility Andrews, TX	NA	NA	NA	Maximum acceptable Ra-226 activity=30 pCi/g (NORM). Persistent problems with regulatory agencies; 6 violations classified as major since 2004

Based on the information summarized in Table 7-4, the most economical facility to dispose of the stockpiled soil is Allied Waste Foothills Landfill. The material meets the acceptance criteria, and the School has remaining capacity in the approval letter from the CDPHE to use this landfill for Site soils. This was confirmed by CDPHE in a letter dated July 28, 2007.

Table of Contents for Section 8

8. Detailed Analysis of Alternatives 8-1
8.1 Site Disposition ARARs 8-3
8.2 Analysis of Alternatives 8-5
8.2.1 Alternative 1: No Action 8-5
8.2.2 Alternative 2: Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility. 8-7
8.2.3 Alternative 3: Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository 8-11
8.2.4 Alternative 4: Onsite Solidification and Placement into an Above-Grade Repository 8-13
8.3 Comparative Analysis of Alternatives 8-16
8.3.1 Protection of Human Health and the Environment 8-17
8.3.2 Compliance with ARARs 8-18
8.3.3 Long-Term Effectiveness and Permanence 8-19
8.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment 8-19
8.3.5 Short-Term Effectiveness 8-20
8.3.6 Implementability 8-21
8.3.7 Cost 8-23
8.3.8 State Acceptance 8-25
8.3.9 Community Acceptance 8-25
8.4 Summary 8-25

List of Tables

Table 8-1 ARARs for Soils, Groundwater, and Surface Water 8-4
Table 8-2 Dose Predictions under Alternative 2 with Failure of Institutional Controls 8-8
Table 8-3 RESRAD-Predicted Worker Doses for Excavation Activities under Alternative 2 8-9
Table 8-4 Evaluation of Alternatives 8-16
Table 8-5 Factors Associated with Protection of Human Health and the Environment Criteria and ARARs Criteria 8-18
Table 8-6 Estimated Schedules 8-21
Table 8-7 Availability of Disposal Facilities 8-23
Table 8-8 Cost Information for Each Alternative 8-23
Table 8-9 Cost Information for Each Alternative including Stigma Value (in millions of dollars) 8-24

8. Detailed Analysis of Alternatives

Section 121 of CERCLA establishes five principal requirements for the selection of remedies. The remedies must:

- protect human health and the environment;
- comply with ARARs unless a waiver is justified;
- be cost-effective;
- utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and
- satisfy a preference for treatment as a principal element, or provide an explanation in the ROD as to why this preference was not met.

The five CERCLA requirements are further refined in 40 CFR §300.430(e)(9)(iii) into nine criteria for evaluating remedial alternatives to ensure that the important considerations are factored into remedy selection decisions. These criteria are derived from the statutory requirements of Section 121, as well as technical and policy considerations that have proven to be important for selecting among remedial alternatives. The nine-criterion analysis comprises two steps: an individual evaluation of each alternative with respect to each criterion and a comparison of options to determine the relative performance of the alternatives and identify major trade-offs among them (i.e., relative advantages and disadvantages). The nine criteria are described below.

1. **Overall protection of human health and the environment.** Alternatives are assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals consistent with 40 CFR §300.430(e)(2)(i). Overall protection of human health and the environment draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. Several alternatives presented in Section 7 were screened out due to their inability to be protective of human health and the environment.

2. **Compliance with ARARs.** The alternatives are assessed to determine whether they attain ARARs under federal environmental laws and state environmental or facility siting laws or provide grounds for invoking one of the waivers under paragraph 40 CFR 300.430(f)(1)(ii)(C).

3. **Long-term effectiveness and permanence.** Alternatives are assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. Factors that must be considered include the following:

   - Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. The characteristics of the residuals should be considered to the degree that they remain hazardous, taking into account their volume, toxicity, mobility, and propensity to bioaccumulate.

- Adequacy and reliability of controls such as containment systems and institutional controls necessary to manage treatment residuals and untreated waste. This factor addresses in particular the uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cap, slurry wall, or treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement.

4. **Reduction of toxicity, mobility, or volume through treatment.** Evaluates which alternatives use recycling or treatment that reduces toxicity, mobility, or volume, including how treatment is used to address the principal threats posed by the site. The following factors are evaluated:

   - Treatment or recycling processes the alternatives employ and materials they will treat;
   - Amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled;
   - Degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring;
   - Degree to which the treatment is irreversible;
   - Type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and propensity to bioaccumulate of such hazardous substances and their constituents; and
   - Degree to which treatment reduces the inherent hazards posed by principal threats at the site.

5. **Short-term effectiveness.** The short-term effects of alternatives must be assessed considering the following:

   - Short-term risks that might be posed to the community during implementation of an alternative;
   - Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures;
   - Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and
   - Time until protection is achieved.

6. **Implementability.** The ease or difficulty of implementing the alternatives must be assessed by considering the following types of factors as appropriate:

   - Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.

- Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to acquire any necessary approvals and permits from other agencies (for offsite actions).
- Availability of services and materials, including the availability of adequate offsite treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure necessary additional resources; the availability of services and materials; and availability of prospective technologies.

7. **Cost.** The types of costs that shall be assessed include the following:

   - Capital costs, including both direct and indirect costs;
   - Annual operation and maintenance costs; and
   - Net present value of capital and operation and maintenance costs.

8. **State acceptance.** Assessment of all State of Colorado (including Colorado School of Mines and Colorado Department of Public Health and Environment) concerns may not be completed until comments on the 2010 RI/FS are received but are discussed in the Proposed Plan issued for public comment. The State of Colorado's concerns from the 2004 and/or 2007 RI/FS are taken into account. The State concerns that shall be assessed include the following:

   - The State's position and key concerns related to the preferred alternative and other alternatives; and
   - State comments on ARARs.

9. **Community acceptance.** This assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until comments on the proposed plan are received, although the community's comments from earlier RI/FS work are taken into account.

Of the nine criteria, the first two are considered threshold criteria that must be attained by the selected remedial action. The next five criteria are the primary balancing criteria, which are considered together to identify significant trade-offs and determine the optimal alternative among those having passed the threshold criteria. The final two criteria are modifying criteria, which are evaluated following public comment on the RI/FS and Proposed Plan.

8.1 Site Disposition ARARs

A significant number of ARARs apply to the Site because of the nature of the materials of concern. EPA typically regulates metal contaminants, but the NRC regulates radionuclides. The primary focus for EPA is the risk or hazard associated with the material, while the NRC focuses on the radioactive material dose. At the State level, CDPHE regulates some of the matters that both EPA and NRC regulate. Different types of land use result in a variety of possible exposures and require different levels of cleanup protection. Multiple chemical and physical variables associated with metals in soil also complicate the regulatory picture making the development of numerical standards problematic. Ecological risk assessment is a developing science that adds uncertainties to the current decision-making process.

Primary ARARs for the Site are those that define the acceptable dose, risk, and hazard standards associated with the current conditions and final disposition of the property. Additional ARARs apply material handling standards required during excavation operations. The following ARARs presented in Table 8-1 for soils, groundwater and surface water were determined to be major decision drivers for Site disposition. Additional ARARs that apply to remedial alternatives, including excavation and transportation, are summarized in Appendix E.

Table 8-1
ARARs for Soils, Groundwater, and Surface Water

Media	Site-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered
Soil	10 CFR §20.1402 and 1403, NRC Standards for Protection Against Radiation, Radiological Criteria for Unrestricted and Restricted Use – Requires that exposures to onsite receptors do not result in a dose in excess of 25 mrem/yr plus ALARA, and 100 mrem/yr if institutional controls fail for restricted use cleanups.
	6 CCR 1007-1, §4.61.2 – 4.61.3, Colorado Radiation Control regulations, Radiological Criteria for Unrestricted and Restricted Use - Requires that exposures to onsite receptors do not result in a dose in excess of 25 mrem/yr plus ALARA, and 100 mrem/yr if institutional controls fail for restricted use cleanups.
	EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, August 1997 – Uses a risk-based approach to recommend limiting exposures to less than 15 mrem/yr for NCP compliance.
	EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, July 22,1996 – Initial discussion that resulted in the recommended 15 mrem/yr dose.
	EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, Directive No. 9200.4-25, February 1998 – Clarification of the use of 40 CFR 192 for the development of radionuclide soil standards.
	40 CFR §192.12, Subpart B; 6 CCR 1007-1, Part 18 Appendix A —Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites, Standards – Limits radium-226 surface activities (up to 15 cm) to 5 pCi/g and subsurface activities (greater than 15 cm) to 15 pCi/g. For occupied or habitable structures it requires that remedial efforts result in an annual radon decay product concentration (including background) of less than 0.2 WL (in any case the concentration should not exceed 0.3 WL). And interior gamma shall not exceed background by more than 20 microroentgens per hour.
	40 CFR §192.02, Subpart A; 6 CCR 1007-1, Part 18 Appendix A —Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites, Standards – Specifies that the control of residual radioactive materials and their listed constituents shall be designed to be effective for up to 1,000 years, and in any case for at least 200 years. Also imposes limits on acceptable radon air concentrations and requires groundwater monitoring when necessary.
	CDPHE, Colorado Soil Evaluation Values (CSEV Table), July 2011, as updated
	EPA Region 9 Memorandum, Region 9 Regional Screening Levels (formerly PRGs) , updated as of June 2011 – Describes risk-based approach to soil cleanup and provides table of preliminary remediation goals for soils. CDPHE recommends the use of these PRGs for materials not covered by their proposed soil standards.

Table 8-1
ARARs for Soils, Groundwater, and Surface Water

Media	Site-Specific Applicable or Relevant and Appropriate Requirements and To Be Considered
Groundwater and Surface Water	40 CFR §192.02 Standards, §192.03 Monitoring, §192.04 Corrective Action, Subpart A—Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites – Details the requirements specific to groundwater.
	40 CFR §192.20 Guidance for implementation, §192.20 Criteria for applying supplemental standards, Subpart C – Implementation – Additional groundwater requirements.
	40 CFR 141.11, National Primary Drinking Water Regulations, Maximum contaminant levels for inorganic chemicals.
	40 CFR 141.15, National Primary Drinking Water Regulations, Maximum contaminant levels for uranium, radium-226, radium-228, and gross alpha particle radioactivity in community water systems.
	40 CFR 141.51, National Primary Drinking Water Regulations, Maximum contaminant level goals for inorganic contaminants.
	40 CFR 141.55, National Primary Drinking Water Regulations, Maximum contaminant level goals for radionuclides.
	5 CCR 1003-1, Colorado Primary Drinking Water Regulations, Maximum contaminant levels for uranium and arsenic, among other substances.
	5 CCR 1002-41, Colorado Department Of Health, Water Quality Control Commission Regulation No. 41, Basic Standards for Ground Water.
	5 CCR 1002-38, Colorado Department Of Health, Water Quality Control Commission Regulation No. 38, Classifications And Numeric Standards South Platte River Basin (including Clear Creek as a tributary), Laramie River Basin, Republican River Basin, Smoky Hill River Basin.
	5 CCR 1002-31, Colorado Department Of Public Health And Environment, Water Quality Control Commission, Regulation No. 31, The Basic Standards And Methodologies For Surface Water, Section 31.8 Antidegradation Rule.

8.2 Analysis of Alternatives

This section presents the results of the analysis of each alternative with respect to the nine evaluation criteria.

8.2.1 Alternative 1: No Action

Under Alternative 1, the affected soils would remain in the lined stockpile without any controls. Even though the rationale behind performing a characterization procedure that excavated the impacted soil from the flood plain supported eliminating the no action alternative it is carried through this evaluation to validate that rationale and evaluate the action alternatives for the stockpiled soil.

8.2.1.1 Alternative 1 - Protection of Human Health and the Environment

Alternative 1, the no-further action alternative, does not provide adequate protection of human health and the environment as discussed in Section 7.2. It does not address the risks associated with potential skin contact, inhalation, or ingestion of contaminants from the elevated material. With the 40 CFR §192.02(a) requirement of 1,000 years (or at least 200 years) of protection, the no-further action alternative is not appropriate. In that amount of time, land use could reasonably revert to the urban resident modeled in the baseline risk assessment as discussed in

Section 6. The risk assessment evaluated four scenarios in addition to resident including, recreational user, student athlete, and groundskeeper.

The predicted dose of the impacted soil for the urban resident scenario on the flood plain prior to segregation and stockpiling was as high as 133 mrem/yr including radon. This dose is approximately 5 times higher than the 25 mrem/yr radiological criteria limit for unrestricted and restricted use. Total risk from radionuclides, prior to segregation and stockpiling was up to 9.77×10^{-5}

Windborne particles would migrate offsite from the stockpile. Metals and radionuclides would be absorbed by vegetation, which could then migrate offsite in the form of leaves and debris.

The major weakness in the no-further action alternative is the failure to provide adequate protection of human health and the environment.

8.2.1.2 Alternative 1 - Compliance with ARARs

Assuming the urban resident receptor, the no-further action alternative fails to meet the ARARs presented in Section 8.1, as explained above in Section 8.2.1.1. The groundwater, drinking water and surface water ARARs also are not met.

8.2.1.3 Alternative 1 - Long-term Effectiveness and Permanence

The alternative would provide no reduction in risk and does not reduce toxicity, mobility, or volume of Site contaminants. It would remain a long-term source of possible contamination to groundwater and surface water.

8.2.1.4 Alternative 1 - Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment is associated with no-further action, resulting in no reduction of toxicity, mobility, or volume.

8.2.1.5 Alternative 1 - Short-Term Effectiveness

The short-term effects of the no-further action alternative would be unchanged from the current risks posed by the elevated material. Because no excavation is required, there would be minimal risk to workers. No elevated short-term risks would result from implementation of this alternative.

8.2.1.6 Alternative 1 - Implementability

Alternative 1 is technically feasible; however, the administrative feasibility of this alternative is problematic because it would not likely meet the criteria for radioactive materials license decommissioning, and it will be problematic to get a solid waste disposal license.

8.2.1.7 Alternative 1 - Cost

Cost elements associated with the no-further action alternative. There is the cost of loss in property value for the 1 acre of land associated with the soil stockpile. This loss of property value is estimated to be $0.37 million. Cost breakdown data for each alternative are provided in Section 8.3.7.

8.2.1.8 Alternative 1 - State Acceptance

CDPHE acceptance is unlikely because of possible metals and radionuclide exposure and lack of groundwater protection. The School and CDPHE have indicated that some proactive remedial action at the Site is required.

8.2.1.9 Alternative 1 - Community Acceptance

Comments received during an open house conducted by the School in September 2010 indicated that local residents preferred offsite disposal, making community acceptance of no-further action unlikely. The City of Golden long-term development plans include construction of a pedestrian/bike path that would traverse the top of the flood plain terrace in close proximity to the existing stockpile location, and possibly have a segment that comes down to the flood plain area. In addition, the School plans an auxiliary parking lot for their athletic fields on the current site of the stockpile.

8.2.2 Alternative 2: Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility.

Alternative 2 is the excavation and offsite disposal of the radionuclide- and metal-affected soil in the existing stockpile.

The material has already been consolidated into a stockpile containing approximately 1,400 cubic yards of material with a mean Ra-226 concentration of 20.5 pCi/g. The stockpile would be shipped to an offsite licensed disposal facility under Alternative 2.

Alternative 2 uses one landfill for the stockpile. Several possible landfill options were considered: the U.S. Ecology facility in Idaho; the Clean Harbors Deer Trail facility in Colorado; the Waste Management CSI facility in Bennett, Colorado; the Waste Management Denver Arapahoe Disposal Site; the Energy Solutions landfill in Utah; the Waste Control Specialist facility in Texas; and the Allied Waste Foothills Landfill in Jefferson County, Colorado. The transportation/disposal costs and administrative feasibility for each one vary considerably based on distance to the facility and actual tipping fees.

The assumption used for Alternative 2 is that the stockpile would be disposed of at one landfill because it meets the waste acceptance criteria for each landfill evaluated. An estimated 1,400 cubic yards or about 2,100 tons (assuming a estimated weight of 1.5 tons per cubic yard) of material would be shipped offsite for disposal.

8.2.2.1 Alternative 2 - Protection of Human Health and the Environment

Alternative 2 assumes offsite disposal of all affected material above action levels. In this RI/FS, RESRAD predicted a dose of 133 mrem/yr including radon and a risk of $9.73 \times 10^{-5}$for urban resident if the stockpile were to remain on site. The subsistence farmer scenario was not modeled as the stockpile did not represent enough arable land to farm. These dose and risk levels assumed no backfilling of the area where the stockpile is managed. In addition a soil sampling plan would be implemented after remediation to ensure impacted soils are not present under the area where the stockpile was managed.

The excavation of the majority of the Ra-226 significantly reduces potential radon emanation rate on the flood plain. In Section 6, RESRAD predicts a dose of 16.1 mrem/yr and a risk or 1.35×10^{-6} (urban resident) on the flood plain after the stockpile is taken to offsite disposal facilities. Alternative 2 is protective of human health and the environment for all four scenarios evaluated in the RA. The addition of an environmental covenant for the Site is warranted due to high background levels of radium-226 in the area. A covenant for the flood plain requiring radon mitigation systems for structures will reduce doses to well below 15 mrem/yr.

8.2.2.2 Alternative 2 - Compliance with ARARs

Alternative 2 complies with the ARARs listed in Section 8.1, with the possible exception of some requirements for ongoing groundwater monitoring to verify the effectiveness of the source excavation from the flood plain area. However, compliance with ground water ARARs will be assessed when the Ground Water OU2 RI/FS is performed. As shown in Table 8-2, even with the failure of institutional controls, the potential dose due to radon emanation into a future residence is 16.1 mrem/yr in the flood plain area. This is less than the 100 mrem/yr limit for failure of institutional controls (radon mitigation systems) allowing Alternative 2 to comply with ARARs. It is less tha the 25 mrem/yr ARAR but slightly above the 15 mrem/yr ARAR. The covenant of radon mitigation systems for residential structures will reduce the mrem/yr dose below 15. Landfill disposal criteria need to be addressed to determine which alternative would be appropriate for offsite disposal. Of all the alternatives considered, Alternative 2 appears to meet ARARs best and was the remedy also selected in the 2007 FS.

Table 8-2
Dose Predictions under Alternative 2 with Failure of Institutional Controls

Alternative/Receptor	Predicted Dose with Failure of Institutional Controls
Urban Resident	16.1 mrem/yr

8.2.2.3 Alternative 2 - Long-Term Effectiveness and Permanence

Disposal at a solid waste landfill successfully mitigates the potential long-term effects associated with the elevated metals and radionuclides in the soil on the flood plain area and stockpile. With inclusion of the covenants mentioned earlier, this alternative provides for use of the entire property.

8.2.2.4 Alternative 2 - Reduction of Toxicity, Mobility, or Volume through Treatment

This alternative does not reduce the toxicity, mobility, or volume of affected material through treatment. All of the material is moved to an offsite landfill where it can be properly managed, but no treatment would be expected.

8.2.2.5 Alternative 2 – Short-Term Effectiveness

Excavation and transport activities pose an elevated short-term exposure risk to onsite workers, transportation workers, and nearby residents due to airborne particulate generation. Direct exposure of workers during implementation of this alternative would be minimized through use of appropriate safety measures and procedural controls. Table 8-3 summarizes RESRAD predicted worker doses and risks associated with excavation activities. Conservative parameters were used in the model to predict upper limits for the operation. Assumptions included direct access to the soil when in fact workers will spend most of their time in excavation equipment. Area factors also must be considered for the worker exposure.

Table 8-3
RESRAD-Predicted Worker Doses for Excavation Activities under Alternative 2

Worker Exposure	Dose (mrem)	Risk
Stockpile Excavation- 6 weeks after Agency approval of RI/FS	22.7	8.38×10^{-7}

Hazards associated with metals would be expected to be minimal during remedial operations. Risks associated with inhalation of fugitive dusts are controllable through air monitoring, the use of appropriate health and safety equipment, and dust suppression techniques. Air monitoring also would be used to identify potential offsite risks to the neighboring community.

A low to moderate risk to the local area would be associated with the truck traffic required to move equipment and material (i.e., traffic accidents). Access to State Highway 6 which was used during the implementation of the 2007 remedy would limit the risk to the immediate neighborhood. This option may no longer be available, however, due to the expansion of School athletic facilities and the construction of a new pedestrian/bike path. A somewhat higher risk is associated with transportation of the material through the neighborhood. This risk is regarded as low due to the limited number of truckloads (less than 100) that would be required to transport the material to the landfill.

Based on worker risk assessment evaluations, there is a small incremental short-term risk of potential adverse health consequences during a transportation-related accident. Exposure times would result in a risk significantly lower than the 1×10^{-6} threshold (assumes cleanup operations are completed within 24 hours and the only receptors are emergency response personnel). Typically access to transportation-related spills is not allowed to members of the general public. An accident involving an overturned truckload of affected material would have a small environmental risk if the material were to enter a drainage channel. However, the environmental risk would be limited because of the nature of the material (soil versus liquid) and containment procedures followed by emergency response teams.

Access to U.S. Highway 6 would eliminate the need to transport material and equipment through nearby residential areas. In the event that access to U.S. Highway 6 is not available, truck traffic through the 12th Street Historic District will likely result in public annoyance due to short-term noise and vibration in a residential area. Some operational noise would be expected that could be noticed by nearby residents.

8.2.2.6 Alternative 2 - Implementability

The technical feasibility of offsite disposal at a commercial landfill relies on use of conventional excavation and transport technology. Necessary equipment is readily available for implementation of this alternative.

Factors involving the administrative feasibility of the alternative include obtaining approval from CDOT to access Highway 6 or working with the City of Golden to control traffic during transport of material through their community and meeting the landfill acceptance criteria requirements. Physical construction of an access lane on Highway 6 in 2004 under CDOT Access Permit No. 603100 was completed during earlier RI/FS work. Stoller used this access lane for disposal of the soil stockpiled during the 2007 RI/FS under CDOT Access Permit 605167. However; direct access to this route has since been blocked by construction of a soccer field, and Stoller would need to utilize the newly constructed pedestrian/bike path to access the Highway 6 access lane. It is likely that CDOT would issue another use permit to allow transport of additional soil using this access point. However, both the City of Golden and the School are in agreement that closure of the pedestrian/bike path would be a less favorable route option for transport of the stockpile.

The above-listed landfills in Section 8.2.2 are administratively feasible, except for the following landfills:

- The Waste Management Denver Arapahoe Disposal facility will not accept these materials.
- The Waste Management CSI facility in Bennett, Colorado is not currently accepting material due to an Adams County letter to CSI stating that the landfill should not accept this type of waste due to the litigation pending between Adams County and Clean Harbors related to the Clean Harbors facility's ability to accept NORM. Although settlement talks are underway the facility does not know when the issue will be resolved.
- The Clean Harbors Deer Trail facility is available to accept NORM and TNORM waste if waste acceptance is met.
- The Foothills Landfill (Allied Waste) accepted the waste generated during the 2007 RI/FS Approval to dispose of up to a total of 30,000 cubic yards of similar material was given by CDPHE at that time. The analytical results from stockpile samples show that the soil in the stockpile is similar to the material that was approved for up to 30,000 yards, and CDPHE concurred. The stockpile material meets the acceptance criteria for the Foothills facility and the School has remaining capacity on the basis of the approval letter from CDPHE dated July 28, 2007 to use this landfill for Site soils.

8.2.2.7 Alternative 2 - Cost

Cost elements associated with Alternative 2 include loading the stockpiled material into trucks, transportation to the selected landfill, and re-grading and site reclamation. After the offsite disposal is performed, the two years of groundwater monitoring will be continued to analyze ground water quality and confirm the effectiveness of the excavation in the flood plain, which will be assessed during the OU2 Ground Water RIFS at a later date. The total present value of these cost elements is estimated at $0.72 million. Property values are not significantly affected by this alternative because the land will be available for residential and other use with the environmental covenant. The estimated schedule for Alternative 2 is about six weeks from the time the CDPHE approves the selected remedy in the RI//FS.

Cost breakdown data for each alternative are provided in Section 8.3.7.

8.2.2.8 Alternative 2 - State Acceptance

CDPHE has stated its preference for offsite disposal (Alternative 2) and this remedial alternative was chosen, with CDPHE approval, in 2007. The School also prefers offsite disposal.

8.2.2.9 Alternative 2 - Community Acceptance

Comments received during an open house conducted by the School in 2010 indicated that local residents preferred this alternative.

8.2.3 Alternative 3: Leave Stockpile Material Onsite and Design/Build a Below-Grade Repository

Alternative 3 would begin with the stockpiled material staying on site and the engineering and construction of a disposal cell. A properly sized area would be excavated on the upper terrace to hold the cell. An engineered clay liner base would be installed followed by a geosynthetic liner and additional cover soil. The stockpiled material would be transferred into the cell. Once all of the material is in the disposal cell, a cushion layer and geosynthetic liner would be placed over the cell (encapsulating the material) and a clay cap would be installed using suitable material from an offsite location. Once the encapsulation has been completed, the area would be re-graded. Fill would need to be placed over the remaining Site to bring the area to a useable grade and to control stormwater.

Institutional controls for Alternative 3 would include deed restrictions for the flood plain and the upper terrace of the Site, requiring radon mitigation for all structures as well as maintenance requirements for approximately 1 acre of land affected by the footprint of the disposal cell. Deed restrictions associated with the disposal cell would include limiting construction activities and excavation and ensuring the integrity of the cap. While construction has been allowed for some capped sites, it makes cap maintenance problematic. In accordance with 40 CFR §192.02(a), a long-term maintenance plan would be required to maintain cap integrity along with long-term groundwater monitoring.

8.2.3.1 Alternative 3 - Protection of Human Health and the Environment

Ra-226 would be a continuing long-term source of radon gas generating a dose of 136 mrem/yr in the absence of institutional controls, which does not meet one of the ARARs. Institutional controls would be needed to ensure that radon abatement systems are a requirement for any structure built at the Site.

Institutional controls for the disposal area would be required to prevent the degradation of the cap or excavation into disposal cell as well as to ensure radon mitigation techniques are employed for future residential development. Failure to maintain the institutional controls could jeopardize future protection of human health and the environment. In the event of institutional control failure, RESRAD predicts a dose of 136 mrem/yr to a residential receptor due to radon emanation from Ra-226 below the cap.

8.2.3.2 Alternative 3 - Compliance with ARARs

Alternative 3 complies with the ARARs listed in Section 8.1, with the exception of groundwater requirements and the radon standard. If the institutional controls failed, the expected dose would exceed 100 mrem/yr. Groundwater radionuclide activities and metals concentrations would be expected to decrease with time because the source material is controlled. Short-term restrictions on groundwater use coupled with a limited groundwater-monitoring program would be needed to meet ARARs. Long-term groundwater monitoring would be required for the disposal area.

8.2.3.3 Alternative 3 - Long-term Effectiveness and Permanence

If the cap is maintained, the alternative(s) would be effective; however, permanence is more difficult to predict. Using the 1,000-year life recommended by 40 CFR §192.02, it would be difficult to anticipate the permanence of the remedy. Although cap designs are advertised as having life spans of this magnitude, there are no existing examples of this type of performance. A number of claims are made about caps providing a radon barrier but this is highly dependent on maintaining moisture content. Semiarid climates make prescribed moisture content difficult to maintain.

8.2.3.4 Alternative 3 - Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 addresses the toxicity (reduces bioavailability) and mobility of the material through encapsulation, but the volume is not reduced. Alternative 3 addresses the mobility and toxicity. There would be no volume reduction.

8.2.3.5 Alternative 3 – Short-Term Effectiveness

Soil relocation activities pose an elevated short-term exposure risk to onsite workers, transportation workers, and nearby residents due to airborne particulate generation. Alternative 3 potentially would generate additional air particulate because of mixing and grinding operations. Direct exposure of workers during implementation of this alternative would be minimized through use of appropriate safety measures and procedural controls. RESRAD-predicted worker doses and risks associated with soil handling activities would essentially be the same as those predicted for alternative 2. Conservative parameters were used in the model to predict upper limits for the operation. Assumptions included direct access to the soil when in fact workers will spend most of their time in excavation equipment.

Hazards associated with metals would be expected to be minimal during remedial operations. Risks associated with inhalation of fugitive dusts are controllable through air monitoring, the use of appropriate health and safety equipment, and dust suppression techniques. Air monitoring also would be used to identify potential offsite risks to the neighboring community.
A low to moderate risk to the local area would be associated with the truck traffic required to move equipment and supplies to the Site (i.e., traffic accidents). Access to State Highway 6 would limit the risk to the immediate neighborhood but could affect the local county (or

counties). A small incremental increase in risk is associated with transportation of equipment and supplies through the neighborhood.

8.2.3.6 Alternative 3 - Implementability

The technical feasibility of material encapsulation and onsite disposal with an engineered cap relies on the use of conventional technology. Necessary equipment and supplies are readily available for implementation of this alternative. This technology has been used successfully on a number of sites.

The alternative is administratively feasible, but long-term institutional controls for the disposal area must be considered. Permits may be required for onsite disposal, although they would take considerable time to obtain.

8.2.3.7 Alternative 3 - Cost

Cost elements associated with Alternative 3 include engineering, material excavation and consolidation, construction of the disposal cell, geosynthethic materials, import of clay and barrier layer rock, installation of the cap, re-grading of the Site, installation of the groundwater monitoring wells around the repository, long-term maintenance and inspection of the cap, and long-term groundwater monitoring. Assuming only the cost for 100 years of annual and more robust five vear inspections of the disposal cell the cost is estimated to be $660,000. In addition to the above net present value cost, there is a cost associated with the loss in property value because of the remaining contaminants and the land use restrictions ($0.37 million). Groundwater cost are not considered here but will be addressed in a separate RI/FS for OU1. The estimated schedule for Alternative 3 is about seven months.

8.2.3.8 Alternative 3 - State Acceptance

The School is unlikely to accept an onsite disposal alternative. Problems associated with onsite disposal at the Shattuck Chemical Superfund Site in nearby Denver may reduce CDPHE acceptance. CDPHE has stated in meetings that it will not support an onsite disposal remedy.

8.2.3.9 Alternative 3 - Community Acceptance

Comments received during the open house conducted by the School in 2010 indicated that local residents preferred the off-site disposal of the material. In addition, considerable time would be needed for public meetings and to subsequently address any and all community concerns.

8.2.4 Alternative 4: Onsite Solidification and Placement into an Above-Grade Repository

The stockpiled soil would be consolidated for this option and disposed of onsite using solidified matrix (soil/concrete/cement kiln dust,/fly ash or other reagent mixture) with an engineered cap constructed over the top. An estimated 1,400 cubic yards of soil would be solidified. Alternative 4 consolidates all soils with radionuclides above DCGLs and metals above proposed residential soil standards.

Alternative 4 would begin with the solidification operation preparation. The required equipment would be mobilized to the Site and required materials would be stockpiled. A properly sized area would be graded to hold the total volume of the consolidated material and reagent mixture. A clay liner base would be installed followed by a geosynthetic liner. The affected soil would then be sorted for use in the process. After the solidification has been completed, the area would be re-graded and a second engineered clay and/or geosynthetic liner will be placed over the cell (encapsulating the material) and a cap will be installed using the material from an offsite location. Fill would need to be placed over the remaining site to bring the area to a useable grade and to control stormwater. A groundwater monitoring network would need to be placed around the solidified matrix.

Institutional controls would include deed restrictions for the Site, requiring radon mitigation for all structures as well as maintenance requirements for the 1 acre of land affected by the solidified matrix. Deed restrictions associated with the solidified matrix would include limiting construction activities and excavation and ensuring the integrity of the cap. Although construction has been allowed for some capped sites, it makes cap maintenance problematic. In accordance with 40 CFR §192.02(a), a long-term maintenance plan would be required to maintain cap integrity along with long-term groundwater monitoring.

8.2.4.1 Alternative 4 - Protection of Human Health and the Environment

Residual Ra-226 would be a continuing source of radon gas. Institutional controls are needed to ensure that radon abatement systems are a requirement for building construction at the Site. In the absence of institutional controls, RESRAD predicted a dose of 133 mrem/yr to an urban resident due to radon emanation into the house. The urban resident is not assumed to be a user of Site groundwater. Drinking water for the urban resident is supplied from a public water supply. The data set for the RESRAD model was generated from analytical results of samples collected from the soil stockpiles for waste characterization purposes.

Institutional controls for the disposal area would be required to prevent the degradation of the cap or excavation into the solidified structure or disposal cell as well as to ensure radon mitigation techniques are employed for future residential development. Failure to maintain the institutional controls could jeopardize future protection of human health and the environment.

8.2.4.2 Alternative 4 - Compliance with ARARs

Alternative 4 complies with the ARARs listed in Section 8.1, with the exception of groundwater requirements and the radon standard. If the institutional controls failed, the expected dose would exceed 100 mrem/yr. Groundwater radionuclide activities and metals concentrations would be expected to decrease with time once the source material is controlled. Short-term restrictions on groundwater use coupled with a limited groundwater-monitoring program would be needed to meet ARARs and provide unrestricted use of areas not affected by the disposal cell. Long-term groundwater monitoring would be required for the disposal area.

8.2.4.3 Alternative 4 - Long-term Effectiveness and Permanence

If the cap is maintained, the alternative would be effective; however, permanence is more difficult to predict. Using the 1,000-year life recommended by 40 CFR §192.02, it would be difficult to anticipate the permanence of the remedy. The solidified material would be more resistant to damage than the disposal cell, but loss of the cap would be problematic. Although cap designs are advertised as having life spans of this magnitude, there are no existing examples of this type of performance. A number of claims are made about caps providing a radon barrier but this is highly dependent on maintaining moisture content. Semiarid climates make prescribed moisture content difficult to maintain. The long-term integrity of the solidified matrix for Alternative 4 also is uncertain. Recent problems at the Shattuck Site in Denver demonstrate this.

8.2.4.4 Alternative 4 - Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 addresses the toxicity (reduces bioavailability) and mobility of the material through treatment (solidification), but the volume actually increases (typically 20 percent or more) due to the addition of reagents. Alternative 4 addresses the mobility and toxicity. There would be no volume reduction.

8.2.4.5 Alternative 4 – Short-Term Effectiveness

Excavation activities pose an elevated short-term exposure risk to onsite workers, transportation workers, and nearby residents due to airborne particulate generation. Alternative 4 potentially would generate additional air particulate because of mixing and grinding operations. Direct exposure of workers during implementation of this alternative would be minimized through use of appropriate safety measures and procedural controls. RESRAD-predicted worker doses and risks associated with soil handling activities would essentially be the same as those predicted for alternative 2. Conservative parameters were used in the model to predict upper limits for the operation. Assumptions included direct access to the soil when in fact workers will spend most of their time in excavation equipment.

Hazards associated with metals would be expected to be minimal during remedial operations. Risks associated with inhalation of fugitive dusts are controllable through air monitoring, the use of appropriate health and safety equipment, and dust suppression techniques. Air monitoring also would be used to identify potential offsite risks to the neighboring community.

A low to moderate risk to the local area would be associated with the truck traffic required to move equipment and supplies to the Site (i.e., traffic accidents). Access to State Highway 6 would limit the risk to the immediate neighborhood but could affect the local county (or counties). A small incremental increase in risk is associated with transportation of equipment and supplies through the neighborhood.

8.2.4.6 Alternative 4 - Implementability

The technical feasibility of material solidification and placement of an engineered cap over the top relies on the use of conventional technology. Necessary equipment and supplies are readily available for implementation of this alternative. This technology has been used successfully on a number of sites but failures have occurred because of improper determination of the necessary mix of soil and concrete. Pilot tests would be necessary to determine the proper mixture, but these tests can be misleading if there is significant soil heterogeneity.

The alternative is administratively feasible, but long-term institutional controls for the disposal area must be considered. Permits may be required for onsite disposal, and these could take considerable time to obtain.

8.2.4.7 Alternative 4 - Cost

Cost elements associated with Alternative 4 include engineering, bench testing, material excavation and consolidation, geosynthethic materials, imported clay, mobilization and demobilization of the equipment needed to produce the solidified structure, materials, installation of the cap, re-grading of the Site, installation of the groundwater monitoring wells, long-term maintenance and inspection of the cap, and long-term groundwater monitoring. Assuming only the cost for 100 years of annual and more robust five vear inspections of the disposal cell the cost is estimated to be $660,000. In addition to the above net present value cost, there is a cost associated with the loss in property value because of the remaining contaminants and the land use restrictions ($0.37 million). Groundwater cost are not considered here but will be addressed in a separate RI/FS for OU1. The estimated schedule for Alternative 4 is about eight months.

Cost breakdown data for each alternative are provided in Section 8.3.7.

8.2.4.8 Alternative 4 - State Acceptance

The School is unlikely to accept an onsite disposal alternative. Recent problems associated with onsite disposal with the Shattuck Chemical Superfund Site in nearby Denver and other reasons may reduce CDPHE acceptance. CDPHE has stated in meetings that it will not support an onsite disposal remedy.

8.2.4.9 Alternative 4 - Community Acceptance

Comments received during the open house conducted in 2010 by the School indicated that local residents preferred offsite removal of the material.

8.3 Comparative Analysis of Alternatives

The purpose of this section is to evaluate the relative performance of each alternative in relation to the other alternatives. A brief summary of the alternatives and the nine evaluation criteria is presented in Table 8-4.

Table 8-4
Evaluation of Alternatives

Alternative	Protective of Human Health & Environment	ARAR Compliance	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability (Feasibility)	Cost Ranking[1]	State Acceptance	Community Acceptance
1 - No Action	N	N	N	N	Y	L	1	N	N
2 - Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	Y	Y	Y	Y	Y	H	2	Y	Y
3 - Leave Stockpile Material Onsite and	Y	N	U	N	Y	M	4	U	U

Table 8-4
Evaluation of Alternatives

Alternative	Protective of Human Health & Environment	ARAR Compliance	Long-term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume through Treatment	Short-term Effectiveness	Implementability (Feasibility)	Cost Ranking[1]	State Acceptance	Community Acceptance
design/build a Below-Grade Repository									
4 - Onsite solidification and Placement into an Above-Grade Repository	Y	N	U	N	Y	M	3	U	U

Notes: Y, addresses criteria; N, does not address criteria; U, uncertainty associated with this element; Implementability factors, highly feasible (H) through problematic (L); Rankings range lowest to highest cost
[1] Costs account for loss of property value for onsite remedies.

8.3.1 Protection of Human Health and the Environment

Alternative 1, the no-further action alternative, as discussed in Section 7.2, does not provide adequate protection of human health and the environment because it does not adequately address the exposure pathways. The alternative does not address the migration of metals (especially uranium) and radionuclides to groundwater. Unauthorized Site access by neighborhood children also is a possibility with this alternative. Trespassers have already breached the existing security fence on a number of occasions. With a 1,000-year time horizon, access to the Site is reasonably foreseeable.

Alternatives 2, 3, and 4 effectively address the direct exposure pathways by either preventing access to the material using caps and a variety of containment options or offsite disposal. In each case, institutional controls would be required to ensure that radon abatement systems are a requirement for any structure or building constructed on the Site. Groundwater fluctuations and the presence of a City of Golden water main provide potential mechanisms for migration of affected material left onsite. Table 8-5 summarizes some of the factors associated with the protection of human health and the environment criteria. Factors associated with the ARARs criteria also are included.

Table 8-5
Factors Associated with Protection of Human Health and the Environment Criteria and ARARs Criteria

Alternative	Risk $<10^{-4}$	Dose <15 mrem/yr	Dose <25 mrem/yr	Hazard Index <1	PbB <10 µg/dL	Soil Lead <400 mg/kg	Protective of Groundwater	Dose < 100 mrem/yr with institution control failure
1 - No Action	N	N	N	N	N	N	N	N
2 - Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	Y	Y	Y	Y	Y	Y	Y	Y
3 - Leave Stockpile Material Onsite and design/build a Below-Grade Repository	Y	Y	Y	Y	Y	Y	Y	N
4 - Onsite solidification and Placement into an Above-Grade Repository	Y	Y	Y	Y	Y	Y	Y	N

Notes: Evaluation based on urban resident; Y, meets requirement; N, does not meet requirement; U, uncertainty associated with this element;

A short-term groundwater-monitoring program is currently ongoing and would continue if Alternatives 2, 3 and 4 are selected because of residual metals and radionuclides remaining in the groundwater system. However, because the ground water has been separated as an operable unit from the soil in the flood plain area, the ground water issue will be addressed separately in the future. The solidified matrix or disposal cell associated with Alternatives 3 and 4 would require, nonetheless, a long-term groundwater monitoring as well as a long-term operations and maintenance program to ensure the ongoing integrity of the repository. The long-term ground water monitoring would required due to the presence of the repository, which is a separate issue than the one being evaluated under the current short-term ground water monitoring program.

In the absence of institutional controls, the potential dose due to radon emanation into a residential structure ranges from 16.1 mrem/yr on the floodplain after the stockpile is remediated (Alternative 2) to 133 mrem/yr if no action were taken. Alternative 2 would provide the most protection to human health and the environment as it takes the source away from the Site.

8.3.2 Compliance with ARARs

Alternative 1 does not meet the ARARs that have been identified for the Site. Alternatives 3, and 4 do not meet ARARs. With the failure of institutional controls, the dose to the urban resident exceeds 100 mrem/yr in each case. Alternative 2 is compliant with ARARs by offsite disposal of the affected material.

Alternative 2 has the least uncertainty associated with the site-specific ARARs.

8.3.3 Long-Term Effectiveness and Permanence

Alternatives are assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful.

8.3.3.1 Magnitude of Residual Risk

Alternative 1 has no long-term effectiveness or permanence because the material would remain in place and be a continuing source of hazard and risk to human health and the environment. This alternative would have the largest remaining risk for the Site and surrounding area. Wind and water erosion would move the material offsite. Precipitation would continue to cause the material to migrate to groundwater. Access by neighborhood children would be a continuing problem. With a 1,000-year time horizon, other access to the Site is reasonably foreseeable.

The remaining alternatives would sufficiently address residual risk although some uncertainty is associated with the groundwater pathway for the alternatives 3 and 4. These alternatives involve a repository that would have a degree of uncertainty associated with long-term permanence. If the integrity of the repository was compromised it could result in significant risks to human health and the environment.

8.3.3.2 Adequacy and Reliability of Controls

Alternatives 3 and 4 rely on containment systems and institutional controls to ensure protection of human health and the environment. A number of uncertainties are associated with these types of controls and need to be addressed when evaluating the alternatives.

The provision in 40 CFR §192.02 requires the control measures to be effective for 1,000 years (at least 200 years). Long-term effectiveness of caps can be compromised by failure to implement institutional controls and the lack of maintenance. In addition to human activities, freeze-thaw cycles, vegetation, and burrowing animals can compromise cap material. The literature refers to problems with the leaching of mercury and arsenic from solidified matrixes (Alternative 4). The magnitude of this effect would be site-specific but could be problematic in the long term.

Alternative 2, offsite disposal, has the least uncertainty associated with long-term effectiveness and permanence.

8.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 3 and 4 are the only alternatives that address the material through treatment. Toxicity and mobility are addressed because the matrix prevents material migration and reduces toxicity through reduced bioavailability. Properly maintained the solidified matrix would be expected to remain intact for an extended period of time. But as mentioned in Section 7.3, there is some question about the leaching of arsenic and mercury.

Alternatives 3 and 4 use caps to address toxicity and mobility by limiting contact and infiltration. Onsite volumes are reduced in Alternative 3 and 4, and eliminated in Alternative 2.

8.3.5 Short-Term Effectiveness

The short-term effects of alternatives is assessed below considering the following:

- Short-term risks that might be posed to the community during implementation of an alternative;
- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures;
- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation; and
- Time until protection is achieved.

8.3.5.1 Risks to Community

All of the alternatives except Alternative 1 (no-further action) involve some short-term risk to the surrounding community. A low to moderate risk would be associated with the truck traffic required to move equipment or material (i.e., traffic accidents). Access to State Highway 6 would limit the risk to the immediate neighborhood but could affect the local county (or counties). A somewhat higher risk is associated with transportation of the material through the neighborhood. Based on the number of trucks required to complete the task, Alternative 2 would be the highest risk, followed by Alternatives 3 and 4.

Based on worker risk assessment evaluations, there is a minimal short-term risk of potential adverse health consequences during a transportation-related accident. Exposure times would result in a risk significantly lower than the $1x10^{-6}$ threshold (assumes cleanup operations are completed within 24 hours and the only receptors are emergency response personnel). Typically access is not allowed to members of the general public.

The potential for air emissions during implementation of the selected remedial action will be controlled by dust control measures (e.g., limiting operations during high velocity winds and use of water spray). Control measures will be monitored by the installation of perimeter air monitoring to evaluate controls on a day-to-day basis.

Alternative 2 followed by Alternatives 3 and 4 have the highest short-term risk for the surrounding community because of the number of loads of affected soil. The risk applies only to traffic accidents, not to exposure to affected soils.

8.3.5.2 Risks to Workers

Table 8-3 presented a summary of short-term dose and risk to workers. The assessment assumes an average of 2 months of exposure to the Site materials while performing excavation activities. These values are provided to show the magnitude of the risk. Values for specific alternatives could be expected to be somewhat higher or lower but by less than an order of magnitude. The primary pathway is the radiation exposure route, but this would be limited by the amount of time spent in material handling equipment and required safety equipment. Material screening/sizing operations associated with Alternatives 3 and 4 would generate the greatest inhalation risk, but again would be controlled by engineered safety equipment.

As presented earlier in this section hazards associated with metals would be expected to be minimal during remedial operations.

Worker exposure would be the greatest for Alternatives 3 and 4 because of the mixing and grinding operations. Alternative 2 would have lesser risk.

8.3.5.3 Environmental Effects

Stormwater controls will be used to prevent affected material from leaving the Site and affecting environmental receptors. The largest short-term risk to the environment is a delay in schedule that would allow additional material to migrate to groundwater and eventually to Clear Creek. Extended schedule delays also could result in the re-vegetation of the Site along with a variety of insect or animal receptors. Materials such as mercury bioaccumulate and could be a long-term risk. Alternative 1 is the primary example of environmental risk.

A limited environmental risk is associated with transportation of the material to offsite landfills. An accident involving an overturned truckload of affected soil would have a small environmental risk if the material were to enter a drainage channel. However, the environmental risk would be limited because of the nature of the material (soil versus liquid) and containment procedures followed by emergency response teams.

8.3.5.4 Timeline

Estimated schedules for the alternatives are provided in Table 8-6 and include the period from when the remedy is approved by stakeholders until it is implemented. The schedule neither includes client, public or agency comment/review nor does it account for continued groundwater monitoring or long term operations and maintenance.

Table 8-6
Estimated Schedules

Alternative	Description	Estimated Schedule (months)
1a, 1b and 1c	No Action	0
2	Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	1-2
3	Leave Stockpile Material Onsite and design/build a Below-Grade Repository	6-8
4	Onsite solidification and Placement into an Above-Grade Repository	4-8

8.3.6 Implementability

8.3.6.1 Technical Feasibility

Alternative 1, no action/institutional controls, is relatively easy to implement.

Alternatives 2, 3, and 4 are technically feasible. Each alternative involves standard construction and earth-moving techniques. Alternative 4 has the most uncertainty because a reagent/soil mixture would need to be determined. Proper installation of a disposal cell can be problematic (Alternatives 3 and 4). Alternatives 2, 3, and 4 are sensitive to weather conditions especially during the winter months. Inclement weather conditions will reduce the ability to work efficiently. Wet or frozen soils typically require additional handling time depending on the type of equipment used. Compaction operations are especially problematic when soils are wet or frozen. Weather also can affect the placement of material at offsite disposal locations.

8.3.6.2 Administrative Feasibility

Alternatives 2, 3, and 4 require truck access to the Site. New Horizons completed physical construction of an access lane on Highway 6 in 2004 under CDOT Access Permit No. 603100. Stoller used this access lane for disposal of the bagged soil in December 2005 under CDOT Access Permit 605167. It is unlikely that using this access point would be acceptable to the community because the route would now require closure of the new pedestrian/bike path to access the Site. This approval will not affect the comparative analysis because it is an element common to each alternative.

Alternative 1 could require a license for leaving the material onsite. However, CERCLA typically exempts onsite remedies from licensing requirements, although certain substantive requirements must be met. The administrative feasibility for this alternative is high if no license is required because of the continuing requirements of the monitoring and institutional controls; otherwise it is low.

Alternatives 3 and 4 may require a solid waste disposal license for onsite solidification or disposal cells. Again the CERCLA exemption may apply but have substantive requirements. If no license is required, the administrative feasibility for leaving the material in place is medium to high because of the continuing requirements of the monitoring and institutional controls; otherwise it is low.

For Alternative 2, AWI Foothills Facility on Highway 93 accepted the material from the 2007 remedy with full approval to accept a total of 30,000 cubic yards of similar material from the CSMRI Site. The current stockpile of 1,400 cubic yards, if sent to the Foothills facility, would be within the approved volume. The CDPHE radiation control unit has already approved disposal of the 1,400 yards at the Foothills Landfill consistent with CPDHE's previous authorization for the 30,000 yards. Existing landfills are authorized to accept wastes similar to the Site material, although ones in Adams County have uncertainty due to a changing political environment. The landfills must demonstrate the ability to protect human health and the environment. The administrative feasibility for these sites to accept the elevated materials is high.

8.3.6.3 Availability of Services and Materials

No limitations would be expected for the availability of the services or materials anticipated for any of the alternatives.

8.3.6.4 Availability of Disposal Facilities

The availability of disposal facilities is provided in Table 8-7.

Table 8-7
Availability of Disposal Facilities

Disposal Facility	Stockpile	Comments
Allied Waste – BFI Foothills Landfill, Golden, CO	Yes	Material has been pre-approved pending waste acceptance criteria are met; still need CDPHE solid waste unit approval
Clean Harbors – Deer Trail Facility, Last Chance, CO	Maybe	Can currently accept NORM and TNORM if waste acceptance is met.
Waste Management – CSI Facility, Bennett, CO	Yes	The County has asked CSI to not accept the type waste like that in the the stockpile; however they are in negotiations with WM and the issue has not been resolved nor does WM have a timeline for resolution.
EnviroCare in Utah	Yes	Price eliminates this option from serious consideration.
Waste Management Denver Arapahoe Disposal Site	No	Waste Management provided a quote for disposal at their CSI facility but declined to bid disposal at the DADS facility.

8.3.7 Cost

Costs are assessed below and include the following:

- Capital costs, including both direct and indirect costs;
- Annual operation and maintenance costs; and
- Net present value of capital and operation and maintenance costs.

8.3.7.1 Detailed Cost Estimate

Cost estimates have been prepared for each of the remedial alternatives under consideration. Detailed cost estimates for each alternative are provided in Appendix F. The summarized cost information for each alternative is presented in Table 8-8. Detailed cost information for the offsite disposal alternatives were provided by the disposal facility. A number of vendors were contacted for actual cost bids for specific tasks such as transportation, surveying, geotechnical testing, liner installation and consumables. Average industry costs were used for solidification equipment, monitoring well installation, and equipment rental.

Table 8-8
Cost Information for Each Alternative

Cost Breakout	Alternative Cost (in thousands of dollars)						
	1		2		3		4
Mobilization/demob	$0.00		$52		$89		$113
Construction Cost	$0.00		$88		$985		$669
Equipment Cost	$0.00		$34		incl. w/const.		incl. w/const.
Reclamation Cost	$0.00		$15		$47		$50
Disposal Cost	$0.00		$68		$0.00		$0.00
Engineering Cost	$0.00		$0.00		$66		$72
Long Term O & M (Groundwater	$0.00		$0.00		$660		$660

only, will be addressed in separate RI/FS))							
Closure Report	$0.00		$32		$57		$64
Total	$0.00		$289		$1,926		$1629
Rank	1		2		4		3
Ratio to Least Expensive	na		1		6.6:1		5.6:1

Based on an appraisal performed on behalf of the Colorado School of Mines in December 2003 (Dyco Real Estate, Inc., December 17, 2003) the value of the entire six acre CSMRI Site (without the Parfet/Golden property – Parfet/Golden property consists primarily of the previously described treed portion of the Site) was $2.4 million when considered for its highest and best use (i.e., residential development). Using the Zillow Market Index, residential home prices in Golden, Colorado have increased 3.4% between December 2003 and October 2011. The essentially unchanged median home price between 2003 and 2011 indicates that the property value assigned in 2003 is likely still within the range of error for the property value today. However, this value would be for a site that never had any contamination. A "stigma" factor would need to be applied to the highest and best use value. For purposes of comparison, a 20-percent stigma value was applied to the property. Application of the stigma value would result in an estimated property value of $2.2 million or about $367,000/acre. The appraisal considered the property to be of no marketable value if contamination remained on Site and it were to be utilized solely for recreational use. A new appraisal was not performed because the potential for lost property value is viewed as incidental to the evaluation of the remedial alternatives.

A partial property value loss would be applied to Alternatives 3 and 4 for the loss of a percentage of land (disposal area). Table 8-9 summarizes the effect of including those costs. The addition of the property value does not change the relative ranking of the alternatives: Alternative 2 is still the most cost-effective alternative. A copy of the original Site appraisal document was included in Appendix I of the 2004 RI/FS.

Table 8-9
Cost Information for Each Alternative including Stigma Value
(in millions of dollars)

Alternative	Description	Cost from Spreadsheet	Property Value Loss	Total Cost
1	No Action	0	0	0
2	Ship Contaminated Stockpile to an Offsite Commercial Waste Disposal Facility	0.289	0.0	.0.289
3	Leave Stockpile Material Onsite and design/build a Below-Grade Repository	1.24	.367	1.61
4	Onsite solidification and Placement into an Above-Grade Repository	.969	.367	1.34

8.3.7.2 Cost Minimization/Alternative Risk

Cost risks associated with the various alternatives include weather delays (Alternatives 2, 3, and 4), construction delays associated with access to U.S. Highway 6 (Alternatives 2, 3 and 4), inability to determine a proper solidification mixture (pilot test for Alternative 4), subcontractor problems (Alternatives 2, 3, and 4), transportation problems (Alternative 2), and landfill selection issues (Alternative 2). Alternatives 3 and 4 could have additional cost risks associated with licensing applications. Depending on the weight assigned to each of the risks, it would appear that Alternatives 3 and 4 have the highest number of potential cost risks. However, with the exception of the Alternative 4 pilot test, none of the identified risks appear to be capable of leading to the selection of another remedial action.

8.3.8 State Acceptance

Alternative 1 is unacceptable to CDPHE and the School. Although the remaining alternatives meet the requirements of most of the ARARs, onsite disposal may be problematic because of the recent action at the Shattuck site and CDPHE statements that it does not support onsite disposal (Alternatives 3 and 4).

8.3.9 Community Acceptance

Comments received during an open house conducted by the School indicated that local residents preferred offsite disposal of the material. Alternative 2 would have the highest community acceptance followed by Alternatives 3 and 4.

8.4 Summary

Alternative 1 is not protective, does not comply with ARARs, and is the least likely to be accepted by CDPHE, the School, and the local community. Alternatives 3 and 4 meet most ARARs and are protective, but have long-term maintenance and monitoring issues, technical uncertainty, and elevated costs. Alternative 2 is the preferred option because of the lack of maintenance and monitoring, elimination of uncertainties, and the lowest cost. Alternative 2 also is the preferred alternative of CDPHE, the School, and the local community. Foothills Landfill is the preferred facility for final disposition of the stockpiled material because it is less expensive and has less administrative uncertainty than the other landfill options.

Table of Contents for Section 9

9. Remedy Selection 9-1
9.1 Criteria Review 9-1
9.2 Remedy Selection Process 9-1
9.3 Proposed Plan 9-1
9.4 Incorporation of RI/FS and Proposed Plan Comments 9-1
9.5 Final Remedy Selection 9-2
9.6 Record of Decision 9-2

9. Remedy Selection

9.1 Criteria Review

Regulation 40 CFR §300.430(f) indicates that the cleanup remedies selected shall reflect the scope and purpose of the actions being undertaken and how the action relates to long-term, comprehensive response at the Site. As discussed in the introduction of Section 8, the nine evaluation criteria are divided into three groups. The groups are defined as follows:

- Threshold criteria. Overall protection of human health and the environment and compliance with ARARs (unless a specific ARAR is waived) are threshold requirements that each alternative must meet in order to be eligible for selection.
- Primary balancing criteria. The five primary balancing criteria are long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost.
- Modifying criteria. State and community acceptance are modifying criteria that shall be considered in remedy selection.

9.2 Remedy Selection Process

Regulations 40 CFR §300.430(e) and (f) and §300.515(e) require the participation of the State (CDPHE and School) in discussions of the alternatives addressed in the FS prior to preparation of the proposed plan and ROD. The School and CDPHE discussed alternatives. As presented in the Proposed Plan, CDPHE preferred the offsite disposal (Alternative 2). Specifics of Alternative 2 will be addressed at the completion of the public comment period.

9.3 Proposed Plan

The Proposed Plan for the CSMRI Site is provided in Appendix H. The plan includes information about the public comment period, the upcoming public meeting, and the location of the administrative record. The Proposed Plan is Alternative 2.

9.4 Incorporation of RI/FS and Proposed Plan Comments

Additional components of the community relations required by 40 CFR §300.430(f)(3) after the release of the RI/FS and Proposed Plan include:

- Keeping a transcript of the public meeting held during the public comment period and making the transcript available to the public.
- Preparing a written summary of significant comments, criticisms, and new relevant information submitted during the public comment period and the School response to each issue.

This information shall be made available in the ROD. Following the publication of the Proposed Plan and before documenting the selected remedy in a ROD, any new information that significantly changes the basic features of the remedy (e.g., scope, performance, or cost) will be considered. If additional public comment is required to review the changes, a revised RI/FS and/or Proposed Plan will be resubmitted to the public for comment.

9.5 Final Remedy Selection

Following the public comment period and after all comments are received, the final remedy shall be selected. The final remedy will address comments and concerns submitted by the public and CDPHE.

9.6 Record of Decision

A ROD will be issued to document the final remedy selection. The ROD will be generated in accordance with 40 CFR 300.430(f)(5). The ROD becomes the official Site cleanup document after CDPHE approval.

Following the CDPHE approval of the ROD, the public will be notified of its completion. Prior to the start of the remedial action, a notice of the ROD's availability will be published in local newspapers and a copy will be available in the Administrative Record locations. Additional public comment will not be provided as this requirement, if any, is being satisfied pursuant to this RI/FS public comment period.

Table of Contents for Section 10

10. References 10-1

10. References

Abelquist, E.W., 2001. Decommissioning Health Physics, A Handbook for MARSSIM Users, Institute of Physics Publishing, Philadelphia, PA, 438 p. Baltimore, Maryland.

Advanced Sciences, Inc., 1989. Preliminary Assessment of the Potential for Water-Borne Migration of Contaminants in the Claypits, J. Kunkel, Advanced Sciences, October 20.

ATSDR 1989

CDPHE 1997. Soil Remediation Objectives, A Policy Outlining the Process for Developing Site-Specific Soil Remediation Objectives, Hazardous Materials and Waste Management Division, December.

Chishti 2005. Chishti, Hafeez M., Environmental Investigation Methodology for Contaminated Sites, Trafford Publishing, 205 pp.

Eckerman, K. F. and J. C. Ryman. 1993. External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12. EPA 402 R-93-081.

Emmons S.F., *et al.* Geology of the Denver Basin in Colorado: U.S. Geological Survey Monograph 27, 1896.

EPA Integrated Risk Information System (IRIS), http://www.epa.gov/iris. (CASRN 7440-38-2)

EPA, 1982. U.S. Environmental Protection Agency, Surface Gamma Ray Scanner Survey.

EPA, 1988. U.S. Environmental Protection Agency, Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, EPA/540/G-89/004, OSWER Directive 9355.3-01, October.

EPA, 1989. U.S. Environmental Protection Agency, Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media, EPA 230/02-89-042, February.

EPA, 1989. Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) Interim Final, EPA/540/1-89/002, December.

EPA. 1991. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim, EPA/540/R-92/003, December.

EPA, 1991. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions, Washington, D.C. OSWER Directive 9355.0-30.

EPA 1994a. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children, EPA 9285.7-15-1, February.

EPA, 1994b. U.S. Environmental Protection Agency, Revised Interim Soil Lead Guidance for CERCLA and RCRA Corrective Action Facilities, OSWER Directive 9355.4-12, July.

EPA, 1995. U.S. Environmental Protection Agency, Contaminants and Remedial Options at Selected Metal-Contaminated Sites, Office of Research and Development, EPA/540/R-95/512, July.

EPA, 1997**.** Exposure Factors Handbook, Vol. 1, EPA/600/P-95/002Fa, August 1997.

EPA, 1997a. U.S. Environmental Protection Agency, Memorandum: Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA, OSWER No. 9200.4-23, August 22.

EPA, 1997b. U.S. Environmental Protection Agency, Rules of Thumb for Superfund Remedy Selection, Solid Waste and Emergency Response, EPA 540-R-97-013, OSWER 9355.0-69, PB97-963301, August.

EPA, 1999. U.S. Environmental Protection Agency, Presumptive Remedy for Metals-in-Soil Sites, Office of Solid Waste and Emergency Response, EPA 540-F-98-054, OSWER-9355.0-72FS, PB99-963301.

EPA, 2000. U.S. Environmental Protection Agency, Soil Screening Guidance for Radionuclides: User's Guide, EPA/540-R-00-007, October.

EPA, 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. EPA530-R-05-006, September.

EPA 2011. U.S. Environmental Protection Agency, Human Health Risk Assessment, Region 3 Risk Assessment Guidance, last update July 26, 2011.

Gingery and Associates, Inc. Flood Hazard Area Delineation, Clear Creek, Adams County and Jefferson County, November 1979.

Grant, 1990a. CSM Environmental Sampling & Analysis Program: Claypits Site & CSMRI Facility, James L. Grant & Associates, August 9.

Grant, 1990b. Task 1: Site Characterization and Pathways Analysis, Claypits Site and CSMRI Facility, Golden, Colorado, Project No. 809334, James L. Grant & Associates, April 30.

Grant, 1991. Characterization Plan for Claypits & CSMRI Creekside and Table Mountain Research Center Sites, James L. Grant & Associates, March 22.

Grove Software. 2005. MicroShield 7.0.3 Dose Assessment Program. Grove Software, Inc., Lynchburg, Virginia.

Havelick, Linn 2006.

HHS, 1992. U.S. Department of Health and Human Services, Analysis Paper: Impact of Lead-Contaminated Soil on Public Health, from website: http://www.atsdr.cdc.gov/cxlead.html, Public Health Service, Agency for Toxic Substances and Disease Registry.

ICRP 1960

Industrial Compliance Inc., 1989. Tailings Pond, CSMRI, Creekside Sampling Report, October.

Jacobs, 1987. CSMRI Environmental Assessment, Jacobs Engineering Group Inc., October.

MacPherson, 1988. Claypits Report to CDPHE, Robert MacPherson, October 20.

New Horizons, 1998. Conceptual Subsurface Sampling & Analysis Plan, CSMRI Site.

New Horizons, 2003a. Concrete and Asphalt Removal and Disposal [Final Report], April 11.

New Horizons, 2003b. CSMRI Characterization Summary, August 21.

New Horizons, 2004. Remedial Investigation / Feasibility Study and Proposed Plan, Colorado School of Mines Research Institute Site, Golden, Colorado, January 21.

NRC, 1998. Probabilistic Modules for the RESRAD and RESRAD-BUILD Computer Codes, NUREG/CP-0163, Argonne National Laboratory.

Radiant Energy Management, 1989. Preliminary Assessment of Radiological Risks at CSMRI, Creekside, L. Hersloff, September.

Removal Action Options Analysis (RAOA), Colorado School of Mines Research Institute, Golden, Colorado, Submitted to U.S. Environmental Protection Agency, Region VIII, Denver, Colorado, in compliance with Unilateral Administrative Order No. CERCLA-VIII-95-06, multiple authors, June 12, 1995 (3 vols.)

Robson, S.G., 1983. Hydraulic Characteristics of the Principal Bedrock Aquifers in the Denver Basin, Colorado: U.S. Geological Survey Hydrologic Investigations Atlas HA-659, scale 1:500,000.

Robson, S. G, 1984. Bedrock Aquifers in the Denver Basin, Colorado – A Quantitative Water-Resources Appraisal: U.S. Geological Survey Open File Report 84-431.

Robson, S.G., *et al.* 1981a. Geologic Structure, Hydrology, and Water Quality of the Arapahoe Aquifer in the Denver Basin, Colorado: U.S. Geological Survey Hydrologic Investigations Atlas HA-647, scale 1:500,000.

Robson, S.G., *et al.* 1981b. Geologic Structure, Hydrology, and Water Quality of the Laramie-Fox Hills Aquifer in the Denver Basin, Colorado: U.S. Geological Survey Hydrologic Investigations Atlas HA-650, scale 1:500,000.

SR & K, 1994. Preliminary Remedial Alternative Evaluation for the CSM Creekside Stockpile, August 25.

Stoller, 2005a. Dose Assessment for the Emplacement of the CSMRI Site Containerized and Remaining Subsurface Soil into a RCRA Subtitle D Solid Waste Landfill, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, March 1.

Stoller, 2005b. CSMRI Creekside Site Draft Report on Background, prepared for Colorado School of Mines Research Institute, Golden, Colorado, prepared by S.M. Stoller Corporation, September 13.

Stoller, 2005c. CSMRI Creekside Site Contaminated Soil Disposal Work Plan, Revision 2, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, November 3.

Stoller, 2006a. CSMRI Creekside Site Bagged Soil Disposal Summary Report, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, February 6.

Stoller, 2006b. CSMRI Creekside Site Final Site Characterization Work Plan, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, May 12.

Stoller, 2006c. CSMRI Site Flood Plain Characterization Work Plan, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, November 21.

Stoller, 2006d. CSMRI Site Groundwater Monitoring Well Installation Work Plan, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, December 6.

Stoller 2007a. Revised Remedial Investigation / Feasibility Study and Proposed Plan, Colorado School of Mines Research Institute Site, The S.M. Stoller Corporation, original RI/FS date: January 21, 2004, revision date: May 2007.

Stoller 2007b. CSMRI Record of Decision, S.M. Stoller Corporation, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, original ROD date: March 31, 2004, revision date: July 9.

Stoller 2009. CSMRI Remedial Action Implementation Report, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, September.

Stoller 2010a. CSMRI Final Work Plan Environmental Assessment and Characterization, Flood Plain Area, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, August.

Stoller 2010b. Monitoring Report for CSMRI Third Quarter 2010, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, November.

Stoller 2011, Monitoring Report for CSMRI Site Fourth Quarter 2010, prepared for Colorado School of Mines, Golden, Colorado, prepared by S.M. Stoller Corporation, February.

URS 1999. Analytical Results Report, Colorado School of Mines Research Institute Site, prepared by URS Corporation.

URS 2000. Background Characterization Report, prepared for Colorado School of Mines Environmental Health and Safety, prepared by URS Greiner Woodward Clyde International-Americas, Inc., July 7.

URS 2001. A Characterization Survey Work Plan, prepared by URS Corporation, July 23.

URS 2002a. Colorado School of Mines Research Institute Supplementary Background Characterization draft final report, prepared by URS Corporation, January 28.

URS 2002b. Feb 11, 2002

URS 2002c. Concrete and Asphalt Characterization Report, May 18.

USACE 2002. U.S. Army Corps of Engineers, White Paper: Using RESRAD in a CERCLA Radiological Risk Assessment, prepared by Science Applications International Corporation.

Van Horn, Richard, 1976. Geology of the Golden Quadrangle, Colorado, Geological Survey Professional Paper 872, U.S. Government Printing Office, Washington.

Weimer, R.J., 1976. Cretaceous Stratigraphy, Tectonics and Energy Resources, Western Denver Basin, Colorado School of Mines.

Yu, C., Zielen, A.J., Cheng, J.J., LePoire, D.J., Gnanapragagasam, E., Kamboj, S., Arnish, J., Wallo III, A. Williams, W.A., and Peterson, H., 2001, User's Manual for RESRAD Version 6.5, ANL/EAD-4, Environmental Assessment Division, Argonne National Laboratory.

Yu, C. Loureiro*, J.-J. Cheng, L.G. Jones, Y.Y. Wang, Y.P. Chia,* and E. Faillace, 1993. Data Collection Handbook to Support Modeling Impacts of Radioactive Material, Argonne Nation Laboratory, Argonne, Illinois, April.

3.1 Laying out 10 ft x 10 ft grid on the characterization area with the GPS and collecting data with field screening instruments.

3.2 Grade checking to verify the 1-ft vertical lift is removed before laying out 10 ft x10 ft grid and field screening next soil horizon.

3.3 One of two air samplers stationed downwind of the characterization area and run continuously during active field operations.

4.1 The lines drawn behind the excavator shows the area of impacted soil left in place around grid locations 00236 and 00237. The blue marking on the silt fence is the approximate location of the City's water main.

4.2 Abandoned in place water supply tunnel originally used in 1912.

4.3 All fill material in the tunnel within approximately 20 of the entrance was removed with the vacuum truck. A 3/8-inch steel plate was then placed to block the entrance of the tunnel and 108 sacks of bentonite chips (total of 5,400 lbs) were hand placed behind the plate to create an impermeable plug approximately 3 feet thick.

4.4 Typical artificial fill from historic CSMRI activities note the crucibles and brick along with other debris.

4.5 Field screening artificial fill on the western portion of the characterization area for gamma activity. In addition to activity greater than 2x background XRF screening of many of these discolored soils detected elevated concentrations of metals including lead and arsenic.

4.6 The characterization stockpile located on the upper terrace is managed inside the lined containment area and is sprayed with a soil tackifier to minimize erosion and airborne dust.

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1010198-20

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 08-Oct-10
Date Prepared: 28-Oct-10
Date Analyzed: 05-Nov-10

Prep Batch: AS101103-3
QCBatchID: AS101103-3-2
Run ID: AS101103-3TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 22200000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	2.2E-15 +/- 2.1E-15	3.4E-15	1E-10	U
14269-63-7	Th-230	-1.6E-15 +/- 1.9E-15	3.7E-15	1E-10	U
7440-29-1	Th-232	1.3E-15 +/- 8.2E-16	8.7E-16	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.980E-13	1.46E-13	uCi/ml	73.5	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1010198-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1010198-20

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 08-Oct-10
Date Prepared: 28-Oct-10
Date Analyzed: 05-Nov-10

Prep Batch: AS101103-4
QCBatchID: AS101103-4-2
Run ID: AS101103-4UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 22200000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	1.8E-15 +/- 1.1E-15	1.3E-15	1E-10	LT
15117-96-1	U-235	0E+00 +/- 5.1E-16	7.6E-16	1E-10	U
7440-61-1	U-238	1.34E-15 +/- 8.7E-16	1.05E-15	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	2.020E-13	1.61E-13	uCi/ml	79.9	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1010198-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 8

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1010198-20

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 08-Oct-10
Date Prepared: 03-Nov-10
Date Analyzed: 12-Nov-10

Prep Batch: RE101103-2
QCBatchID: RE101103-2-1
Run ID: RE101103-2A
Count Time: 30 minutes
Report Basis: As Received

Final Aliquot: 22100000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	9.1E-15 +/- 7.5E-15	1.1E-14	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.230E+04	2.680E+04	ug	83.0	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1010198-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 10

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1010198-20

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 08-Oct-10
Date Prepared: 03-Nov-10
Date Analyzed: 15-Nov-10

Prep Batch: RA101103-1
QCBatchID: RA101103-1-2
Run ID: RA101103-1A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 22200000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC1115

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	9E-15 +/- 2.4E-14	5.1E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.230E+04	2.380E+04	ug	73.8	40 - 110 %	
YTTRIUM	9.040E+03	7.160E+03	ug	79.2	40 - 110 %	
Total				58.5	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1010198-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010299
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1010299-14

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 15-Oct-10
Date Prepared: 28-Oct-10
Date Analyzed: 05-Nov-10

Prep Batch: AS101103-3
QCBatchID: AS101103-3-2
Run ID: AS101103-3TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 29700000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	1.7E-15 +/- 1.6E-15	2.5E-15	1E-10	U
14269-63-7	Th-230	0E+00 +/- 1.6E-15	2.8E-15	1E-10	U
7440-29-1	Th-232	8.6E-16 +/- 6.5E-16	8.6E-16	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.480E-13	1.08E-13	uCi/ml	72.8	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1010299-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010299
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1010299-14

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 15-Oct-10
Date Prepared: 28-Oct-10
Date Analyzed: 05-Nov-10

Prep Batch: AS101103-4
QCBatchID: AS101103-4-2
Run ID: AS101103-4UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 29700000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	9.6E-16 +/- 5.4E-16	5.2E-16	1E-10	LT
15117-96-1	U-235	7E-17 +/- 3.3E-16	6.2E-16	1E-10	U
7440-61-1	U-238	5.1E-16 +/- 4.4E-16	6.1E-16	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	1.510E-13	1.39E-13	uCi/ml	92.4	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1010299-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 10

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010299
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1010299-14

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 15-Oct-10
Date Prepared: 03-Nov-10
Date Analyzed: 15-Nov-10

Prep Batch: RA101103-1
QCBatchID: RA101103-1-2
Run ID: RA101103-1A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 29700000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC1115

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	1.3E-14 +/- 2E-14	4E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.230E+04	2.370E+04	ug	73.2	40 - 110 %	
YTTRIUM	9.040E+03	7.080E+03	ug	78.3	40 - 110 %	
Total				57.3	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1010299-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 8

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010299
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain	**Sample Matrix:** FILTER	**Prep Batch:** RE101103-2	**Final Aliquot:** 29600000 ml
Lab ID: 1010299-14	**Prep SOP:** PAI 783 Rev 8	**QCBatchID:** RE101103-2-1	**Prep Basis:** As Received
	Date Collected: 15-Oct-10	**Run ID:** RE101103-2A	**Moisture(%):** NA
	Date Prepared: 03-Nov-10	**Count Time:** 30 minutes	**Result Units:** uCi/ml
	Date Analyzed: 12-Nov-10	**Report Basis:** As Received	**File Name:** Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	2.2E-15 +/- 3.9E-15	6.8E-15	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.230E+04	2.860E+04	ug	88.5	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1010299-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12
Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1011055-21

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 22-Oct-10
Date Prepared: 12-Nov-10
Date Analyzed: 19-Nov-10

Prep Batch: AS101112-1
QCBatchID: AS101112-1-1
Run ID: AS101112-1TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 32500000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	1E-16 +/- 1.1E-15	1.9E-15	1E-10	U
14269-63-7	Th-230	2.3E-15 +/- 1.7E-15	2.6E-15	1E-10	U
7440-29-1	Th-232	1.5E-15 +/- 7.1E-16	5E-16	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.360E-13	9.4E-14	uCi/ml	69.7	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1011055-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011055-21

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 22-Oct-10
Date Prepared: 12-Nov-10
Date Analyzed: 19-Nov-10

Prep Batch: AS101112-2
QCBatchID: AS101112-2-1
Run ID: AS101112-2UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 32500000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	6.5E-16 +/- 5.8E-16	8.5E-16	1E-10	U
15117-96-1	U-235	4.4E-16 +/- 3.4E-16	1.7E-16	1E-10	LT
7440-61-1	U-238	1.08E-15 +/- 5.3E-16	4E-16	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	1.380E-13	1.17E-13	uCi/ml	85.2	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1011055-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 8

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1011055-21

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 22-Oct-10
Date Prepared: 17-Nov-10
Date Analyzed: 02-Dec-10

Prep Batch: RE101117-1
QCBatchID: RE101117-1-1
Run ID: RE101117-1A
Count Time: 45 minutes
Report Basis: As Received

Final Aliquot: 32400000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	9E-16 +/- 3.6E-15	6.5E-15	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.210E+04	2.820E+04	ug	87.7	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1011055-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 11

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011055-21

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 22-Oct-10
Date Prepared: 08-Dec-10
Date Analyzed: 17-Dec-10

Prep Batch: RA101208-1
QCBatchID: RA101208-1-1
Run ID: RA101208-1A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 32400000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC1217

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	1.3E-14 +/- 1.6E-14	3.3E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.010E+04	2.200E+04	ug	73.2	40 - 110 %	
YTTRIUM	9.050E+03	7.250E+03	ug	80.0	40 - 110 %	
Total				58.6	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1011055-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011055-23

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 29-Oct-10
Date Prepared: 12-Nov-10
Date Analyzed: 19-Nov-10

Prep Batch: AS101112-1
QCBatchID: AS101112-1-1
Run ID: AS101112-1TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 36800000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	-1E-16 +/- 1.1E-15	2E-15	1E-10	U
14269-63-7	Th-230	1.4E-15 +/- 1.4E-15	2.3E-15	1E-10	U
7440-29-1	Th-232	6.4E-16 +/- 6.1E-16	9.2E-16	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.200E-13	8.4E-14	uCi/ml	69.8	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1011055-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011055-23

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 29-Oct-10
Date Prepared: 12-Nov-10
Date Analyzed: 19-Nov-10

Prep Batch: AS101112-2
QCBatchID: AS101112-2-1
Run ID: AS101112-2UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 36800000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	1.94E-15 +/- 8.8E-16	1.06E-15	1E-10	LT
15117-96-1	U-235	2.8E-16 +/- 4.4E-16	7.5E-16	1E-10	U
7440-61-1	U-238	1.02E-15 +/- 6.1E-16	7.7E-16	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	1.220E-13	9.9E-14	uCi/ml	81.0	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1011055-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 8

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011055-23

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 29-Oct-10
Date Prepared: 17-Nov-10
Date Analyzed: 02-Dec-10

Prep Batch: RE101117-1
QCBatchID: RE101117-1-1
Run ID: RE101117-1A
Count Time: 45 minutes
Report Basis: As Received

Final Aliquot: 36600000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	1.5E-15 +/- 2.8E-15	4.8E-15	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.190E+04	2.800E+04	ug	87.9	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1011055-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 11

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011055-23

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 29-Oct-10
Date Prepared: 08-Dec-10
Date Analyzed: 17-Dec-10

Prep Batch: RA101208-1
QCBatchID: RA101208-1-1
Run ID: RA101208-1A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 36700000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC1217

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	5E-15 +/- 1.1E-14	2.3E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.010E+04	2.790E+04	ug	92.6	40 - 110 %	
YTTRIUM	9.050E+03	7.320E+03	ug	80.9	40 - 110 %	
Total				74.9	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1011055-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Flooodplain
Lab ID:	1011264-16

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 05-Nov-10
Date Prepared: 03-Dec-10
Date Analyzed: 09-Dec-10

Prep Batch: AS101206-1
QCBatchID: AS101206-1-1
Run ID: AS101206-1TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 38200000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	1E-16 +/- 1.2E-15	2.1E-15	1E-10	U
14269-63-7	Th-230	5E-16 +/- 1.3E-15	2.3E-15	1E-10	U
7440-29-1	Th-232	1.34E-15 +/- 6.3E-16	4.5E-16	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.180E-13	7.8E-14	uCi/ml	66.4	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1011264-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Flooodplain
Lab ID:	1011264-16

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 05-Nov-10
Date Prepared: 03-Dec-10
Date Analyzed: 09-Dec-10

Prep Batch: AS101206-2
QCBatchID: AS101206-2-1
Run ID: AS101206-2UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 38200000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	7.2E-16 +/- 4.2E-16	4.5E-16	1E-10	LT
15117-96-1	U-235	1.5E-16 +/- 2.4E-16	3.7E-16	1E-10	U
7440-61-1	U-238	3.8E-16 +/- 3.5E-16	5.1E-16	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	1.170E-13	1.05E-13	uCi/ml	89.3	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1011264-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 9
Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Flooodplain
Lab ID: 1011264-16

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 05-Nov-10
Date Prepared: 07-Dec-10
Date Analyzed: 17-Dec-10

Prep Batch: RE101207-1
QCBatchID: RE101207-1-1
Run ID: RE101207-1A
Count Time: 45 minutes
Report Basis: As Received

Final Aliquot: 38000000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	1.8E-15 +/- 3E-15	5.1E-15	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.380E+04	3.040E+04	ug	89.9	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1011264-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 11

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Flooodplain
Lab ID: 1011264-16

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 05-Nov-10
Date Prepared: 07-Dec-10
Date Analyzed: 04-Jan-11

Prep Batch: RA101207-3
QCBatchID: RA101207-3-1
Run ID: RA101207-3A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 38100000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC0104

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	-3E-15 +/- 1.4E-14	3E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.380E+04	2.780E+04	ug	82.4	40 - 110 %	
YTTRIUM	9.640E+03	6.290E+03	ug	65.3	40 - 110 %	
Total				53.8	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1011264-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011264-18

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 10-Nov-10
Date Prepared: 03-Dec-10
Date Analyzed: 09-Dec-10

Prep Batch: AS101206-1
QCBatchID: AS101206-1-1
Run ID: AS101206-1TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 19200000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	7E-16 +/- 3.1E-15	5.3E-15	1E-10	U
14269-63-7	Th-230	2.4E-15 +/- 2.8E-15	4.5E-15	1E-10	U
7440-29-1	Th-232	1.5E-15 +/- 1.1E-15	1.3E-15	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	2.360E-13	1.56E-13	uCi/ml	66.1	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1011264-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1011264-18

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 10-Nov-10
Date Prepared: 03-Dec-10
Date Analyzed: 09-Dec-10

Prep Batch: AS101206-2
QCBatchID: AS101206-2-1
Run ID: AS101206-2UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 19200000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	2E-15 +/- 1.1E-15	1.2E-15	1E-10	LT
15117-96-1	U-235	5.3E-16 +/- 5.7E-16	7.9E-16	1E-10	U
7440-61-1	U-238	1E-15 +/- 7.6E-16	9.8E-16	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	2.340E-13	1.97E-13	uCi/ml	84.1	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1011264-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 9

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Floodplain
Lab ID:	1011264-18

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 10-Nov-10
Date Prepared: 07-Dec-10
Date Analyzed: 17-Dec-10

Prep Batch: RE101207-1
QCBatchID: RE101207-1-1
Run ID: RE101207-1A
Count Time: 45 minutes
Report Basis: As Received

Final Aliquot: 19100000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	5E-15 +/- 5.6E-15	8.9E-15	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.410E+04	2.910E+04	ug	85.4	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1011264-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 11

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Floodplain
Lab ID: 1011264-18

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 10-Nov-10
Date Prepared: 07-Dec-10
Date Analyzed: 04-Jan-11

Prep Batch: RA101207-3
QCBatchID: RA101207-3-1
Run ID: RA101207-3A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 19100000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC0104

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	7E-15 +/- 3.1E-14	6.6E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.410E+04	2.270E+04	ug	66.7	40 - 110 %	
YTTRIUM	9.640E+03	7.340E+03	ug	76.2	40 - 110 %	
Total				50.8	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1011264-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Terrace
Lab ID: 1010198-19

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 08-Oct-10
Date Prepared: 28-Oct-10
Date Analyzed: 05-Nov-10

Prep Batch: AS101103-3
QCBatchID: AS101103-3-2
Run ID: AS101103-3TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 22500000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	-8E-16 +/- 2.2E-15	3.9E-15	1E-10	U
14269-63-7	Th-230	-1.7E-15 +/- 2E-15	3.7E-15	1E-10	U
7440-29-1	Th-232	2.8E-16 +/- 6.7E-16	1.21E-15	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.960E-13	1.44E-13	uCi/ml	73.4	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1010198-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Terrace
Lab ID: 1010198-19

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 08-Oct-10
Date Prepared: 28-Oct-10
Date Analyzed: 05-Nov-10

Prep Batch: AS101103-4
QCBatchID: AS101103-4-2
Run ID: AS101103-4UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 22500000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	8.9E-16 +/- 6.3E-16	7.3E-16	1E-10	LT
15117-96-1	U-235	9E-17 +/- 4.6E-16	2.6E-16	1E-10	U
7440-61-1	U-238	8E-16 +/- 7.6E-16	1.13E-15	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	1.990E-13	1.67E-13	uCi/ml	83.8	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1010198-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 8

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Terrace
Lab ID:	1010198-19

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 08-Oct-10
Date Prepared: 03-Nov-10
Date Analyzed: 12-Nov-10

Prep Batch: RE101103-2
QCBatchID: RE101103-2-1
Run ID: RE101103-2A
Count Time: 30 minutes
Report Basis: As Received

Final Aliquot: 22400000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	1.9E-15 +/- 7.6E-15	1.43E-14	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.210E+04	2.700E+04	ug	84.3	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1010198-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 10

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1010198
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Terrace
Lab ID:	1010198-19

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 08-Oct-10
Date Prepared: 03-Nov-10
Date Analyzed: 15-Nov-10

Prep Batch: RA101103-1
QCBatchID: RA101103-1-2
Run ID: RA101103-1A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 22500000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC1115

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	1.1E-14 +/- 2.3E-14	4.7E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.210E+04	2.510E+04	ug	78.3	40 - 110 %	
YTTRIUM	9.040E+03	7.160E+03	ug	79.2	40 - 110 %	
Total				62.0	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1010198-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12
Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Terrace
Lab ID:	1011055-22

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 22-Oct-10
Date Prepared: 12-Nov-10
Date Analyzed: 19-Nov-10

Prep Batch: AS101112-1
QCBatchID: AS101112-1-1
Run ID: AS101112-1TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 27000000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	-1.8E-15 +/- 2.3E-15	4.3E-15	1E-10	U
14269-63-7	Th-230	-4E-16 +/- 2.1E-15	3.8E-15	1E-10	U
7440-29-1	Th-232	1.5E-15 +/- 1.1E-15	1.4E-15	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.630E-13	9.1E-14	uCi/ml	56.0	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1011055-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Terrace
Lab ID: 1011055-22

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 22-Oct-10
Date Prepared: 12-Nov-10
Date Analyzed: 19-Nov-10

Prep Batch: AS101112-2
QCBatchID: AS101112-2-1
Run ID: AS101112-2UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 27000000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	1.06E-15 +/- 7.2E-16	9.3E-16	1E-10	LT
15117-96-1	U-235	1.6E-16 +/- 5.4E-16	1.02E-15	1E-10	U
7440-61-1	U-238	4E-16 +/- 6.8E-16	1.15E-15	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	1.660E-13	1.44E-13	uCi/ml	86.8	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1011055-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 8

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Terrace
Lab ID:	1011055-22

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 22-Oct-10
Date Prepared: 17-Nov-10
Date Analyzed: 02-Dec-10

Prep Batch: RE101117-1
QCBatchID: RE101117-1-1
Run ID: RE101117-1A
Count Time: 45 minutes
Report Basis: As Received

Final Aliquot: 26900000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	9E-16 +/- 3.5E-15	6.6E-15	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.130E+04	2.620E+04	ug	83.7	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1011055-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 11
Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011055
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Terrace
Lab ID:	1011055-22

Sample Matrix: FILTER
Prep SOP: PAI 746 Rev 8
Date Collected: 22-Oct-10
Date Prepared: 08-Dec-10
Date Analyzed: 17-Dec-10

Prep Batch: RA101208-1
QCBatchID: RA101208-1-1
Run ID: RA101208-1A
Count Time: 250 minutes
Report Basis: As Received

Final Aliquot: 27000000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: RAC1217

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	1.1E-14 +/- 1.7E-14	3.4E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.010E+04	2.690E+04	ug	89.3	40 - 110 %	
YTTRIUM	9.050E+03	7.290E+03	ug	80.5	40 - 110 %	
Total				71.9	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1011055-1*

Isotopic Thorium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Terrace
Lab ID:	1011264-17

Sample Matrix: FILTER
Prep SOP: PAI 777 Rev 9
Date Collected: 05-Nov-10
Date Prepared: 03-Dec-10
Date Analyzed: 09-Dec-10

Prep Batch: AS101206-1
QCBatchID: AS101206-1-1
Run ID: AS101206-1TH
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 38100000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
14274-82-9	Th-228	2E-15 +/- 1.9E-15	2.9E-15	1E-10	U
14269-63-7	Th-230	9E-16 +/- 1.5E-15	2.6E-15	1E-10	U
7440-29-1	Th-232	9.3E-16 +/- 7.8E-16	1.13E-15	1E-10	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
Th-229	1.190E-13	6.4E-14	uCi/ml	54.0	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *TH1011264-1*

Isotopic Uranium By Alpha Spectroscopy

PAI 714 Rev 12

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Terrace
Lab ID: 1011264-17

Sample Matrix: FILTER
Prep SOP: PAI 778 Rev 13
Date Collected: 05-Nov-10
Date Prepared: 03-Dec-10
Date Analyzed: 09-Dec-10

Prep Batch: AS101206-2
QCBatchID: AS101206-2-1
Run ID: AS101206-2UR
Count Time: 1000 minutes
Report Basis: As Received

Final Aliquot: 38100000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Spectrum #1

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13966-29-5	U-234	7E-16 +/- 4E-16	4E-16	1E-10	LT
15117-96-1	U-235	5E-17 +/- 2.5E-16	3.8E-16	1E-10	U
7440-61-1	U-238	7E-16 +/- 4E-16	4E-16	1E-10	LT

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
U-232	1.180E-13	1E-13	uCi/ml	85.3	30 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *UR1011264-1*

Ra-226 by Radon Emanation - Method 903.1

PAI 783 Rev 9

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID:	AS Terrace
Lab ID:	1011264-17

Sample Matrix: FILTER
Prep SOP: PAI 783 Rev 8
Date Collected: 05-Nov-10
Date Prepared: 07-Dec-10
Date Analyzed: 17-Dec-10

Prep Batch: RE101207-1
QCBatchID: RE101207-1-1
Run ID: RE101207-1A
Count Time: 45 minutes
Report Basis: As Received

Final Aliquot: 37900000 ml
Prep Basis: As Received
Moisture(%): NA
Result Units: uCi/ml
File Name: Manual Entry

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
13982-63-3	Ra-226	6E-16 +/- 2.4E-15	4.5E-15	1E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.400E+04	2.930E+04	ug	86.2	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RE1011264-1*

Radium-228 Analysis by GFPC

PAI 724 Rev 11

Sample Results

Lab Name: ALS Environmental -- FC
Work Order Number: 1011264
Client Name: S.M. Stoller Corp.
ClientProject ID: 4349-410 CO School of Mines

Field ID: AS Terrace **Lab ID:** 1011264-17	**Sample Matrix:** FILTER **Prep SOP:** PAI 746 Rev 8 **Date Collected:** 05-Nov-10 **Date Prepared:** 07-Dec-10 **Date Analyzed:** 04-Jan-11	**Prep Batch:** RA101207-3 **QCBatchID:** RA101207-3-1 **Run ID:** RA101207-3A **Count Time:** 250 minutes **Report Basis:** As Received	**Final Aliquot:** 38000000 ml **Prep Basis:** As Received **Moisture(%):** NA **Result Units:** uCi/ml **File Name:** RAC0104

CASNO	Target Nuclide	Result +/- 2 s TPU	MDC	Requested MDC	Lab Qualifier
15262-20-1	Ra-228	1.4E-14 +/- 1.4E-14	2.7E-14	5E-09	U

Chemical Yield Summary

Carrier/Tracer	Amount Added	Result	Units	Yield	Control Limits	Flag
BARIUM	3.400E+04	2.760E+04	ug	81.0	40 - 110 %	
YTTRIUM	9.640E+03	7.390E+03	ug	76.7	40 - 110 %	
Total				62.1	40 - 110 %	

Comments:

Qualifiers/Flags:

U - Result is less than the sample specific MDC.

Y1 - Chemical Yield is in control at 100-110%. Quantitative Yield is assumed.

Y2 - Chemical Yield outside default limits.

LT - Result is less than Requested MDC, greater than sample specific MDC.

M3 - The requested MDC was not met, but the reported activity is greater than the reported MDC.

M - The requested MDC was not met.

Abbreviations:

TPU - Total Propagated Uncertainty

MDC - Minimum Detectable Concentration

BDL - Below Detection Limit

Data Package ID: *RA1011264-1*

Appendix C

Offsite Analytical Laboratory Sample and Data Validation Summary Reports for the Laboratory Data Packages

A quality assurance/quality control (QA/QC) review was conducted on all soil and air filter samples that were submitted for laboratory analyses. Sample laboratory data were evaluated based on the following parameters:

- Data completeness
- Holding times and preservation (not applicable for radioisotopic analyses)
- Initial and continuing calibration verification
- Contract-required detection limit
- Preparation/initial calibration checks and continuing calibration checks
- Interference check sample results
- Matrix spike and matrix spike duplicate results
- Duplicate sample results
- Laboratory control samples and laboratory control samples duplicate results
- Serial dilution sample results
- Compound quantitation and reporting limits (full validation only)

Rejected Data

Only one soil sample, 00163-03, was rejected [R] for uranium. All serial dilutions were less than 10 percent (%) for all soil samples except sample 00163-003. The serial dilution for this sample resulted in a value of 55%, well above the 10% criteria. A reanalysis of this sample was not conducted.

Estimated Data

Several soil samples were identified as Estimated [J] for a variety of reasons. All 13 soil samples associated with SDG No. 1010299 (00163-03, 00165-03, 00185-03, 00195-03, 00196-03, 00200-03, 00202-03, 00205-03, 00214-03, 00231-03, 00232-03, 00236-03, and 00237-03) for the inductively coupled plasma – atomic emission spectrometry (ICP-AES) analyses for the metals arsenic, lead, vanadium, and molybdenum are all Estimated because the Line Calibration report that is included in the data package was identified as incorrect. The reported "Y" was not used for calculations but the correct "Paragon" was used. The correct file was inadvertently deleted by the laboratory analyst and could not be reported.

Lead in sample 00163-03 is qualified as Estimated due to matrix spike failure.

Arsenic, lead, molybdenum, and uranium in sample 00163-03 are qualified as Estimated for matrix spike failure.

Mercury in sample 00196-003 for the matrix spike duplicate is qualified as Estimated for duplicate failure.

Mercury in sample 00387-003 is qualified as Estimated for duplicate failure.

Radium-228 in samples 00436-03 and 00437-03 are qualified as Estimated and flagged Tentatively Identified (TI) due to potential peak shift in quantitation.

Overall Comments

The data reviewer noticed that in some radium analyses, the laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation had a concentration of less than the concentration added. The laboratory manually adjusted the values to the known concentration to calculate the chemical yield in order to avoid a low bias in all samples, including the QC samples. In some cases the reported barium concentrations are less than that known to be added. The analytical results are reported as accepted without qualification for the affected samples.

The laboratory reports that the samples originally prepared in batch RA101123-1 on November 23, 2010, and due to analyst error, a complete loss of the samples occurred during the preparation process. The samples were re-prepared with the reserved fraction in batch RA1-1208-1 on December 06, 2010. The samples were within the 180-day holding time and no data qualification action was necessary.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 23, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010198

This report presents the inorganic metals data validation for the data obtained for eighteen total metals and total Uranium for the CSMRI soil samples collected on October 08, 2010, October 11, 2010, October 12, 2010, and October 13, 2010 and submitted to ALS Laboratory Group on October 13, 2010 for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the inorganic metals results that were obtained by SW-846, 3rd edition, Method 6010B and ALS Laboratory Group SOP 834R8 for Total metals by Inductively Coupled Plasma (ICP) atomic emission spectrometry analysis, Total Mercury by 812R14 Cold Vapor Atomic Absorption (CVAA), Total Uranium by Method 6020A ALS Laboratory Group Procedure SOP 827R7 by Inductively Coupled Plasma mass spectrometry (ICP-MS) analysis for SDG 1010198 by ALS Laboratory Group (Fort Collins, CO). The samples were extracted and analyzed on October 14, 2010 for Total ICP metals and Total Uranium by ICP-MS, and for Total Mercury by CVAA on October 15, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00057-03	1010198-1	Soil	October 08, 2010
00073-03	1010198-2	Soil	October 08, 2010
00075-03	1010198-3	Soil	October 08, 2010
00084-03	1010198-4	Soil	October 08, 2010
00091-03	1010198-5	Soil	October 08, 2010
00092-03	1010198-6	Soil	October 08, 2010
00102-03	1010198-7	Soil	October 08, 2010
00106-03	1010198-8	Soil	October 11, 2010
00109-03	1010198-9	Soil	October 11, 2010
00112-03	1010198-10	Soil	October 11, 2010
00116-03	1010198-11	Soil	October 11, 2010
00117-03	1010198-12	Soil	October 11, 2010
00124-03	1010198-13	Soil	October 11, 2010
00141-03	1010198-14	Soil	October 12, 2010
00144-03	1010198-15	Soil	October 12, 2010
00148-03	1010198-16	Soil	October 12, 2010

00152-03	1010198-17	Soil	October 12, 2010
Backfill 001	1010198-18	Soil	October 13, 2010

Data validation was conducted in accordance with the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.

The metals data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Initial and Continuing Calibration Verification
* Contract Required Detection Limit (CRDL)
  Preparation/ Initial (ICB)/ and Continuing (CCB) Calibration Blanks
* Interference Check Sample (ICSA) Results
* Matrix Spike Results
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
  Serial Dilution Sample Results
* Compound Quantitation and Reporting Limits (full validation only)

* **All criteria were met for this parameter**

Data Completeness

The data package was complete except for the missing CRDL (2B) and IDL (10) QC Summary Forms. No results were qualified as a result of the missing data.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met.

The samples were received at a temperature of 5.6 ºC.

Initial and Continuing Calibration Verification

Initial and Continuing Calibration Verification standards were analyzed at the required frequency and all were within the required 90-110% limits for ICP. No action was necessary.

Contract Required Detection Limit (CRDL)

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the %Rs from the instrument raw data. All CRDL %Rs for ICP were within 80-120% limits. No action was necessary.

Preparation and Initial/ Continuing Calibration Blanks

Preparation and Initial/Continuing Calibration Blank analyses were performed at the required frequency. Preparation and Initial/ Continuing Calibration Blanks are evaluated to assess the level of contamination in the preparation and analytical processes.

Preparation and Initial/ Continuing Calibration Blanks were prepared and analyzed at the required frequencies.

All of the blanks that were analyzed had concentrations that were below their respective Reporting Limits (RLs).

However, if blank results were above the Instrument Detection Limits (IDLs) and below the RLs, it caused the associated sample results to be qualified for contamination as estimated and non-detected **[UJ 107]**. If blank results were below the negative IDL and above the negative RL, it caused the associated sample results to be qualified for negative contamination as estimated **[J 107]**. No sample results were qualified due to blank contamination.

Interference Check Sample (ICSA) Results

Interference Check Samples were prepared and analyzed at the required frequencies. No action was necessary.

Matrix Spike/Matrix Spike Duplicate Results

MS/MSD analyses were performed at the required frequency. All ICP and ICP-MS percent recoveries were within 75-125% limits. No action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. All ICP, and ICP-MS original sample/duplicate sample and MS/MSD differences were less than 20% RPD or less than the RDL for results less than (5)(RDL). No actions were necessary.

Laboratory Control Samples

LCS analyses were performed at the required frequency. The laboratory analyzed laboratory control samples for all metals. All recoveries were within 80-120% limits. No action was necessary.

Serial Dilution Results

All Serial Dilutions %Ds were less than 10% and all acceptance criteria were met. . No action was necessary.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The data are acceptable as reported. Uranium by ICP-MS samples were analyzed at a dilution in order to bring uranium into analytical range.

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the results from the raw data. No action was necessary.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 23, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010198 Radium-226

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting for SDG 1010198 from ALS Laboratory Group (Fort Collins, CO). This report consists of two air filter samples for the Colorado School of Mines/4349-410 project collected on October 08, 2010 and submitted to ALS Laboratory Group on October 13, 2010. The samples were analyzed for Radium-226 by Radon Emanation Counting on November 12, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Terrace	1010198-19	Filter	October 08, 2010
AS Floodplain	1010198-20	Filter	October 08, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. Radium-226 was detected in the Method Blank above the MDC and below the RDL. The sample results were well below the RDL and considered non-detects. The data are not affected and no action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to limited sample volume the laboratory prepared a LCSD in lieu of a client sample Duplicate. All isotopic activities for Radium-226 LCS Duplicate and LCS original analysis were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

Overall, the data are of good quality and are usable as reported by the laboratory without qualification.

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation. Several samples showed barium concentrations less than zero. The laboratory manually adjusted the values to 0.0 in order to avoid a low bias. All QC criteria were within control limits and no action was necessary. The data are not affected.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalysis.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 23, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010198 Radium-228

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Radium-228 by gas proportional counting for SDG 1010198 from ALS Laboratory Group (Fort Collins, CO). This report consists of two air filter samples for the Colorado School of Mines/4349-410 project collected on October 08, 2010 and submitted to ALS Laboratory Group on October 13, 2010. The samples were analyzed for Radium-228 by Radon Gas Proportional Counting on November 15, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Terrace	1010198-19	Filter	October 08, 2010
AS Floodplain	1010198-20	Filter	October 08, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 724R11 for Radium-228 by Gas Flow Proportional Counting for SDG 1010198.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC’s in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Radium-228 LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation had a concentration of less than the concentration added. The laboratory manually adjusted the values to the known concentration to calculate the chemical yield in order to avoid a low bias in all samples including the QC. All samples reported barium concentrations less than that known to be added. The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R	-	Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.
J	-	The associated numerical value is an estimated quantity because the Quality Control criteria were not met.
U J	-	The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.
U	-	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
NR	-	Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 23, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010198 Isotopic Thorium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1010198 from ALS Laboratory Group (Fort Collins, CO). This report consists of two air filter samples for the Colorado School of Mines/4349-410 project collected on October 08, 2010 and submitted to ALS Laboratory Group on October 13, 2010. The samples were analyzed for Isotopic Thorium by Alpha Spectroscopy on November 05, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Terrace	1010198-19	Filter	October 08, 2010
AS Floodplain	1010198-20	Filter	October 08, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1010198.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Thorium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 23, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010198 Isotopic Uranium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1010198 from ALS Laboratory Group (Fort Collins, CO). This report consists of two air filter samples for the Colorado School of Mines/4349-410 project collected on October 08, 2010 and submitted to ALS Laboratory Group on October 13, 2010. The samples were analyzed for Isotopic Uranium by Alpha Spectroscopy on November 05, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Terrace	1010198-19	Filter	October 08, 2010
AS Floodplain	1010198-20	Filter	October 08, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1010198.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Uranium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 27, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010299

This report presents the inorganic metals data validation for the data obtained for thirteen trace metals and trace Uranium for the CSMRI soil samples collected on October 13, 2010, October 15, 2010, and October 19, 2010 and submitted to ALS Laboratory Group on October 20, 2010 for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the inorganic metals results that were obtained by SW-846, 3rd edition, Method 6010B and ALS Laboratory Group SOP 834R8 for Total metals by Inductively Coupled Plasma (ICP) atomic emission spectrometry analysis, Total Mercury by 812R14 Cold Vapor Atomic Absorption (CVAA), Total Uranium by Method 6020A ALS Laboratory Group Procedure SOP 827R7 by Inductively Coupled Plasma mass spectrometry (ICP-MS) analysis for SDG 1010299 by ALS Laboratory Group (Fort Collins, CO). The Total ICP, ICP-MS and CVAA metals were extracted on October 22, 2010 and analyzed on October 25, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00163-03	1010299-1	Soil	October 13, 2010
00165-03	1010299-2	Soil	October 13, 2010
00185-03	1010299-3	Soil	October 15, 2010
00195-03	1010299-4	Soil	October 15, 2010
00196-03	1010299-5	Soil	October 15, 2010
00200-03	1010299-6	Soil	October 15, 2010
00202-03	1010299-7	Soil	October 15, 2010
00205-03	1010299-8	Soil	October 15, 2010
00214-03	1010299-9	Soil	October 15, 2010
00231-03	1010299-10	Soil	October 19, 2010
00232-03	1010299-11	Soil	October 19, 2010
00236-03	1010299-12	Soil	October 19, 2010
00237-03	1010299-13	Soil	October 19, 2010

Data validation was conducted in accordance with the USEPA Contract Laboratory

Program National Functional Guidelines for Inorganic Data Review.

The metals data were evaluated based on the following parameters:

- ∗ Data Completeness
- ∗ Holding Times and Preservation
- ∗ Initial and Continuing Calibration Verification
- ∗ Contract Required Detection Limit (CRDL)
- Preparation/ Initial (ICB)/ and Continuing (CCB) Calibration Blanks
- ∗ Interference Check Sample (ICSA) Results
- ∗ Matrix Spike Results
- ∗ Duplicate Sample Results
- ∗ Laboratory Control Samples (LCS) Results
- Serial Dilution Sample Results
- ∗ Compound Quantitation and Reporting Limits (full validation only)

∗ All criteria were met for this parameter

Data Completeness

The data package was complete except for the missing CRDL (2B) and IDL (10) QC Summary Forms. No results were qualified as a result of the missing data.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met.

The samples were received at a temperature of 2.4 ºC.

Initial and Continuing Calibration Verification

Initial and Continuing Calibration Verification standards were analyzed at the required frequency and all were within the required 90-110% limits for ICP. No action was necessary.

Contract Required Detection Limit (CRDL)

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the %Rs from the instrument raw data. All CRDL %Rs for ICP were within 80-120% limits. No action was necessary.

Preparation and Initial/ Continuing Calibration Blanks

Preparation and Initial/Continuing Calibration Blank analyses were performed at the required frequency. Preparation and Initial/ Continuing Calibration Blanks are evaluated to assess the level of contamination in the preparation and analytical processes.

Preparation and Initial/ Continuing Calibration Blanks were prepared and analyzed at the required frequencies.

All of the blanks that were analyzed had concentrations that were below their respective Reporting Limits (RLs).

However, if blank results were above the Instrument Detection Limits (IDLs) and below the RLs, it caused the associated sample results to be qualified for contamination as estimated and non-detected **[UJ 107]**. If blank results were below the negative IDL and above the negative RL, it caused the associated sample results to be qualified for negative contamination as estimated **[J 107]**. No sample results were qualified due to blank contamination.

Interference Check Sample (ICSA) Results

Interference Check Samples were prepared and analyzed at the required frequencies. No action was necessary.

Matrix Spike/Matrix Spike Duplicate Results

MS/MSD analyses were performed at the required frequency. All ICP and ICP-MS percent recoveries were within 75-125% limits with the following exception:

Lead in sample 00163-03 is qualified as Estimated due to MS failure.

MS/MSD recoveries could not be evaluated for Total Uranium by ICP-MS and Mercury by CVAA due to the concentrations of the analytes were greater than four times the MS concentration. No action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. All ICP, and ICP-MS original sample/duplicate sample and MS/MSD differences were less than 20% RPD or less than the RDL for results less than (5)(RDL) with the following exceptions:

- Arsenic, Lead, and Molybdenum in sample 00163-03, Uranium in sample 00163-

03 for MSD and Duplicate, Mercury in sample 00196-003 are qualified as Estimated (J) for duplicate failure.

Laboratory Control Samples

LCS analyses were performed at the required frequency. The laboratory analyzed laboratory control samples for all metals. All recoveries were within 80-120% limits. No action was necessary.

Serial Dilution Results

All Serial Dilutions %Ds were less than 10% and all acceptance criteria were met with the following exception:

Uranium in sample 00163-03 is qualified Rejected (R) %D 55.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. The laboratory reports that the Line Calibration report that is included in the data package is incorrect. The reported “Y” was not used for calculations but the correct “Paragon” was. The correct file was inadvertently deleted by the analyst and could not be reported. The ICP-AES Method 6010B data are qualified as Estimated (J) in all samples.

Overall Comments

The data are acceptable as reported. Uranium by ICP-MS samples were analyzed at a dilution in order to bring uranium into analytical range.

Uranium in sample 00163-03 is qualified Rejected (R) for Serial Dilution failure %D of 55.

Lead in sample 00163-03 is qualified as Estimated (J) due to MS failure.

Arsenic, Lead, and Molybdenum, and Uranium in sample 00163-03, and Mercury in sample 00196-003 are qualified as Estimated (J) for duplicate failure

Analyte Quantitation was evaluated for all samples. The laboratory reports that the Line Calibration report that is included in the data package is incorrect. The reported “Y” was not used for calculations but the correct “Paragon” was. The correct file was inadvertently deleted by the analyst and could not be reported. The ICP-AES Method

6010B data are qualified as Estimated (J) in all samples for Arsenic, Lead, Vanadium, and Molybdenum.

MS/MSD recoveries could not be evaluated for Total Uranium by ICP-MS and Mercury by CVAA due to the concentrations of the analytes were greater than four times the MS concentration. No action was necessary.

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the results from the raw data. No action was necessary.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 25, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010299 Radium-226

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting for SDG 1010299 from ALS Laboratory Group (Fort Collins, CO). This report consists of one air filter sample for the Colorado School of Mines/4349-410 project collected on October 15, 2010and submitted to ALS Laboratory Group on October 20, 2010. The sample was analyzed for Radium-226 by Radon Emanation Counting on November 12, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1010299-14	Filter	October 15, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The holding times for Radium-226 were met. No action was necessary.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. Radium-226 was detected in the Method Blank above the MDC and below the RDL. The sample result was well below the RDL and considered non-detected. The data are not affected and no action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to limited sample volume the laboratory prepared a LCSD in lieu of a client sample Duplicate. All isotopic activities for Radium-226 LCS and LCSD analysis were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

Overall, the data are of good quality and are usable as reported by the laboratory without qualification.

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation. Several samples showed barium concentrations less than zero. The laboratory manually adjusted the values to 0.0 in order to avoid a low bias. All QC criteria were within control limits and no action was necessary. The data are not affected.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R	-	Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.
J	-	The associated numerical value is an estimated quantity because the Quality Control criteria were not met.
U J	-	The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.
U	-	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
NR	-	Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalysis.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 27, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010299 Radium-228

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Radium-228 by gas proportional counting for SDG 1010299 from ALS Laboratory Group (Fort Collins, CO). This report consists of one air filter sample for the Colorado School of Mines/4349-410 project collected on October 15, 2010 and submitted to ALS Laboratory Group on October 20, 2010. The sample was analyzed for Radium-228 by Radon Gas Proportional Counting on December 17, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1010299-14	Filter	October 15, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 724R11 for Radium-228 by Gas Flow Proportional Counting for SDG 1010299.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The holding times for Radium-228 were met. No action was necessary.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Radium-228 LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation had a concentration of less than the concentration added. The laboratory manually adjusted the values to the known concentration to calculate the chemical yield in order to avoid a low bias in all samples including the QC. All samples reported barium concentrations less than that known to be added. The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 26, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010299 Isotopic Thorium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1010299 from ALS Laboratory Group (Fort Collins, CO). This report consists of one air filter sample for the Colorado School of Mines/4349-410 project collected on October 15, 2010 and submitted to ALS Laboratory Group on October 20, 2010. The air filter sample was analyzed on November 05, 2010 for Isotopic Thorium by Alpha Spectroscopy. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1010299-14	Filter	October 15, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1010299.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Thorium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 26, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1010299 Isotopic Uranium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1010299 from ALS Laboratory Group (Fort Collins, CO). This report consists of one air filter sample for the Colorado School of Mines/4349-410 project collected on October 15, 2010 and submitted to ALS Laboratory Group on October 20, 2010. The air filter sample was analyzed on November 05, 2010 for Isotopic Uranium by Alpha Spectroscopy. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1010299-14	Filter	October 15, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

<u>Data Completeness</u>

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1010299.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Uranium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 26, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011055

This report presents the inorganic metals data validation for the data obtained for twenty trace metals and trace Uranium for the CSMRI soil samples collected on October 21, 2010, October 25, 2010, October 26, 2010, October 28, 2010, November 01, and November 02, 2010 and submitted to ALS Laboratory Group on November 13, 2010 for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the inorganic metals results that were obtained by SW-846, 3rd edition, Method 6010B and ALS Laboratory Group SOP 834R8 for Total metals by Inductively Coupled Plasma (ICP) atomic emission spectrometry analysis, Total Mercury by 812R14 Cold Vapor Atomic Absorption (CVAA), Total Uranium by Method 6020A ALS Laboratory Group Procedure SOP 827R7 by Inductively Coupled Plasma mass spectrometry (ICP-MS) analysis for SDG 1011055 by ALS Laboratory Group (Fort Collins, CO). The Total ICP metals samples were extracted on November 08, 2010 and analyzed on November 08, 2010, Total Uranium by ICP-MS were extracted and analyzed on November 08, 2010 and the Total Mercury were extracted on November 05, 2010 and analyzed on November 08, 2010 by CVAA. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00257-03	1011055-1	Soil	October 21, 2010
00259-03	1011055-2	Soil	October 21, 2010
00267-03	1011055-3	Soil	October 21, 2010
00268-03	1011055-4	Soil	October 21, 2010
00279-03	1011055-5	Soil	October 25, 2010
00286-03	1011055-6	Soil	October 26, 2010
00288-03	1011055-7	Soil	October 26, 2010
00305-03	1011055-8	Soil	October 26, 2010
00321-03	1011055-9	Soil	November 01, 2010
00325-03	1011055-10	Soil	November 01, 2010
00336-03	1011055-11	Soil	November 01, 2010
00352-03	1011055-12	Soil	November 01, 2010
00353-03	1011055-13	Soil	November 01, 2010
00354-03	1011055-14	Soil	November 01, 2010

00355-03	1011055-15	Soil	November 01, 2010
00357-03	1011055-16	Soil	November 01, 2010
00374-03	1011055-17	Soil	November 02, 2010
00375-03	1011055-18	Soil	November 02, 2010
00386-03	1011055-19	Soil	October 25, 2010
00387-03	1011055-20	Soil	October 28, 2010

Data validation was conducted in accordance with the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.

The metals data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Initial and Continuing Calibration Verification
* Contract Required Detection Limit (CRDL)
  Preparation/ Initial (ICB)/ and Continuing (CCB) Calibration Blanks
* Interference Check Sample (ICSA) Results
* Matrix Spike Results
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
  Serial Dilution Sample Results
* Compound Quantitation and Reporting Limits (full validation only)

* **All criteria were met for this parameter**

Data Completeness

The data package was complete except for the missing CRDL (2B) and IDL (10) QC Summary Forms. No results were qualified as a result of the missing data.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met.

The samples were received at a temperature of 0.6 ºC.

Initial and Continuing Calibration Verification

Initial and Continuing Calibration Verification standards were analyzed at the required frequency and all were within the required 90-110% limits for ICP. No action was necessary.

Contract Required Detection Limit (CRDL)

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the %Rs from the instrument raw data. All CRDL %Rs for ICP were within 80-120% limits. No action was necessary.

Preparation and Initial/ Continuing Calibration Blanks

Preparation and Initial/Continuing Calibration Blank analyses were performed at the required frequency. Preparation and Initial/ Continuing Calibration Blanks are evaluated to assess the level of contamination in the preparation and analytical processes.

Preparation and Initial/Continuing Calibration Blanks were prepared and analyzed at the required frequencies.

All of the blanks that were analyzed had concentrations that were below their respective Reporting Limits (RLs).

However, if blank results were above the Instrument Detection Limits (IDLs) and below the RLs, it caused the associated sample results to be qualified for contamination as estimated and non-detected **[UJ 107]**. If blank results were below the negative IDL and above the negative RL, it caused the associated sample results to be qualified for negative contamination as estimated **[J 107]**. No sample results were qualified due to blank contamination.

Interference Check Sample (ICSA) Results

Interference Check Samples were prepared and analyzed at the required frequencies. No action was necessary.

Matrix Spike/Matrix Spike Duplicate Results

MS/MSD analyses were performed at the required frequency. All ICP and ICP-MS percent recoveries were within 75-125% limits with the following exceptions:

MS/MSD recoveries could not be evaluated for Total Uranium by ICP-MS and Mercury by CVAA due to the concentrations of the analytes were greater than four times the MS concentration. No action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. All ICP, and ICP-MS original sample/duplicate sample and MS/MSD differences were less than 20% RPD or less than the RDL for results less than (5)(RDL) with the following exception:

- Mercury in sample 00387-003 is qualified as Estimated (J) for duplicate failure.

Laboratory Control Samples

LCS analyses were performed at the required frequency. The laboratory analyzed laboratory control samples for all metals. All recoveries were within 80-120% limits. No action was necessary.

Serial Dilution Results

All Serial Dilutions %Ds were less than 10% and all acceptance criteria were met. . No action was necessary.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The data are acceptable as reported. Uranium by ICP-MS samples were analyzed at a dilution in order to bring uranium into analytical range.

Mercury in sample 00387-003 is qualified as Estimated (J) for duplicate failure.

MS/MSD recoveries could not be evaluated for Total Uranium by ICP-MS and Mercury by CVAA due to the concentrations of the analytes were greater than four times the MS concentration. No action was necessary.

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the results from the raw data. No action was necessary.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 24, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011055 Gamma Spectroscopy

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 713R11 for Radium-226 and Radium-228 by Gamma Spectroscopy for SDG 1011055 from ALS Laboratory Group (Fort Collins, CO). This report consists of eleven Soil samples for the Colorado School of Mines/4349-410 project collected on October 21, 2010, October 25, 2010, October 26, 2010, November 01, 2010, and November 02, 2010 and submitted to ALS Laboratory Group on November 19, 2010. The samples were analyzed for Radium-226 and Radium-228 by Gamma Spectroscopy on January 04, 2011. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00257-03	1011055-01	Soil	October 21, 2010
00259-03	1011055-02	Soil	October 21, 2010
00267-03	1011055-03	Soil	October 21, 2010
00279-03	1011055-04	Soil	October 25, 2010
00305-03	1011055-05	Soil	October 26, 2010
00353-03	1011055-06	Soil	November 01, 2010
00354-03	1011055-07	Soil	November 01, 2010
00355-03	1011055-08	Soil	November 01, 2010
00357-03	1011055-09	Soil	November 01, 2010
00374-03	1011055-10	Soil	November 02, 2010
00375-03	1011055-11	Soil	November 02, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gamma Spectroscopy Module DA-GAM V1, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 713R11 for Radium-226 and Radium-228 by Gamma Spectroscopy for SDG 1011055.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The hold times were met for Radium-226 and Radium-228 by Gamma Spectroscopy.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Due to insufficient sample volume samples 00257-03 and 00259-03 were analyzed in duplicate for Ra-228 and Ra-226.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Radium-228 in samples 00267-03, 00279-03, 00305-03, and 00354-03 are qualified as Estimated (J) and flagged Tentatively Identified “TI” due to potential peak shift in Quantitation.

Overall Comments

Radium-228 in samples 00267-03, 00279-03, 00305-03, and 00354-03 are qualified as Estimated (J) and flagged Tentatively Identified “TI” due to potential peak shift in quantitation.

The MDC was not met for Radium-228 in samples 00305-03, 00353-03, 00355-03, 00374-03, and 00375-03. The activities were greater than 80% their TPU’s and greater than their associated MDC’s and are considered detected without qualification. The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R	-	Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.
J	-	The associated numerical value is an estimated quantity because the Quality Control criteria were not met.
U J	-	The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.
U	-	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
NR	-	Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 25, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011055 Radium-226

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting for SDG 1011055 from ALS Laboratory Group (Fort Collins, CO). This report consists of three air filter samples for the Colorado School of Mines/4349-410 project collected on October 22, 2010, and October 29, 2010 and submitted to ALS Laboratory Group on November 03, 2010. The samples were analyzed for Radium-226 by Radon Emanation Counting on December 02, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1011055-21	Filter	October 22, 2010
AS Terrace	1011055-22	Filter	October 22, 2010
AS Floodplain	1011055-23	Filter	October 29, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The holding times for Radium-226 were met. No action was necessary.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. Radium-226 was detected in the Method Blank above the MDC and below the RDL. The sample results were well below the RDL and considered non-detects. The data are not affected and no action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to limited sample volume the laboratory prepared a LCSD in lieu of a client sample Duplicate. All isotopic activities for Radium-226 LCS and LCSD analysis were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

Overall, the data are of good quality and are usable as reported by the laboratory without qualification.

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation. Several samples showed barium concentrations less than zero. The laboratory manually adjusted the values to 0.0 in order to avoid a low bias. All QC criteria were within control limits and no action was necessary. The data are not affected.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R	-	Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.
J	-	The associated numerical value is an estimated quantity because the Quality Control criteria were not met.
U J	-	The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.
U	-	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
NR	-	Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalysis.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 26, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011055 Radium-228

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Radium-228 by gas proportional counting for SDG 1011055 from ALS Laboratory Group (Fort Collins, CO). This report consists of three air filter samples for the Colorado School of Mines/4349-410 project collected on October 22, 2010, and October 29, 2010 and submitted to ALS Laboratory Group on November 03, 2010. The samples were analyzed for Radium-228 by Radon Gas Proportional Counting on December 17, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1011055-21	Filter	October 22, 2010
AS Terrace	1011055-22	Filter	October 22, 2010
AS Floodplain	1011055-23	Filter	October 29, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

- Data Completeness
- Holding Times and Preservation
- Instrument Initial Calibrations
- Instrument Performance Checks
- Preparation Blanks
- Duplicate Sample Results
- Laboratory Control Samples (LCS) Results
- Laboratory Control Samples Duplicate (LCSD) Results
- Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 724R11 for Radium-228 by Gas Flow Proportional Counting for SDG 1011055.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The holding times for Radium-228 were met. No action was necessary.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Radium-228 LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The laboratory reports that the samples were originally prepared in batch RA101123-1 on November 23, 2010 and due to analyst error a complete loss of the samples occurred during the preparation process. The samples were re-prepared with the reserved fraction in Batch RA101208-1 on December 06, 2010. The samples were within 180 day holding time. No action was necessary.

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation had a concentration of less than the concentration added. The laboratory manually adjusted the values to the known concentration to calculate the chemical yield in order to avoid a low bias in all samples including the QC. All samples reported barium concentrations less than that known to be added. The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 23, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011055 Isotopic Thorium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1011055 from ALS Laboratory Group (Fort Collins, CO). This report consists of eleven soil and three air filter samples for the Colorado School of Mines/4349-410 project collected on October 21, 2010, October 25, 2010, October 26, 2010, October 22, 2010, October 29, 2010, November 01, 2010, and November 02, 2010 and submitted to ALS Laboratory Group on November 04, 2010. The soil samples were analyzed on December 29, 2010 and the filter samples were analyzed on November 19, 2010 for Isotopic Thorium by Alpha Spectroscopy. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00257-03	1011055-01	Soil	October 21, 2010
00259-03	1011055-02	Soil	October 21, 2010
00267-03	1011055-03	Soil	October 21, 2010
00279-03	1011055-04	Soil	October 25, 2010
00305-03	1011055-05	Soil	October 26, 2010
00353-03	1011055-06	Soil	November 01, 2010
00354-03	1011055-07	Soil	November 01, 2010
00355-03	1011055-08	Soil	November 01, 2010
00357-03	1011055-09	Soil	November 01, 2010
00374-03	1011055-10	Soil	November 02, 2010
00375-03	1011055-11	Soil	November 02, 2010
AS Floodplain	1011055-12	Filter	October 22, 2010
AS Terrace	1011055-13	Filter	October 22, 2010
AS Floodplain	1011055-14	Filter	October 29, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1011055.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Thorium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 23, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011055 Isotopic Uranium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1011055 from ALS Laboratory Group (Fort Collins, CO). This report consists of eleven soil and three air filter samples for the Colorado School of Mines/4349-410 project collected on October 21, 2010, October 25, 2010, October 26, 2010, October 22, 2010, October 29, 2010, November 01, 2010, and November 02, 2010 and submitted to ALS Laboratory Group on November 04, 2010. The soil samples were analyzed on December 21, 2010 and the filter samples were analyzed on November 19, 2010 for Isotopic Uranium by Alpha Spectroscopy. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00257-03	1011055-01	Soil	October 21, 2010
00259-03	1011055-02	Soil	October 21, 2010
00267-03	1011055-03	Soil	October 21, 2010
00279-03	1011055-04	Soil	October 25, 2010
00305-03	1011055-05	Soil	October 26, 2010
00353-03	1011055-06	Soil	November 01, 2010
00354-03	1011055-07	Soil	November 01, 2010
00355-03	1011055-08	Soil	November 01, 2010
00357-03	1011055-09	Soil	November 01, 2010
00374-03	1011055-10	Soil	November 02, 2010
00375-03	1011055-11	Soil	November 02, 2010
AS Floodplain	1011055-12	Filter	October 22, 2010
AS Terrace	1011055-13	Filter	October 22, 2010
AS Floodplain	1011055-14	Filter	October 29, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

- Data Completeness
- Holding Times and Preservation
- Instrument Initial Calibrations
- Instrument Performance Checks
- Preparation Blanks
- Duplicate Sample Results
- Laboratory Control Samples (LCS) Results
- Laboratory Control Samples Duplicate (LCSD) Results
- Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1011055.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Uranium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R	-	Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.
J	-	The associated numerical value is an estimated quantity because the Quality Control criteria were not met.
U J	-	The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.
U	-	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
NR	-	Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: March 3, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011264

This report presents the inorganic metals data validation for the data obtained for fifteen soil samples and eleven leachate samples analyzed for trace metals and trace Uranium for the CSMRI Project. The samples were collected on November 03, 2010 and November 17, and submitted to ALS Laboratory Group on November 13, 2010 for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the inorganic metals results that were obtained by SW-846, 3rd edition, Method 6010B and ALS Laboratory Group SOP 834R8 for Total metals by Inductively Coupled Plasma (ICP) atomic emission spectrometry analysis, Total Mercury by 812R14 Cold Vapor Atomic Absorption (CVAA), Total Uranium by Method 6020A ALS Laboratory Group Procedure SOP 827R7 by Inductively Coupled Plasma mass spectrometry (ICP-MS) analysis for SDG 1011264 by ALS Laboratory Group (Fort Collins, CO). The Total ICP metals soil samples were extracted on December 03, 2010 and analyzed on December 13, 2010 and the leachate samples were extracted and analyzed on November 30, 2010. The Total Uranium by ICP-MS were extracted on December 03, 2010 and analyzed on December 06, 2010. The Total Mercury soils samples were extracted and analyzed on November 29, 2010 and the leachate samples were extracted on November 30, 2010 and analyzed on December 01, 2010 by CVAA. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00381-03	1011264-01	Soil	November 03, 2010
00384-03	1011264-02	Soil	November 03, 2010
00388-03	1011264-03	Soil	November 03, 2010
00422-03	1011264-04	Soil	November 03, 2010
00430-03	1011264-05	Soil	November 17, 2010
00431-03	1011264-06	Soil	November 17, 2010
00432-03	1011264-07	Soil	November 17, 2010
00433-03	1011264-08	Soil	November 17, 2010
00434-03	1011264-09	Soil	November 17, 2010
00435-03	1011264-10	Soil	November 17, 2010
00436-03	1011264-11	Soil	November 17, 2010

00437-03	1011264-12	Soil	November 17, 2010
00438-03	1011264-13	Soil	November 17, 2010
00439-03	1011264-14	Soil	November 17, 2010
00431-04	1011264-15	Soil	November 17, 2010
00430-03	1011264-19	Leachat e	November 17, 2010
00431-03	1011264-20	Leachat e	November 17, 2010
00432-03	1011264-21	Leachat e	November 17, 2010
00433-03	1011264-22	Leachat e	November 17, 2010
00434-03	1011264-23	Leachat e	November 17, 2010
00435-03	1011264-24	Leachat e	November 17, 2010
00436-03	1011264-25	Leachat e	November 17, 2010
00437-03	1011264-26	Leachat e	November 17, 2010
00438-03	1011264-27	Leachat e	November 17, 2010
00439-03	1011264-28	Leachat e	November 17, 2010
00431-04	1011264-29	Leachat e	November 17, 2010

Data validation was conducted in accordance with the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.

The metals data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Initial and Continuing Calibration Verification
* Contract Required Detection Limit (CRDL)
  Preparation/ Initial (ICB)/ and Continuing (CCB) Calibration Blanks
* Interference Check Sample (ICSA) Results
* Matrix Spike Results
* Duplicate Sample Results

* Laboratory Control Samples (LCS) Results
  Serial Dilution Sample Results
* Compound Quantitation and Reporting Limits (full validation only)

* **All criteria were met for this parameter**

Data Completeness

The data package was complete except for the missing CRDL (2B) and IDL (10) QC Summary Forms. No results were qualified as a result of the missing data.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met.

The samples were received at a temperature of 3.0 ºC.

Initial and Continuing Calibration Verification

Initial and Continuing Calibration Verification standards were analyzed at the required frequency and all were within the required 90-110% limits for ICP. No action was necessary.

Contract Required Detection Limit (CRDL)

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the %Rs from the instrument raw data. All CRDL %Rs for ICP were within 80-120% limits. No action was necessary.

Preparation and Initial/ Continuing Calibration Blanks

Preparation and Initial/Continuing Calibration Blank analyses were performed at the required frequency. Preparation and Initial/ Continuing Calibration Blanks are evaluated to assess the level of contamination in the preparation and analytical processes.

Preparation and Initial/ Continuing Calibration Blanks were prepared and analyzed at the required frequencies.

All of the blanks that were analyzed had concentrations that were below their respective Reporting Limits (RLs).

However, if blank results were above the Instrument Detection Limits (IDLs) and below the RLs, it caused the associated sample results to be qualified for contamination as estimated and non-detected **[UJ 107]**. If blank results were below the negative IDL and above the negative RL, it caused the associated sample results to be qualified for negative contamination as estimated **[J 107]**. No sample results were qualified due to blank contamination.

Interference Check Sample (ICSA) Results

Interference Check Samples were prepared and analyzed at the required frequencies. No action was necessary.

Matrix Spike/Matrix Spike Duplicate Results

MS/MSD analyses were performed at the required frequency. All ICP and ICP-MS percent recoveries were within 75-125% limits with the following exceptions:

MS/MSD recoveries could not be evaluated for Total Uranium by ICP-MS the concentrations of the analytes were greater than four times the MS concentration. No action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. All ICP, and ICP-MS original sample/duplicate sample and MS/MSD differences were less than 20% RPD or less than the RDL for results less than (5)(RDL).

Laboratory Control Samples

LCS analyses were performed at the required frequency. The laboratory analyzed laboratory control samples for all metals. All recoveries were within 80-120% limits. No action was necessary.

Serial Dilution Results

All Serial Dilutions %Ds were less than 10% and all acceptance criteria were met. No action was necessary.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The data are acceptable as reported. Uranium by ICP-MS samples were analyzed at a dilution in order to bring uranium into analytical range.

MS/MSD recoveries could not be evaluated for Total Uranium by ICP-MS due to the concentration of the analytes were greater than four times the MS concentration. No action was necessary.

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the results from the raw data. No action was necessary.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: March 1, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011264 Gamma Spectroscopy

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 713R11 for Radium-226 and Radium-228 by Gamma Spectroscopy for SDG 1011264 from ALS Laboratory Group (Fort Collins, CO). This report consists of 15 Soil samples for the Colorado School of Mines/4349-410 project collected on October 21, 2010, October 25, 2010, October 26, 2010, November 01, 2010, and November 02, 2010 and submitted to ALS Laboratory Group on November 19, 2010. The samples were analyzed for Radium-226 and Radium-228 by Gamma Spectroscopy on January 04, 2011. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00381-03	1011264-01	Soil	November 03, 2010
00384-03	1011264-02	Soil	November 03, 2010
00388-03	1011264-03	Soil	November 03, 2010
00422-03	1011264-04	Soil	November 03, 2010
00430-03	1011264-05	Soil	November 17, 2010
00431-03	1011264-06	Soil	November 17, 2010
00432-03	1011264-07	Soil	November 17, 2010
00433-03	1011264-08	Soil	November 17, 2010
00434-03	1011264-09	Soil	November 17, 2010
00435-03	1011264-10	Soil	November 17, 2010
00436-03	1011264-11	Soil	November 17, 2010
00437-03	1011264-12	Soil	November 17, 2010
00438-03	1011264-13	Soil	November 17, 2010
00439-03	1011264-14	Soil	November 17, 2010
00431-04	1011264-15	Soil	November 17, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gamma Spectroscopy Module DA-GAM V1, October 1, 2002 and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 713R11 for Radium-226 and Radium-228 by Gamma Spectroscopy for SDG 1011264.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The hold times were met for Radium-226 and Radium-228 by Gamma Spectroscopy.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Due to insufficient sample volume samples 00430-03 and 00431-03 were analyzed in duplicate for Ra-228 and Ra-226.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

Radium-228 in samples 00436-03 and 00437-03 are qualified as Estimated (J) and flagged Tentatively Identified "TI" due to potential peak shift in quantitation.

The MDC was not met for Radium-226 and Radium-228 in several samples. The activities were greater than 80% their TPU's and greater than their associated MDC's and are considered detected without qualification. The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 28, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011264 Radium-226

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting for SDG 1011264 from ALS Laboratory Group (Fort Collins, CO). This report consists of three air filter samples for the Colorado School of Mines/4349-410 project collected on November 05, 2010 and November 10, 2010 and submitted to ALS Laboratory Group on November 19, 2010. The samples were analyzed for Radium-226 by Radon Emanation Counting on December 17, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1011264-16	Filter	November 05, 2010
AS Terrace	1011264-17	Filter	November 05, 2010
AS Floodplain	1011264-18	Filter	November 10, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002 and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The holding times for Radium-226 were met. No action was necessary.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. Radium-226 was detected in the Method Blank above the MDC and below the RDL. The sample results were well below the RDL and considered non-detects. The data are not affected and no action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to limited sample volume the laboratory prepared a LCSD in lieu of a client sample Duplicate. All isotopic activities for Radium-226 LCS and LCSD analysis were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

Overall, the data are of good quality and are usable as reported by the laboratory without qualification.

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation. Several samples showed barium concentrations less than zero. The laboratory manually adjusted the values to 0.0 in order to avoid a low bias. All QC criteria were within control limits and no action was necessary. The data are not affected.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalysis.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 26, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011264 Radium-228

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Radium-228 by gas proportional counting for SDG 1011264 from ALS Laboratory Group (Fort Collins, CO). This report consists of three air filter samples for the Colorado School of Mines/4349-410 project collected on November 05, 2010 and November 10, 2010 and submitted to ALS Laboratory Group on November 19, 2010. The samples were analyzed for Radium-228 by Radon Gas Proportional Counting on January 04, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
AS Floodplain	1011264-16	Filter	November 05, 2010
AS Terrace	1011264-17	Filter	November 05, 2010
AS Floodplain	1011264-18	Filter	November 10, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002 and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 724R11 for Radium-228 by Gas Flow Proportional Counting for SDG 1011264.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The holding times for Radium-228 were met. No action was necessary.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Radium-228 LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation had a concentration of less than the concentration added. The laboratory manually adjusted the values to the known concentration to calculate the chemical yield in order to avoid a low bias in all samples including the QC. All samples reported barium concentrations less than that known to be added. The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R	-	Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.
J	-	The associated numerical value is an estimated quantity because the Quality Control criteria were not met.
U J	-	The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.
U	-	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
NR	-	Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To:	Robert Hill
From:	John Garrett
Date:	February 28, 2011
Project/Site:	Colorado School of Mines
Project No.:	4349-410
SDG No.:	1011264 Isotopic Thorium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1011264 from ALS Laboratory Group (Fort Collins, CO). This report consists of fifteen soil and three air filter samples for the Colorado School of Mines/4349-410 project collected on November 03, 2010, November 05, 2010, November 10, 2010, and November 17, 2010 and submitted to ALS Laboratory Group on November 19, 2010. The soil samples were analyzed on December 10, 2010, and January 5, 2011 and the filter samples were analyzed on December 09, 2010 and December 10, 2010 for Isotopic Thorium by Alpha Spectroscopy. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00381-03	1011264-01	Soil	November 03, 2010
00384-03	1011264-02	Soil	November 03, 2010
00388-03	1011264-03	Soil	November 03, 2010
00422-03	1011264-04	Soil	November 03, 2010
00430-03	1011264-05	Soil	November 17, 2010
00431-03	1011264-06	Soil	November 17, 2010
00432-03	1011264-07	Soil	November 17, 2010
00433-03	1011264-08	Soil	November 17, 2010
00434-03	1011264-09	Soil	November 17, 2010
00435-03	1011264-10	Soil	November 17, 2010
00436-03	1011264-11	Soil	November 17, 2010
00437-03	1011264-12	Soil	November 17, 2010
00438-03	1011264-13	Soil	November 17, 2010
00439-03	1011264-14	Soil	November 17, 2010
00431-04	1011264-15	Soil	November 17, 2010
AS Floodplain	1011264-16	Filter	November 05, 2010
AS Terrace	1011264-17	Filter	November 05, 2010
AS Floodplain	1011264-18	Filter	November 10, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002 and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1011264.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Thorium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 27, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1011264 Isotopic Uranium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1011264 from ALS Laboratory Group (Fort Collins, CO). This report consists of fifteen soil and three air filter samples for the Colorado School of Mines/4349-410 project collected on November 03, 2010, November 05, 2010, November 10, 2010, and November 17, 2010 and submitted to ALS Laboratory Group on November 19, 2010. The soil samples were analyzed on December 22, 2010 and January 12, 2011 and the filter samples were analyzed on December 09, 2010 for Isotopic Uranium by Alpha Spectroscopy. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00381-03	1011264-01	Soil	November 03, 2010
00384-03	1011264-02	Soil	November 03, 2010
00388-03	1011264-03	Soil	November 03, 2010
00422-03	1011264-04	Soil	November 03, 2010
00430-03	1011264-05	Soil	November 17, 2010
00431-03	1011264-06	Soil	November 17, 2010
00432-03	1011264-07	Soil	November 17, 2010
00433-03	1011264-08	Soil	November 17, 2010
00434-03	1011264-09	Soil	November 17, 2010
00435-03	1011264-10	Soil	November 17, 2010
00436-03	1011264-11	Soil	November 17, 2010
00437-03	1011264-12	Soil	November 17, 2010
00438-03	1011264-13	Soil	November 17, 2010
00439-03	1011264-14	Soil	November 17, 2010
00431-04	1011264-15	Soil	November 17, 2010
AS Floodplain	1011264-16	Filter	November 05, 2010
AS Terrace	1011264-17	Filter	November 05, 2010
AS Floodplain	1011264-18	Filter	November 10, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002 and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

- Data Completeness
- Holding Times and Preservation
- Instrument Initial Calibrations
- Instrument Performance Checks
- Preparation Blanks
- Duplicate Sample Results
- Laboratory Control Samples (LCS) Results
- Laboratory Control Samples Duplicate (LCSD) Results
- Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1011264.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Uranium LCS and LCSD analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R	-	Reported value is “rejected.” Resampling or reanalysis may be necessary to verify the presence or absence of the compound.
J	-	The associated numerical value is an estimated quantity because the Quality Control criteria were not met.
U J	-	The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.
U	-	The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
NR	-	Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 24, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1012070 Gamma Spectroscopy

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 713R11 for Radium-226 and Radium-228 by Gamma Spectroscopy for SDG 1012070 from ALS Laboratory Group (Fort Collins, CO). This report consists of three Soil samples for the Colorado School of Mines/4349-410 project collected on October 08, 2010 and submitted to ALS Laboratory Group on October 13, 2010. The samples were analyzed for Radium-226 and Radium-228 by Gamma Spectroscopy on November 05, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00163-03	1012070-01	Soil	October 13, 2010
00236-03	1012070-02	Soil	October 19, 2010
00237-03	1012070-03	Soil	October 19, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gamma Spectroscopy Module DA-GAM V1, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

- Data Completeness
- Holding Times and Preservation
- Instrument Initial Calibrations
- Instrument Performance Checks
- Preparation Blanks
- Duplicate Sample Results
- Laboratory Control Samples (LCS) Results
- Laboratory Control Samples Duplicate (LCSD) Results
- Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 713R11 for Radium-226 and Radium-228 by Gamma Spectroscopy for SDG 1012070.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The hold times were met for Radium-226 and Radium-228 by Gamma Spectroscopy.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

No Duplicate analysis were performed. The Data are not qualified.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The MDC was not met for Radium-228 in samples 00163-03 and 00263-03. The activities were greater than 80% their TPU's and greater than their associated MDC's and are considered detected without qualification. The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 24, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1012070 Isotopic Thorium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1012070 from ALS Laboratory Group (Fort Collins, CO). This report consists of three Soil samples for the Colorado School of Mines/4349-410 project collected on October 13, 2010, and October 19, 2010 and submitted to ALS Laboratory Group on October 20, 2010. The samples were analyzed for Isotopic Thorium by Alpha Spectroscopy on January 05, 2011. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00163-03	1012070-01	Soil	October 13, 2010
00236-03	1012070-02	Soil	October 19, 2010
00237-03	1012070-03	Soil	October 19, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Thorium by Alpha Spectroscopy for SDG 1012070.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Thorium (LCS) and (LCSD) analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: February 24, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1012070 Isotopic Uranium

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group PA SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1012070 from ALS Laboratory Group (Fort Collins, CO). This report consists of three Soil samples for the Colorado School of Mines/4349-410 project collected on October 13, 2010, and October 19, 2010 and submitted to ALS Laboratory Group on October 20, 2010. The samples were analyzed for Isotopic Uranium by Alpha Spectroscopy on December 22, 2010. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
00163-03	1012070-01	Soil	October 13, 2010
00236-03	1012070-02	Soil	October 19, 2010
00237-03	1012070-03	Soil	October 19, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Alpha Spectroscopy Module RC01-v2, October 1, 2002, and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Instrument Initial Calibrations
* Instrument Performance Checks
* Preparation Blanks
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results
* Laboratory Control Samples Duplicate (LCSD) Results
* Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 714R12 for Isotopic Uranium by Alpha Spectroscopy for SDG 1012070.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. All isotopes that were analyzed had activities that were below their respective MDC's in their QC batch preparation blanks.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. Due to insufficient sample volume the laboratory prepared and analyzed a Laboratory Control Sample Duplicate (LCSD) in lieu of a client sample duplicate.

All isotopic activities for Uranium (LCS) and (LCSD) analyses were within the limits of the statistical test for equivalency. No action was required.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were not performed for the samples in this SDG, nor were any required.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The results as reported are accepted without qualification.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: March 7, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1102092

This report presents the inorganic metals data validation for the data obtained for one soil sample collected on November 05, 2010 and submitted to ALS Laboratory Group on February 09, 2011 for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the inorganic metals results that were obtained by SW-846, 3rd edition, Method 6010B and ALS Laboratory Group SOP 834R8 for trace metals by Inductively Coupled Plasma (ICP) atomic emission spectrometry analysis, Total Mercury by 812R15 Cold Vapor Atomic Absorption (CVAA), Total Uranium by Method 6020A ALS Laboratory Group Procedure SOP 827R7 by Inductively Coupled Plasma mass spectrometry (ICP-MS) analysis for SDG 1102092 by ALS Laboratory Group (Fort Collins, CO). The Total ICP metals were extracted on February 10, 2011 and analyzed on February 10, 2011. The ICP-MS metals were extracted and analyzed on February 10, 2011. The CVAA metals were extracted and analyzed on February 14, 2011. All analyses were conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
0404-03	1102092-1	Soil	November 05, 2010

Data validation was conducted in accordance with the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review.

The metals data were evaluated based on the following parameters:

* Data Completeness
* Holding Times and Preservation
* Initial and Continuing Calibration Verification
* Contract Required Detection Limit (CRDL)
  Preparation/ Initial (ICB)/ and Continuing (CCB) Calibration Blanks
* Interference Check Sample (ICSA) Results
* Matrix Spike Results
* Duplicate Sample Results
* Laboratory Control Samples (LCS) Results

Serial Dilution Sample Results
* Compound Quantitation and Reporting Limits (full validation only)

* **All criteria were met for this parameter**

Data Completeness

The data package was complete except for the missing CRDL (2B) and IDL (10) QC Summary Forms. No results were qualified as a result of the missing data.

Holding Times and Preservation

The holding tome criteria were not met for the mercury analysis. The holding time exceeded 2X the 28 day criteria and the sample result is qualified Estimated (J).

The samples were received at a temperature of 4.2 ºC.

Initial and Continuing Calibration Verification

Initial and Continuing Calibration Verification standards were analyzed at the required frequency and all were within the required 90-110% limits for ICP. No action was necessary.

Contract Required Detection Limit (CRDL)

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the %Rs from the instrument raw data. All CRDL %Rs for ICP were within 80-120% limits. No action was necessary.

Preparation and Initial/ Continuing Calibration Blanks

Preparation and Initial/Continuing Calibration Blank analyses were performed at the required frequency. Preparation and Initial/ Continuing Calibration Blanks are evaluated to assess the level of contamination in the preparation and analytical processes.

Preparation and Initial/ Continuing Calibration Blanks were prepared and analyzed at the required frequencies.

All of the blanks that were analyzed had concentrations that were below their respective Reporting Limits (RLs).

However, if blank results were above the Instrument Detection Limits (IDLs) and below the RLs, it caused the associated sample results to be qualified for contamination as estimated and non-detected **[UJ 107]**. If blank results were below the negative IDL and above the negative RL, it caused the associated sample results to be qualified for negative contamination as estimated **[J 107]**. No sample results were qualified due to blank contamination.

Interference Check Sample (ICSA) Results

Interference Check Samples were prepared and analyzed at the required frequencies. No action was necessary.

Matrix Spike/Matrix Spike Duplicate Results

MS/MSD analyses were performed at the required frequency. All ICP and ICP-MS percent recoveries were within 75-125% limits with the following exception:

MS/MSD recoveries could not be evaluated for uranium by ICP-MS and leads by ICP-AES due to the concentrations of the analytes in the sample were greater than four times the spike concentration added. No action was necessary.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. All ICP, and ICP-MS original sample/duplicate sample and MS/MSD differences were less than 20% RPD or less than the RDL for results less than (5)(RDL) with the following exception:

Arsenic in the sample is qualified as Estimated (J) for duplicate failure.

Laboratory Control Samples

LCS analyses were performed at the required frequency. The laboratory analyzed laboratory control samples for all metals. All recoveries were within 80-120% limits. No action was necessary.

Serial Dilution Results

All Serial Dilutions %Ds were less than 10% and all acceptance criteria were met. . No action was necessary.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

The holding tome criteria were not met for the mercury analysis. The holding time exceeded 2X the 28 day criteria and the sample result is qualified Estimated (J).

Arsenic in the sample is qualified as Estimated (J) for duplicate failure.

Uranium by ICP-MS samples were analyzed at a dilution in order to bring uranium into analytical range.

MS/MSD recoveries could not be evaluated for uranium by ICP-MS and leads by ICP-AES due to the concentrations of the analytes in the sample were greater than four times the MS concentration added. No action was necessary.

No CRDL or CRI standard recovery summary forms (EPA Form 2b) were included in the data package. The reviewer obtained the results from the raw data. No action was necessary.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalyses.

DATA VALIDATION REPORT

To: Robert Hill
From: John Garrett
Date: March 8, 2011
Project/Site: Colorado School of Mines
Project No.: 4349-410
SDG No.: 1102092 Radium-226

This report presents the radiological data validation for the data obtained during the field activities for the above referenced work assignment. The purpose of this review is to provide a technical evaluation of the radiological results that were obtained by ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting for SDG 1102092 from ALS Laboratory Group (Fort Collins, CO). This report consists of one soil sample for the Colorado School of Mines/4349-410 project collected on November 05, 2010 and submitted to ALS Laboratory Group on February 09, 2011. The sample was analyzed for Radium-226 by Radon Emanation Counting on February 18, 2011. The analysis was conducted by ALS Laboratory Group. The field sample numbers and corresponding laboratory numbers are presented below:

Client Sample Number	Laboratory Sample Number	Matrix	Collection Date
0404-03	1102092-1	Soil	November 05, 2010

Data validation was conducted in accordance with the Analytical Services Statement of Work for the following modules: Gas Proportional Counting Module RC04-v2, October 1, 2002 and U.S. DOE Quality Systems for Analytical Services Revision 2.6 (QSAS).

The radiological data were evaluated based on the following parameters:

- Data Completeness
- Holding Times and Preservation
- Instrument Initial Calibrations
- Instrument Performance Checks
- Preparation Blanks
- Duplicate Sample Results
- Laboratory Control Samples (LCS) Results
- Laboratory Control Samples Duplicate (LCSD) Results
- Compound Quantitation and Reporting Limits (full validation only)

Data Completeness

The data package was complete as per ALS Laboratory Group Procedure SOP 783R8 for Radium-226 by Radon Emanation Counting.

Holding Times and Preservation

Analytical holding times were evaluated and all criteria were met. However, holding time requirements are not applicable to radiochemistry analyses unless the isotopes of interest have short half-lives. The holding times for Radium-226 were met. No action was necessary.

Calibrations

The instruments were calibrated at the required frequency.

Initial Calibration

All instruments were calibrated properly using NIST traceable SRM.

Instrument Performance Checks

All isotopes were within criteria.

Preparation Blanks

Preparation/Method Blanks were performed at the required frequency. Radium-226 was not detected in the Method Blank above the MDC or the RDL.

Duplicate Sample Analysis

Duplicate analyses were performed at the required frequency. All isotopic activities for Radium-226 original and duplicate analysis were within the limits of the statistical test for equivalency.

Matrix Spike/Matrix Spike Duplicates

Matrix spike/matrix spike duplicates were performed for the samples in this SDG and reporting criteria were met.

Laboratory Control Samples

LCS analyses were performed at the required frequency. All recoveries were within 75-125% limits. No calculation errors or transcription errors were found.

Analyte Quantitation and Reporting Limits

Analyte quantitation was evaluated for all samples. No calculation or transcription errors were found. The results and reporting limits were correctly reported.

Overall Comments

Overall, the data are of good quality and are usable as reported by the laboratory without qualification.

The laboratory reported that the ICP-AES measurement of the added barium carrier prior to chemical separation. Several samples showed barium concentrations less than zero. The laboratory manually adjusted the values to 0.0 in order to avoid a low bias. All QC criteria were within control limits and no action was necessary. The data are not affected.

DATA QUALIFIER DEFINITIONS

For the purpose of Data Validation, the following code letters and associated definitions are provided for use by the data validator to summarize the data quality.

R - Reported value is "rejected." Resampling or reanalysis may be necessary to verify the presence or absence of the compound.

J - The associated numerical value is an estimated quantity because the Quality Control criteria were not met.

U J - The reported quantitation limit is estimated because Quality Control criteria were not met. Element or compound was not detected.

U - The material was analyzed for, but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.

NR - Result was not used from a particular sample analysis. This typically occurs when more than one result for an element is reported due to dilutions and reanalysis.

Stoller

CSMRI - Flood Plain Site Characterization, 2011

VSP Analysis of In-situ Samples/Shots From Lab Results, PPM

Arsenic, As

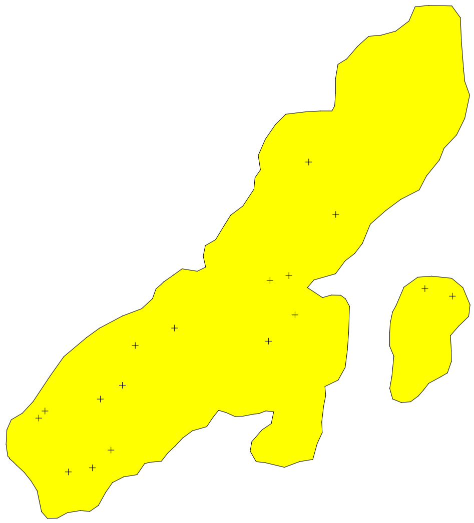
Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Simple random sampling
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	12
Number of samples on map [a]	17
Number of selected sample areas [b]	2
Specified sampling area [c]	13503.31 ft^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.



Area: Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
3075881.4660	1699480.5880	ID_00163	23	Unknown	
3075866.8660	1699435.8530	ID_00237	15	Unknown	
3075874.0050	1699437.7110	ID_00236	14	Unknown	
3075830.8970	1699417.9020	ID_00267	14	Unknown	
3075866.3580	1699412.9270	ID_00257	3.3	Unknown	
3075876.3060	1699422.8600	ID_00259	11	Unknown	
3075816.0780	1699411.2980	ID_00279	17	Unknown	
3075891.6520	1699460.7820	ID_00305	11	Unknown	
3075799.9480	1699365.1180	ID_00387	22	Unknown	
3075802.9320	1699391.0760	ID_00354	10	Unknown	
3075811.2330	1699396.2960	ID_00353	15	Unknown	
3075782.0500	1699386.5720	ID_00375	24	Unknown	
3075779.6920	1699383.9000	ID_00374	4.8	Unknown	
3075790.8730	1699363.5770	ID_00422	8.3	Unknown	
3075806.9380	1699371.8120	ID_00388	6.1	Unknown	

Area: Area 2					
X Coord	Y Coord	Label	Value	Type	Historical
3075935.6440	1699429.9500	ID_00384	9.3	Unknown	
3075925.2910	1699432.7910	ID_00381	5	Unknown	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric random sampling approach was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points randomly provides data that are separated by many distances, whereas systematic samples are all equidistant apart. Therefore, random sampling provides more information about the spatial structure of the potential contamination than systematic sampling does. As with systematic sampling, random sampling also provides information regarding the mean value, but there is the possibility that areas of the site will not be represented with the same frequency as if uniform grid sampling were performed.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$	is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n	is the number of samples,
S_{total}	is the estimated standard deviation of the measured values including analytical error,
Δ	is the width of the gray region,
α	is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β	is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$	is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

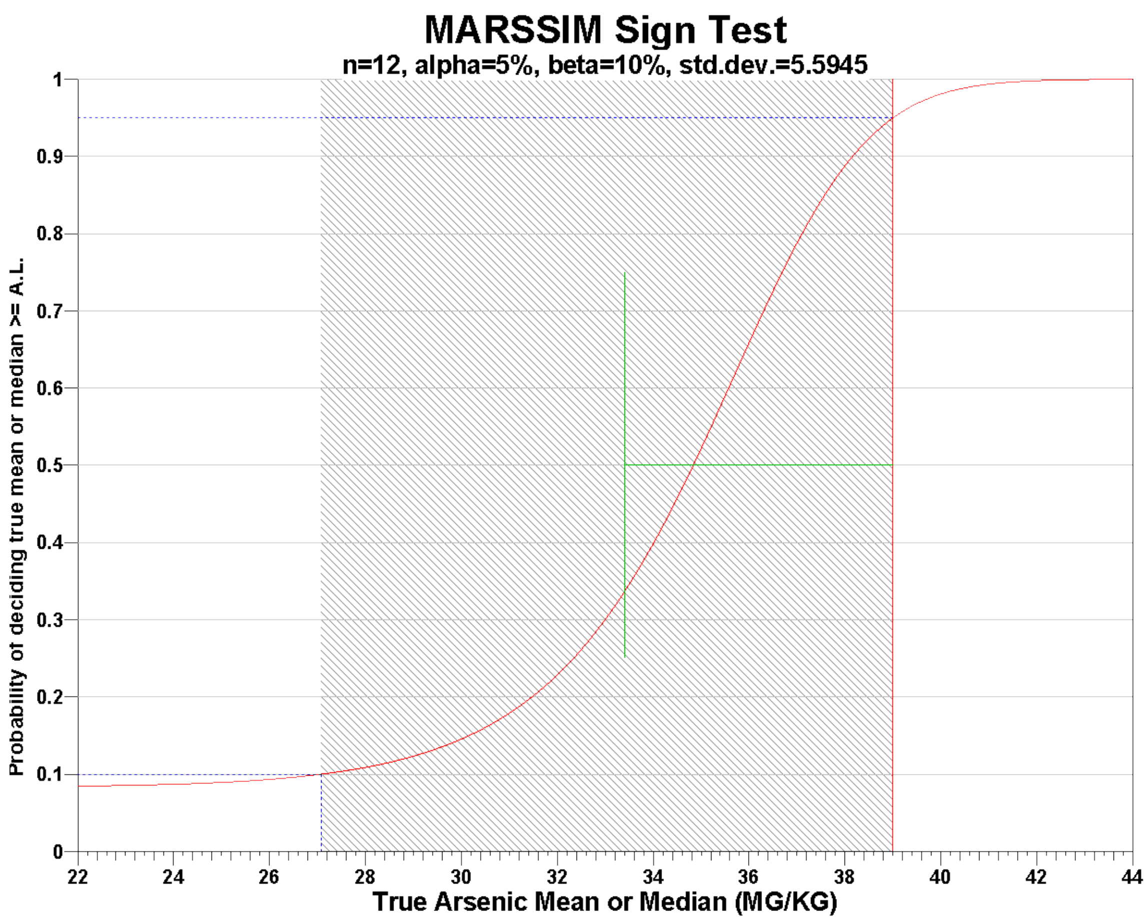
The values of these inputs that result in the calculated number of sampling locations are:

Analyte	n[a]	Parameter					
		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Arsenic	12	5.5945 MG/KG	11.927 MG/KG	0.05	0.1	1.64485	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected randomly.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the sample locations were selected using a random process.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=39		α=5		α=10		α=15	
		s=11.189	s=5.5945	s=11.189	s=5.5945	s=11.189	s=5.5945
LBGR=90	β=5	176	50	140	40	117	34
	β=10	140	40	107	30	88	26
	β=15	117	34	88	26	70	21
LBGR=80	β=5	50	20	40	16	34	14
	β=10	40	16	30	12	26	10
	β=15	34	14	26	10	21	9
LBGR=70	β=5	27	15	22	12	18	10
	β=10	22	12	17	10	14	8
	β=15	18	10	14	8	11	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Data Analysis for Arsenic

The following data points were entered by the user for analysis.

Arsenic (MG/KG)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	3.3	3.3	4.8	5	5	6.1	6.1	8.3	8.3	9.3
10	9.3	10	11	11	11	11	14	14	14	14
20	14	15	15	15	17	17	17	22	23	24

SUMMARY STATISTICS for Arsenic	
n	30
Min	3.3
Max	24
Range	20.7
Mean	11.927
Median	11
Variance	31.298
StdDev	5.5945
Std Error	1.0214
Skewness	0.38298

Interquartile Range				7.25				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
3.3	3.3	4.82	7.75	11	15	21.5	23.45	24

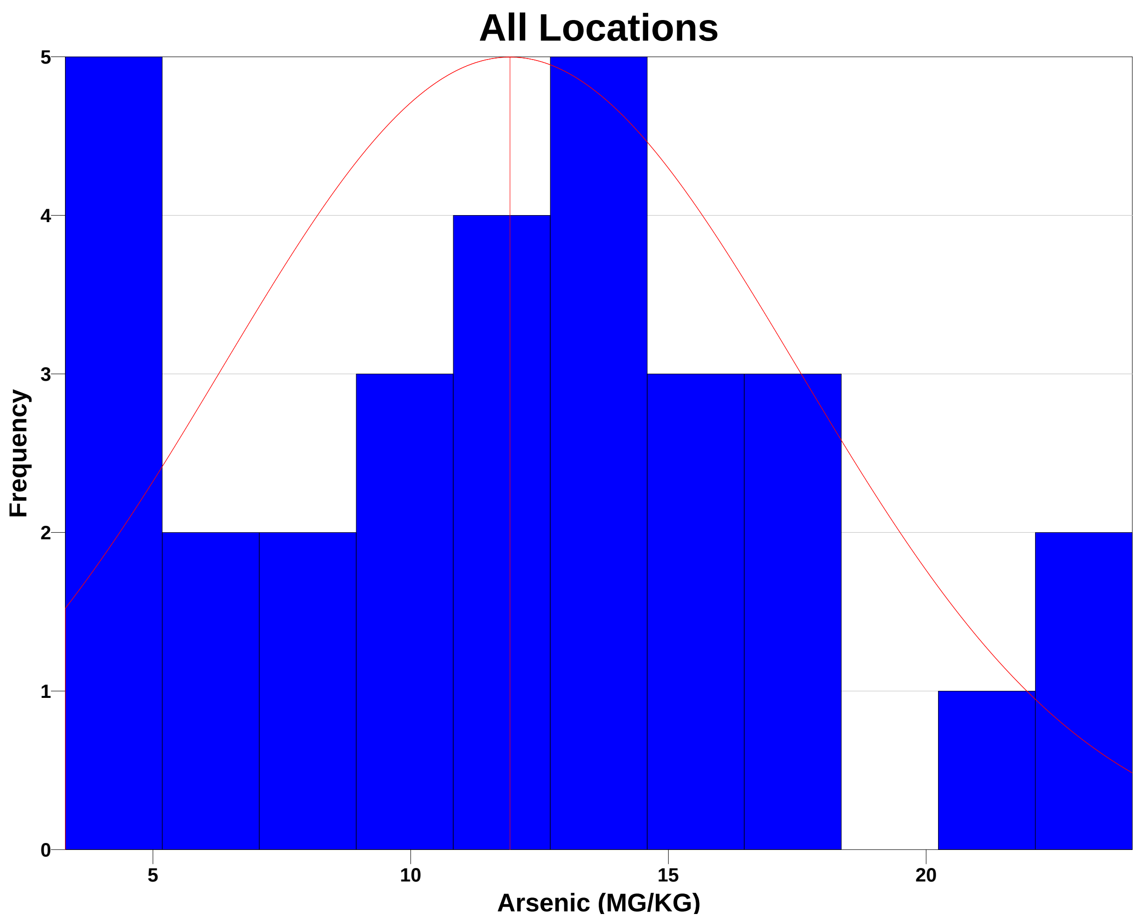
Data Plots

Three graphical displays of the data are shown below: the Histogram, the Box and Whiskers plot, and the Quantile-Quantile (Q-Q) plot.

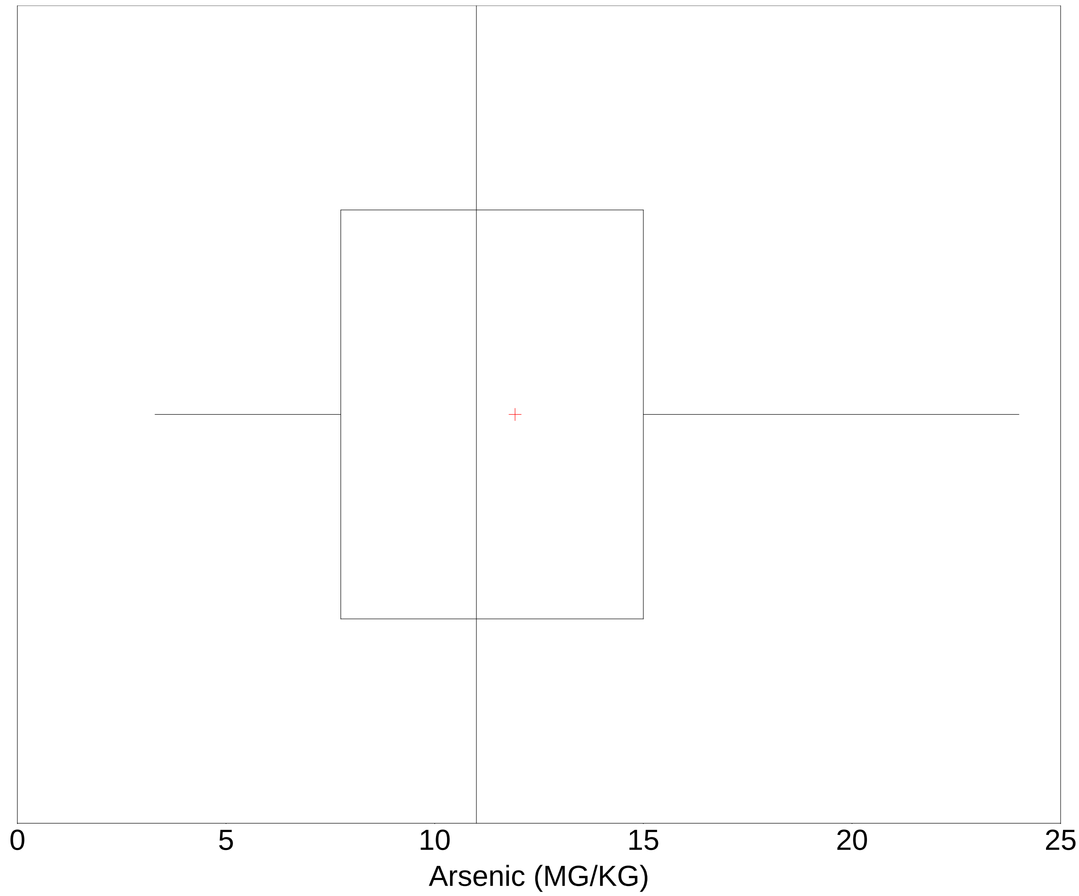
The Histogram is a plot of the fraction of the n observed data that fall within specified data "bins." A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

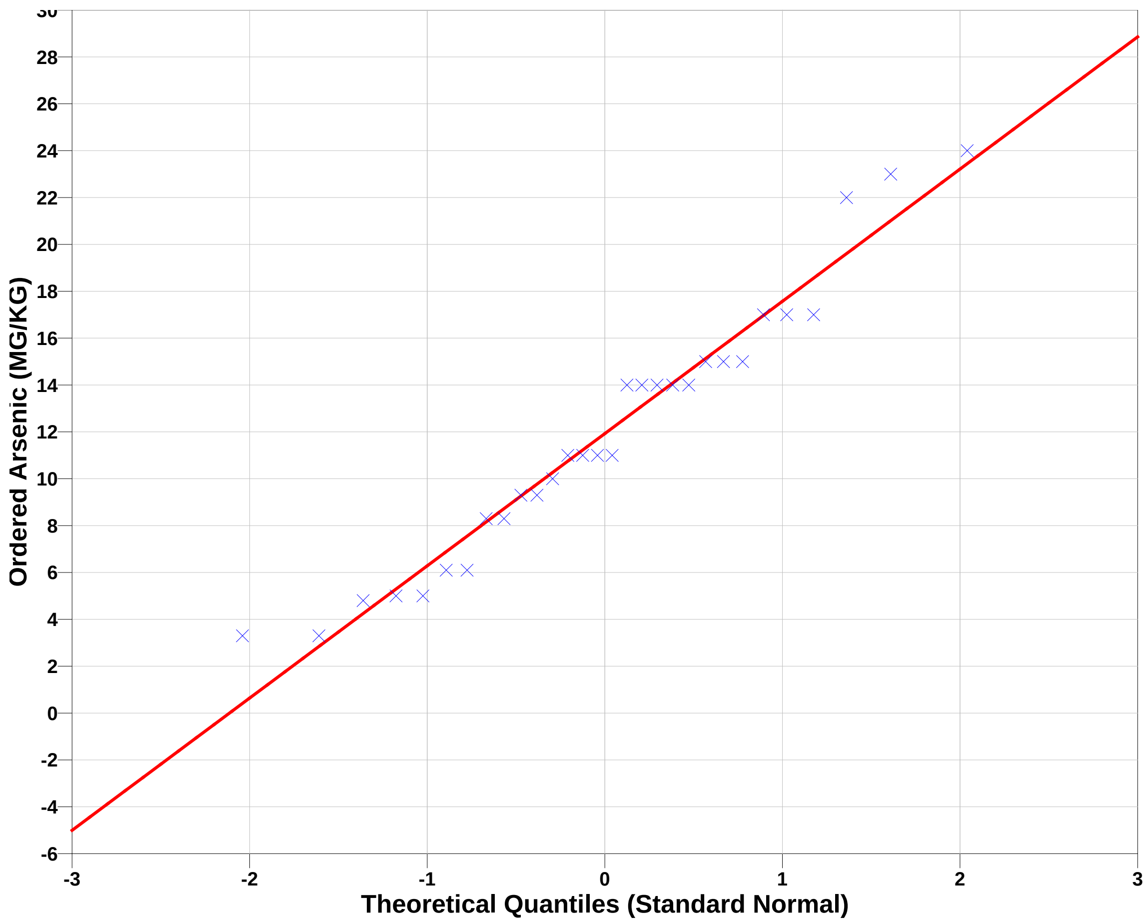
The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25th and 75th percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The pth quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.



All Locations
Frequency
Arsenic (MG/KG)
0
1
2
3
4
5
5
10
15
20


0
5
10
15
20
25
Arsenic (MG/KG)



For more information on these three plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Arsenic

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.9511
Shapiro-Wilk 5% Critical Value	0.927

The calculated SW test statistic exceeds the 5% Shapiro-Wilk critical value, so we cannot reject the hypothesis that the data are normal, or in other words the data appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	13.662
95% Non-Parametric (Chebyshev) UCL	16.379

Because the data appear to be normally distributed according to the goodness-of-fit test performed above, the parametric UCL (13.66) may be a more accurate upper confidence limit on the true mean and may be used as an alternative to the MARSSIM Sign test.

MARSSIM Sign Test

The Sign test was performed in accordance with the guidance given in section 8.3.2 of MARSSIM. Each measurement was subtracted from the action level to obtain n differences $d_i = AL - X_i$. Any differences of zero were discarded from consideration and the sample size was reduced accordingly. The test statistic S+ was calculated by counting the positive differences. S+ was then compared with the critical value k, which was obtained from Table I.3 in Appendix I of MARSSIM.

If $S+ > k$, then the null hypothesis is rejected.

MARSSIM SIGN TEST		
Test Statistic S+	**95% Critical Value**	**Null Hypothesis**
30	19	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, so conclude the site is clean.

Stoller

CSMRI - Flood Plain Site Characterization, 2011

VSP Analysis of In-situ Samples/Shots From Lab Results, PPM

Mercury, Hg

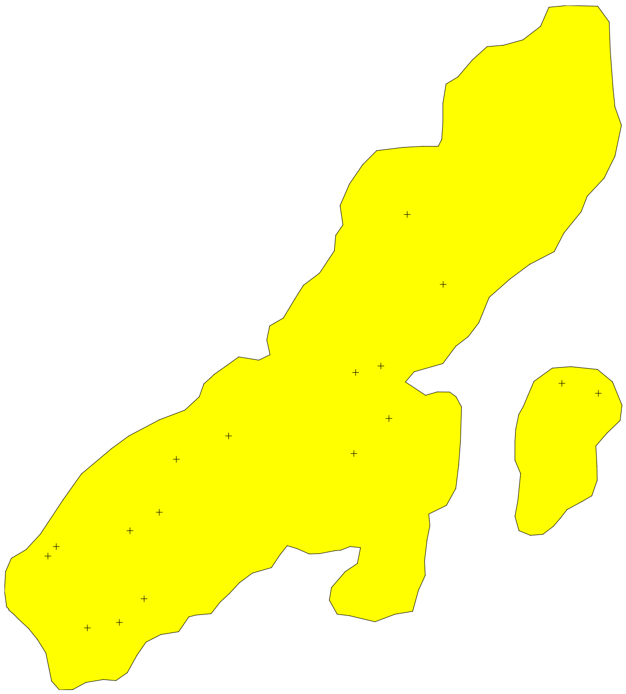
Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	12
Number of samples on map [a]	17
Number of selected sample areas [b]	2
Specified sampling area [c]	13503.31 ft^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.



Area: Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
3075881.4660	1699480.5880	ID_00163	2.7	Unknown	
3075866.8660	1699435.8530	ID_00237	1.2	Unknown	
3075874.0050	1699437.7110	ID_00236	0.84	Unknown	
3075830.8970	1699417.9020	ID_00267	12	Unknown	
3075866.3580	1699412.9270	ID_00257	0.29	Unknown	
3075876.3060	1699422.8600	ID_00259	0.89	Unknown	
3075816.0780	1699411.2980	ID_00279	1.2	Unknown	
3075891.6520	1699460.7820	ID_00305	0.84	Unknown	
3075799.9480	1699365.1180	ID_00387	16	Unknown	
3075802.9320	1699391.0760	ID_00354	0.094	Unknown	
3075811.2330	1699396.2960	ID_00353	0.03	Unknown	
3075782.0500	1699386.5720	ID_00375	14	Unknown	
3075779.6920	1699383.9000	ID_00374	0.44	Unknown	
3075790.8730	1699363.5770	ID_00422	0.48	Unknown	
3075806.9380	1699371.8120	ID_00388	0.35	Unknown	

Area: Area 2					
X Coord	Y Coord	Label	Value	Type	Historical
3075935.6440	1699429.9500	ID_00384	1.2	Unknown	
3075925.2910	1699432.7910	ID_00381	0.26	Unknown	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

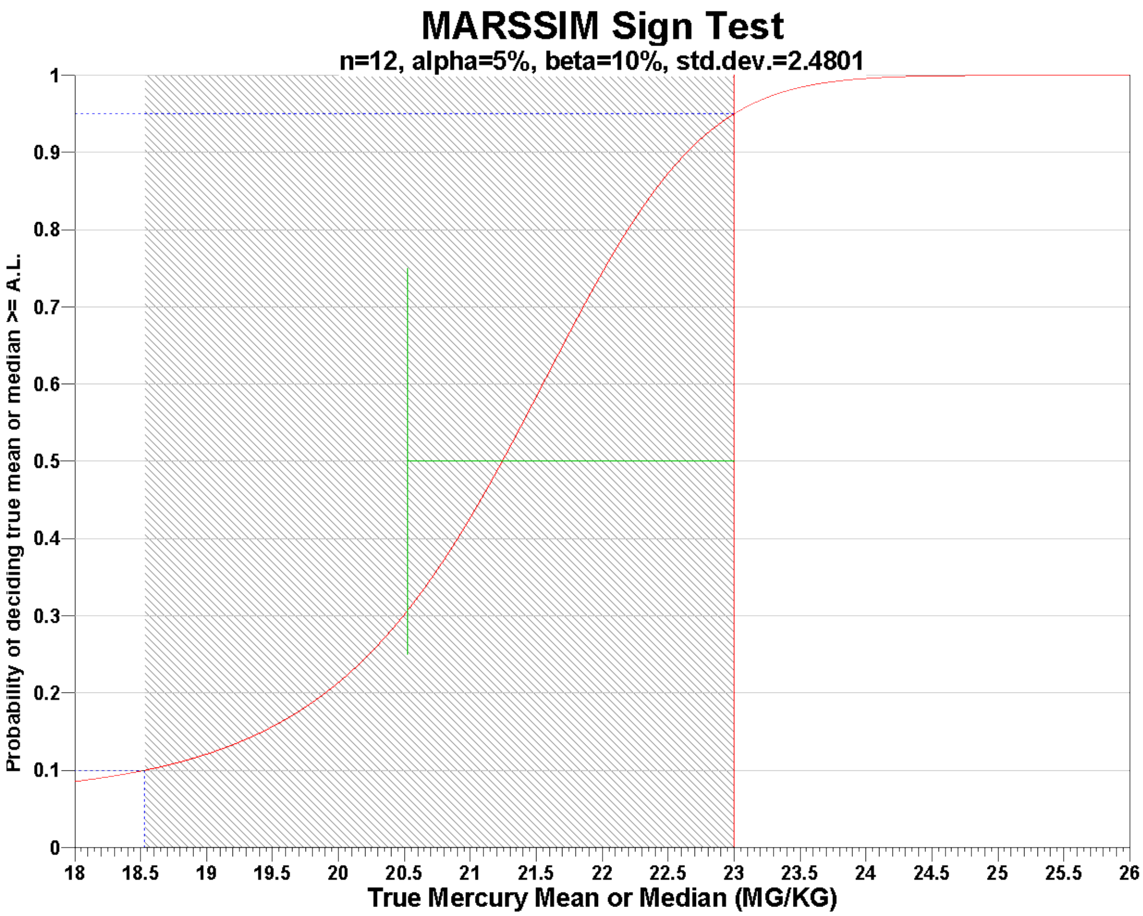
Analyte	n[a]	Parameter

		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Mercury	12	2.4801 MG/KG	4.4689 MG/KG	0.05	0.1	1.64485	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=23		α=5		α=10		α=15	
		s=4.9602	s=2.4801	s=4.9602	s=2.4801	s=4.9602	s=2.4801
LBGR=90	β=5	102	32	82	26	69	22
	β=10	82	26	63	20	52	16
	β=15	69	22	52	16	41	14
LBGR=80	β=5	32	16	26	12	22	11
	β=10	26	12	20	10	16	9
	β=15	22	11	16	9	14	6
LBGR=70	β=5	20	14	16	11	14	10
	β=10	16	11	12	9	10	8
	β=15	14	10	10	8	9	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Data Analysis for Mercury

The following data points were entered by the user for analysis.

Mercury (MG/KG)										
Rank	1	2	3	4	5	6	7	8	9	10
0	0.03	0.094	0.26	0.26	0.29	0.29	0.35	0.35	0.44	0.48
10	0.48	0.84	0.84	0.84	0.84	0.84	0.89	0.89	1.2	1.2
20	1.2	1.2	1.2	1.2	1.2	2.7	12	12	14	16

SUMMARY STATISTICS for Mercury	
n	30
Min	0.03
Max	16
Range	15.97
Mean	2.4801
Median	0.84
Variance	19.971
StdDev	4.4689
Std Error	0.81591
Skewness	2.304

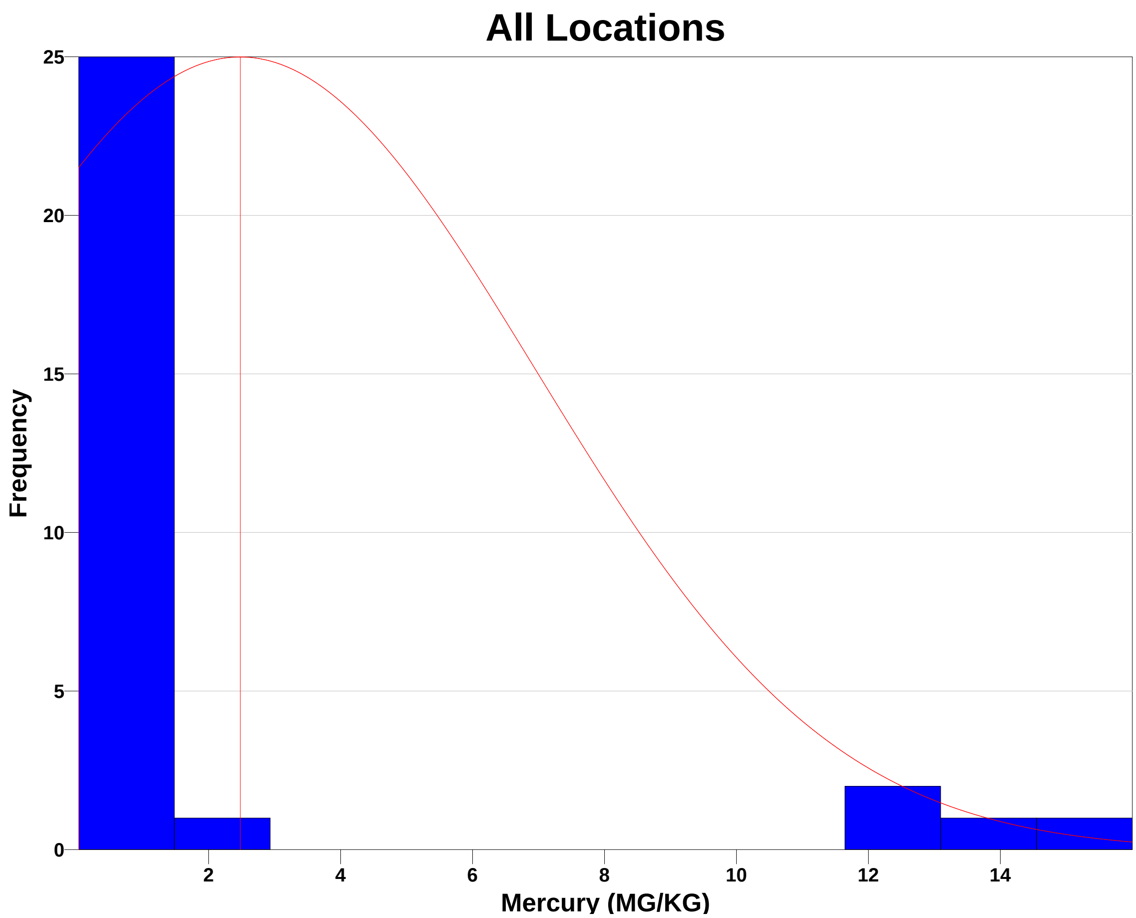
Interquartile Range				0.85				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.03	0.0652	0.26	0.35	0.84	1.2	12	14.9	16

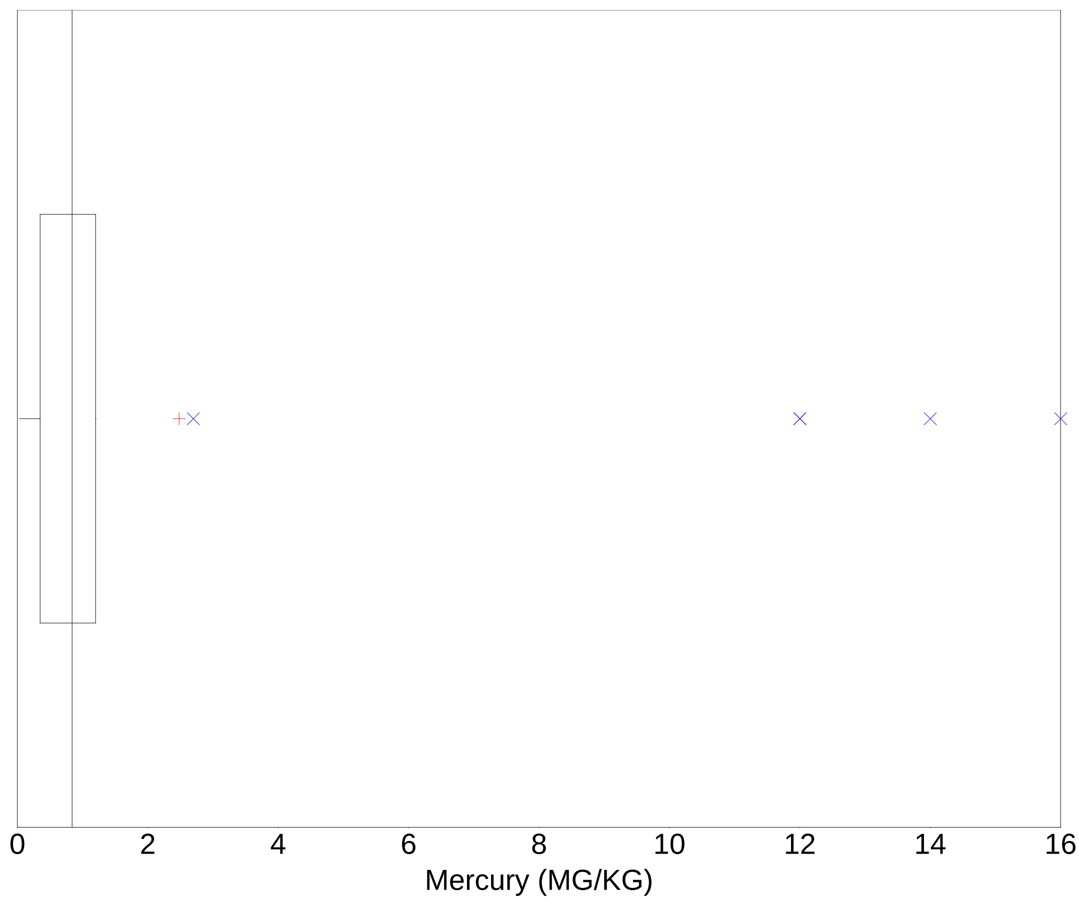
Data Plots
Three graphical displays of the data are shown below: the Histogram, the Box and Whiskers plot, and the Quantile-Quantile (Q-Q) plot.

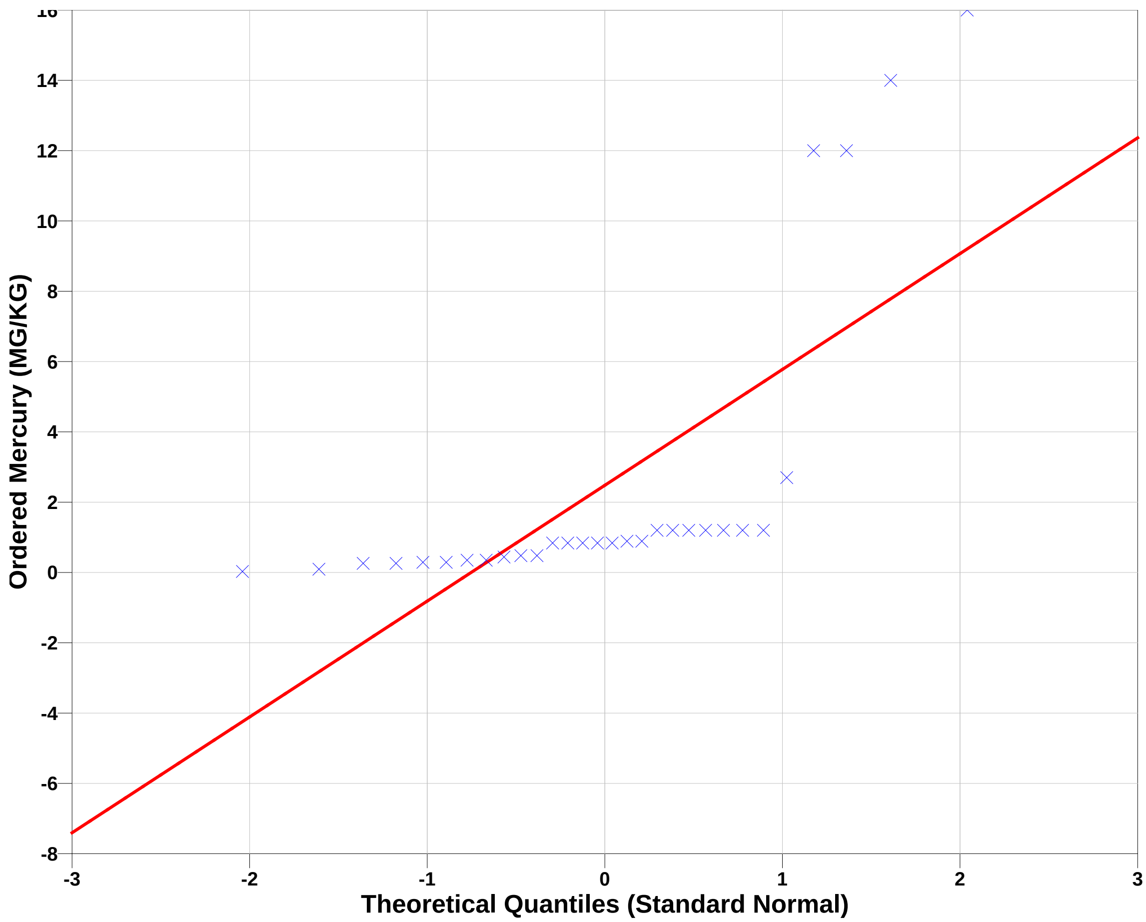
The Histogram is a plot of the fraction of the n observed data that fall within specified data "bins." A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25th and 75th percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The pth quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.


All Locations
Frequency
Mercury (MG/KG)
0
5
10
15
20
25
2
4
6
8
10
12
14


0
2
4
6
8
10
12
14
16
Mercury (MG/KG)



For more information on these three plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Mercury

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.5207
Shapiro-Wilk 5% Critical Value	0.927

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	3.8665
95% Non-Parametric (Chebyshev) UCL	6.0366

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (6.037) may be a more accurate upper confidence limit on the true mean.

MARSSIM Sign Test
The Sign test was performed in accordance with the guidance given in section 8.3.2 of MARSSIM. Each measurement was subtracted from the action level to obtain *n* differences $d_i = AL - X_i$. Any differences of zero were discarded from consideration and the sample size was reduced accordingly. The test statistic S+ was calculated by counting the positive differences. S+ was then compared with the critical value *k*, which was obtained from Table I.3 in Appendix I of MARSSIM.

If $S+ > k$, then the null hypothesis is rejected.

MARSSIM SIGN TEST		
Test Statistic S+	**95% Critical Value**	**Null Hypothesis**
30	19	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, so conclude the site is clean.

This report was automatically produced* by Visual Sample Plan (VSP) software version 6.0.

Software and documentation available at http://vsp.pnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

Stoller

CSMRI - Flood Plain Site Characterization, 2011

VSP Analysis of In-situ Samples/Shots From Lab Results, PPM

Molybdenum, Mo

Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

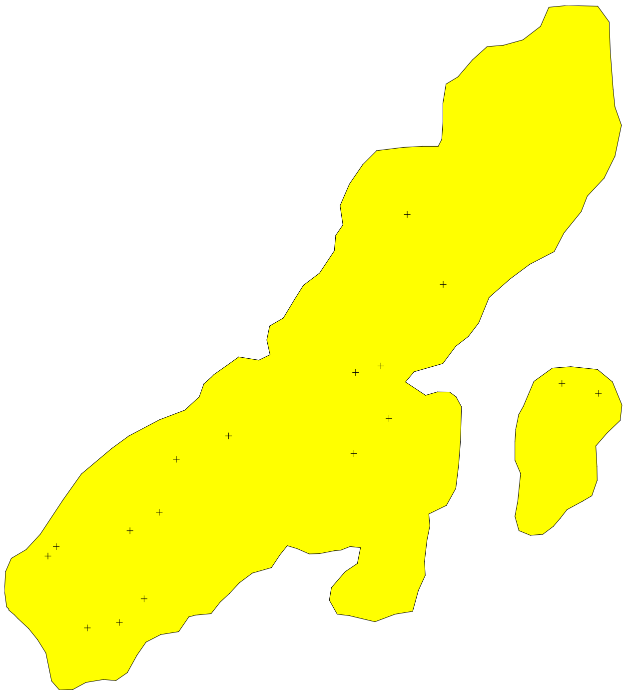
Summary

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	14
Number of samples on map [a]	17
Number of selected sample areas [b]	2
Specified sampling area [c]	13503.31 ft^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.



Area: Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
3075881.4660	1699480.5880	ID_00163	8.2	Unknown	
3075866.8660	1699435.8530	ID_00237	4.2	Unknown	
3075874.0050	1699437.7110	ID_00236	5.3	Unknown	
3075830.8970	1699417.9020	ID_00267	5.2	Unknown	
3075866.3580	1699412.9270	ID_00257	1.2	Unknown	
3075876.3060	1699422.8600	ID_00259	3.2	Unknown	
3075816.0780	1699411.2980	ID_00279	2.2	Unknown	
3075891.6520	1699460.7820	ID_00305	4.1	Unknown	
3075799.9480	1699365.1180	ID_00387	6.5	Unknown	
3075802.9320	1699391.0760	ID_00354	0.53	Unknown	
3075811.2330	1699396.2960	ID_00353	1.6	Unknown	
3075782.0500	1699386.5720	ID_00375	1.7	Unknown	
3075779.6920	1699383.9000	ID_00374	5.1	Unknown	
3075790.8730	1699363.5770	ID_00422	8.4	Unknown	
3075806.9380	1699371.8120	ID_00388	2.6	Unknown	

Area: Area 2					
X Coord	Y Coord	Label	Value	Type	Historical
3075935.6440	1699429.9500	ID_00384	3.8	Unknown	
3075925.2910	1699432.7910	ID_00381	1.8	Unknown	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

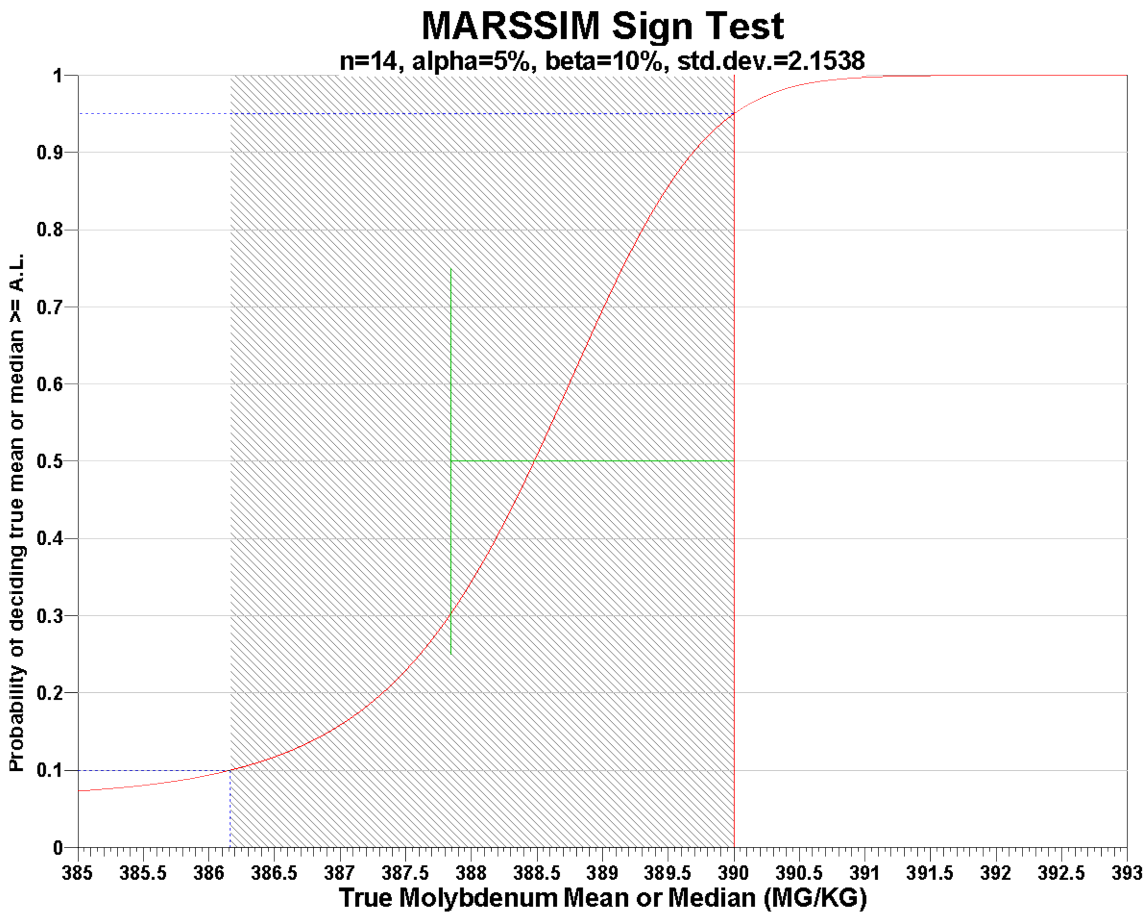
Analyte	n[a]	Parameter

		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Molybdenum	14	2.1538 MG/KG	3.8377 MG/KG	0.05	0.1	1.64485	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=390		α=5		α=10		α=15	
		s=4.3076	s=2.1538	s=4.3076	s=2.1538	s=4.3076	s=2.1538
LBGR=90	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6
LBGR=80	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6
LBGR=70	β=5	14	14	11	11	10	10
	β=10	11	11	9	9	8	8
	β=15	10	10	8	8	6	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Data Analysis for Molybdenum
The following data points were entered by the user for analysis.

Molybdenum (MG/KG)										
Rank	1	2	3	4	5	6	7	8	9	10
0	0.53	1.2	1.2	1.6	1.7	1.8	1.8	2.2	2.2	2.2
10	2.6	2.6	3.2	3.2	3.8	3.8	4.1	4.1	4.2	4.2
20	5.1	5.2	5.2	5.3	5.3	5.3	6.5	8.2	8.4	8.4

SUMMARY STATISTICS for Molybdenum	
n	30
Min	0.53
Max	8.4
Range	7.87
Mean	3.8377
Median	3.8
Variance	4.639
StdDev	2.1538
Std Error	0.39323
Skewness	0.66605

Interquartile Range				3.125				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
0.53	0.8985	1.24	2.1	3.8	5.225	8.03	8.4	8.4

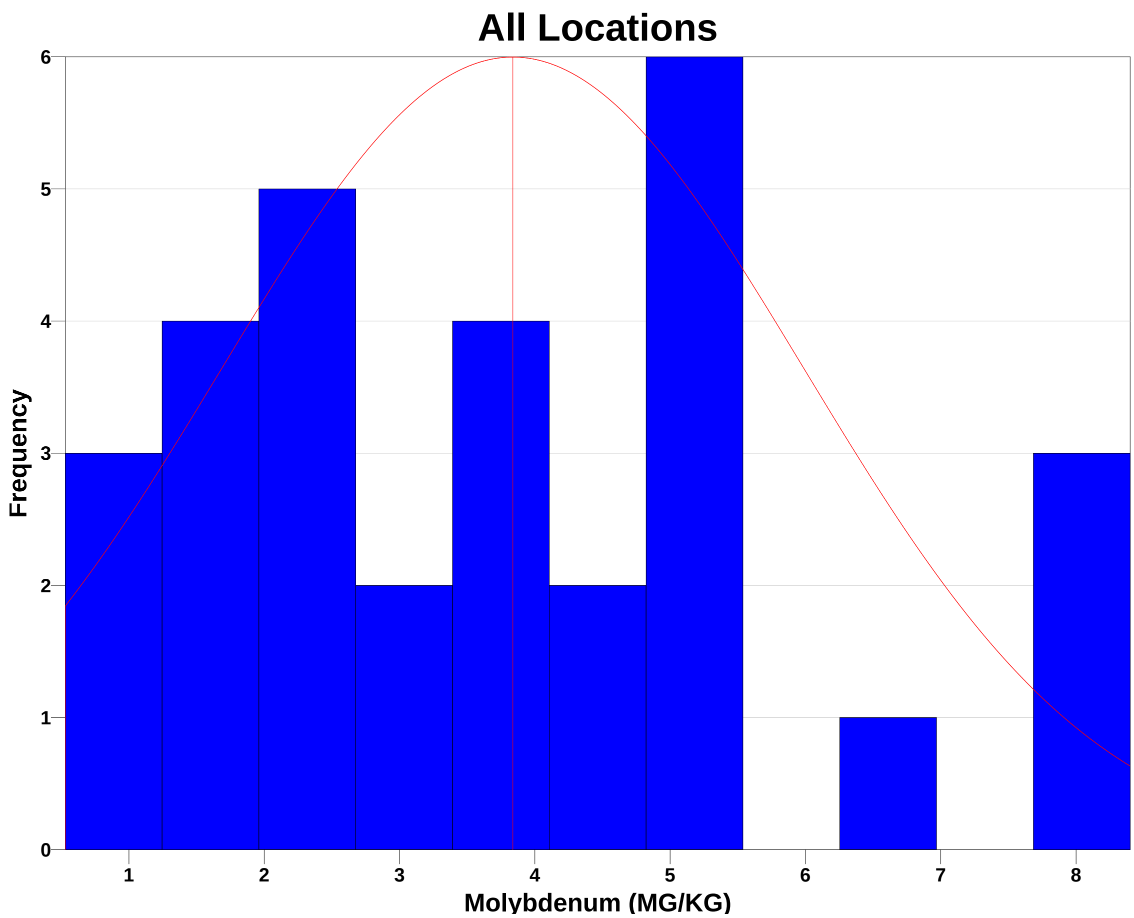
Data Plots

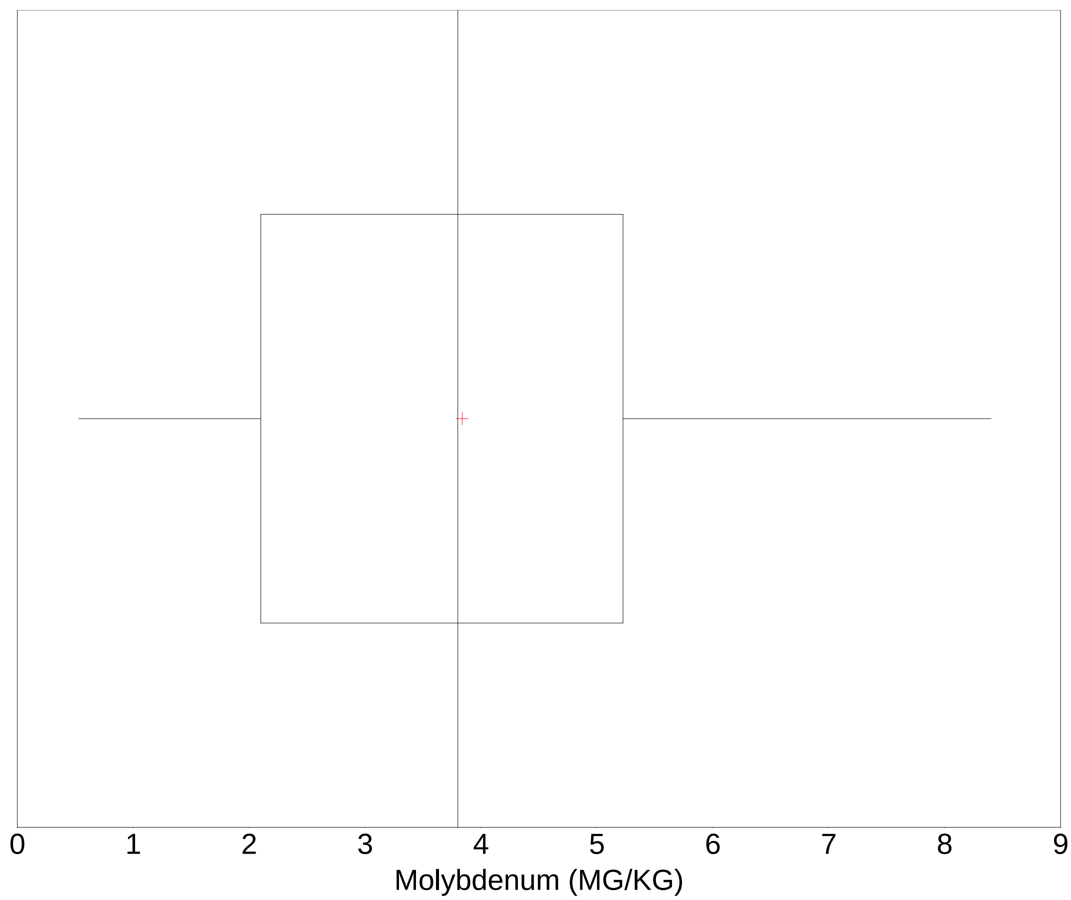
Three graphical displays of the data are shown below: the Histogram, the Box and Whiskers plot, and the Quantile-Quantile (Q-Q) plot.

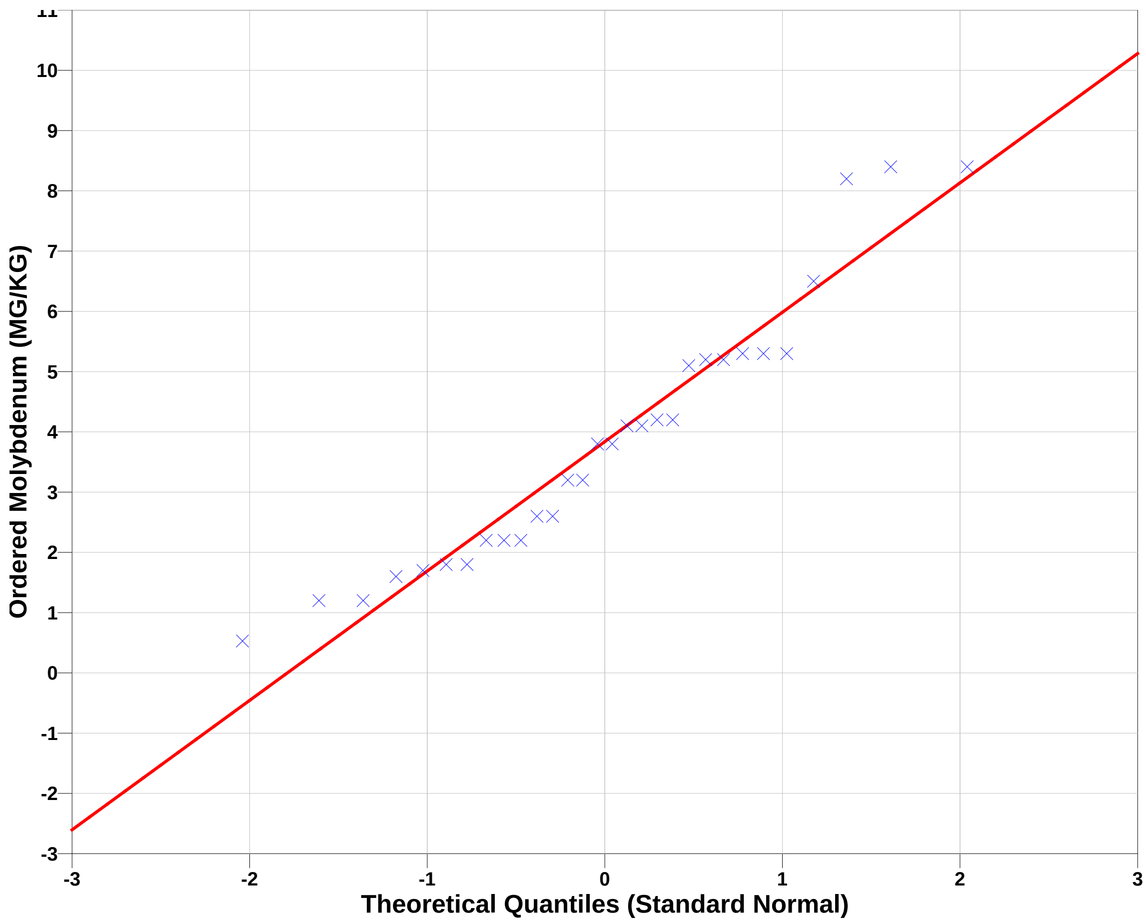
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.


All Locations
Frequency
0
1
2
3
4
5
6
1
2
3
4
5
6
7
8
Molybdenum (MG/KG)


0
1
2
3
4
5
6
7
8
9
Molybdenum (MG/KG)



For more information on these three plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Molybdenum

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.9289
Shapiro-Wilk 5% Critical Value	0.927

The calculated SW test statistic exceeds the 5% Shapiro-Wilk critical value, so we cannot reject the hypothesis that the data are normal, or in other words the data appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	4.5058
95% Non-Parametric (Chebyshev) UCL	5.5517

Because the data appear to be normally distributed according to the goodness-of-fit test performed above, the parametric UCL (4.506) may be a more accurate upper confidence limit on the true mean and may be used as an alternative to the MARSSIM Sign test.

MARSSIM Sign Test
The Sign test was performed in accordance with the guidance given in section 8.3.2 of MARSSIM. Each measurement was subtracted from the action level to obtain n differences $d_i = AL - X_i$. Any differences of zero were discarded from consideration and the sample size was reduced accordingly. The test statistic S+ was calculated by counting the positive differences. S+ was then compared with the critical value k, which was obtained from Table I.3 in Appendix I of MARSSIM.

If $S+ > k$, then the null hypothesis is rejected.

MARSSIM SIGN TEST		
Test Statistic S+	**95% Critical Value**	**Null Hypothesis**
30	19	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, so conclude the site is clean.

This report was automatically produced* by Visual Sample Plan (VSP) software version 6.0.

Software and documentation available at http://vsp.pnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

CSMRI - Flood Plain Site Characterization, 2011

VSP Analysis of In-situ Samples/Shots From Lab Results, PPM

Lead, Pb

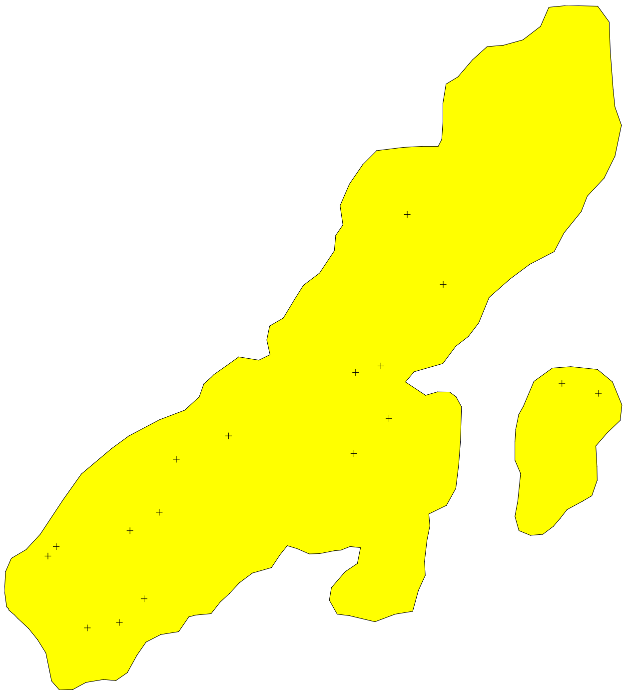
Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	14
Number of samples on map [a]	17
Number of selected sample areas [b]	2
Specified sampling area [c]	13503.31 ft^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.



Area: Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
3075881.4660	1699480.5880	ID_00163	86	Unknown	
3075866.8660	1699435.8530	ID_00237	60	Unknown	
3075874.0050	1699437.7110	ID_00236	68	Unknown	
3075830.8970	1699417.9020	ID_00267	160	Unknown	
3075866.3580	1699412.9270	ID_00257	19	Unknown	
3075876.3060	1699422.8600	ID_00259	51	Unknown	
3075816.0780	1699411.2980	ID_00279	87	Unknown	
3075891.6520	1699460.7820	ID_00305	68	Unknown	
3075799.9480	1699365.1180	ID_00387	220	Unknown	
3075802.9320	1699391.0760	ID_00354	29	Unknown	
3075811.2330	1699396.2960	ID_00353	26	Unknown	
3075782.0500	1699386.5720	ID_00375	170	Unknown	
3075779.6920	1699383.9000	ID_00374	61	Unknown	
3075790.8730	1699363.5770	ID_00422	60	Unknown	
3075806.9380	1699371.8120	ID_00388	40	Unknown	

Area: Area 2					
X Coord	Y Coord	Label	Value	Type	Historical
3075935.6440	1699429.9500	ID_00384	95	Unknown	
3075925.2910	1699432.7910	ID_00381	41	Unknown	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

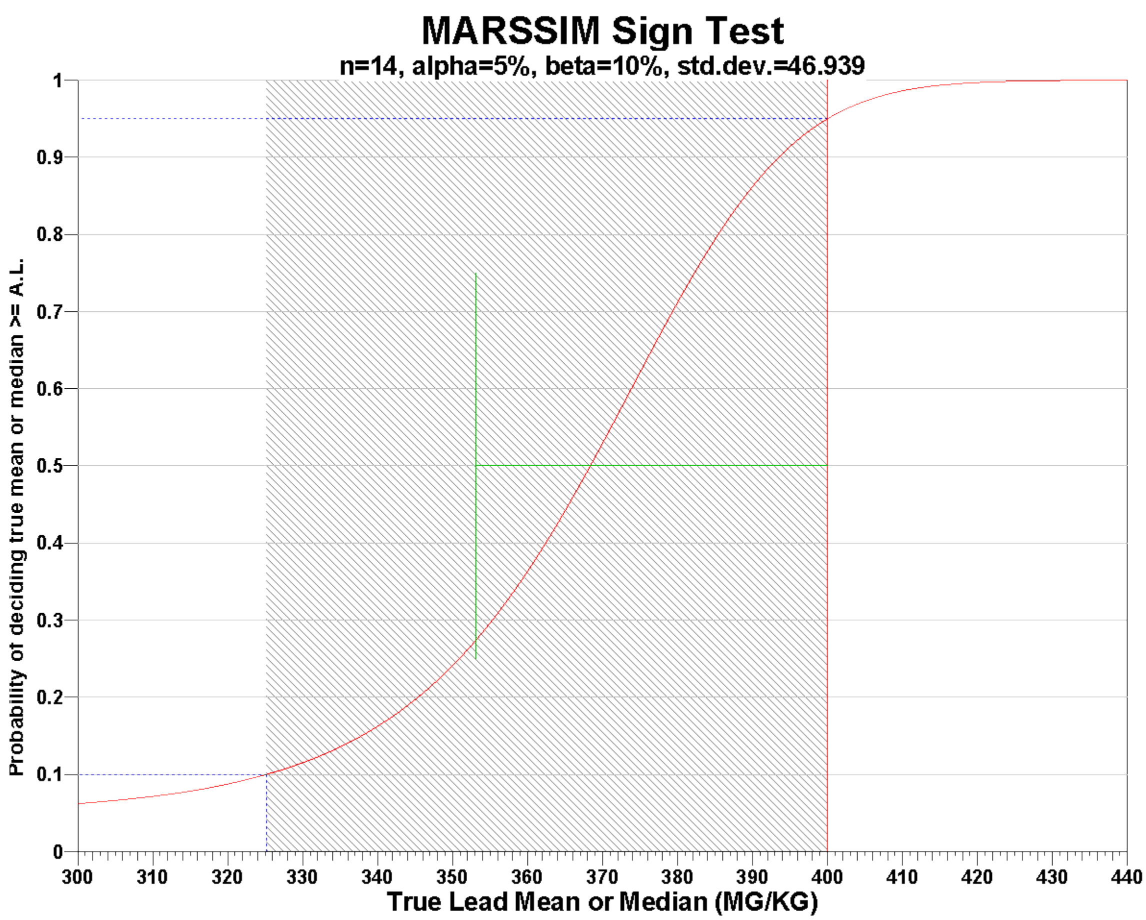
Analyte	n[a]	Parameter

		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Lead	14	46.939 MG/KG	74.833 MG/KG	0.05	0.1	1.64485	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at $1-\alpha$ on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at $1-\alpha$. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions

The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,

3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples								
AL=400		**α=5**		**α=10**		**α=15**		
		s=93.878	**s=46.939**	**s=93.878**	**s=46.939**	**s=93.878**	**s=46.939**
LBGR=90	**β=5**	120	36	95	29	81	24
	β=10	95	29	74	22	60	18
	β=15	81	24	60	18	48	15
LBGR=80	**β=5**	36	17	29	14	24	11
	β=10	29	14	22	10	18	9
	β=15	24	11	18	9	15	8
LBGR=70	**β=5**	21	15	17	11	15	10
	β=10	17	11	14	9	11	8
	β=15	15	10	11	8	9	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Data Analysis for Lead

The following data points were entered by the user for analysis.

Lead (MG/KG)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	19	19	26	29	40	40	41	41	51	51
10	60	60	60	60	61	68	68	68	68	68
20	86	87	87	87	95	95	160	160	170	220

SUMMARY STATISTICS for Lead	
n	30
Min	19
Max	220
Range	201
Mean	74.833
Median	64.5
Variance	2203.3
StdDev	46.939
Std Error	8.5699
Skewness	1.5763
Interquartile Range	46
Percentiles	

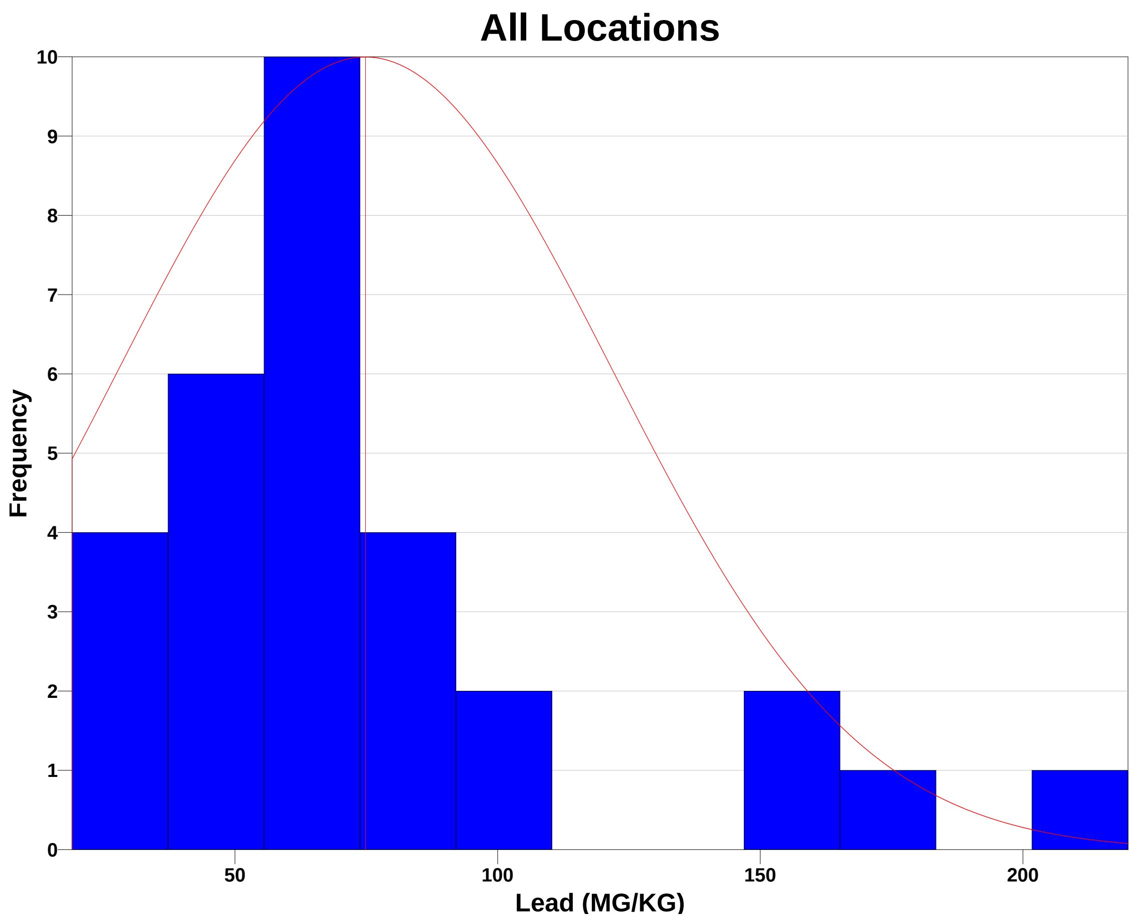
1%	5%	10%	25%	50%	75 %	90 %	95%	99 %
19	19	26.3	41	64.5	87	160	192.5	220

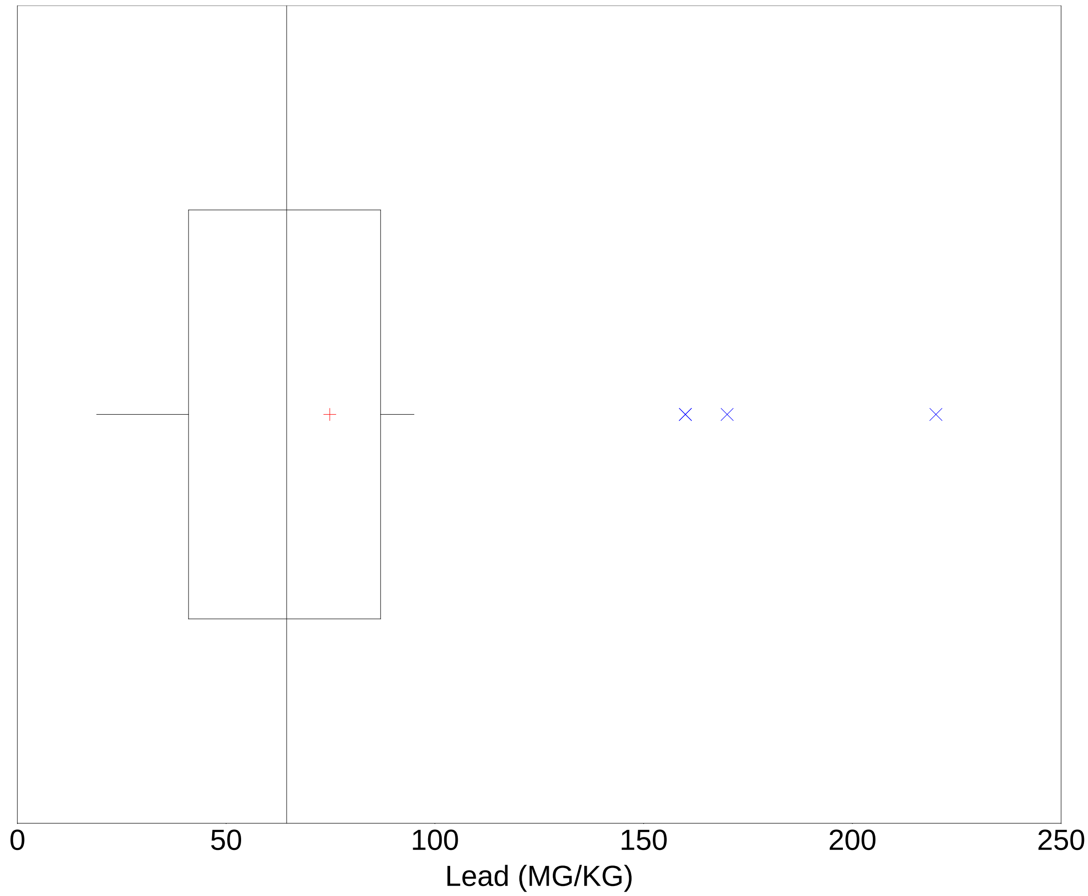
Data Plots
Three graphical displays of the data are shown below: the Histogram, the Box and Whiskers plot, and the Quantile-Quantile (Q-Q) plot.

The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

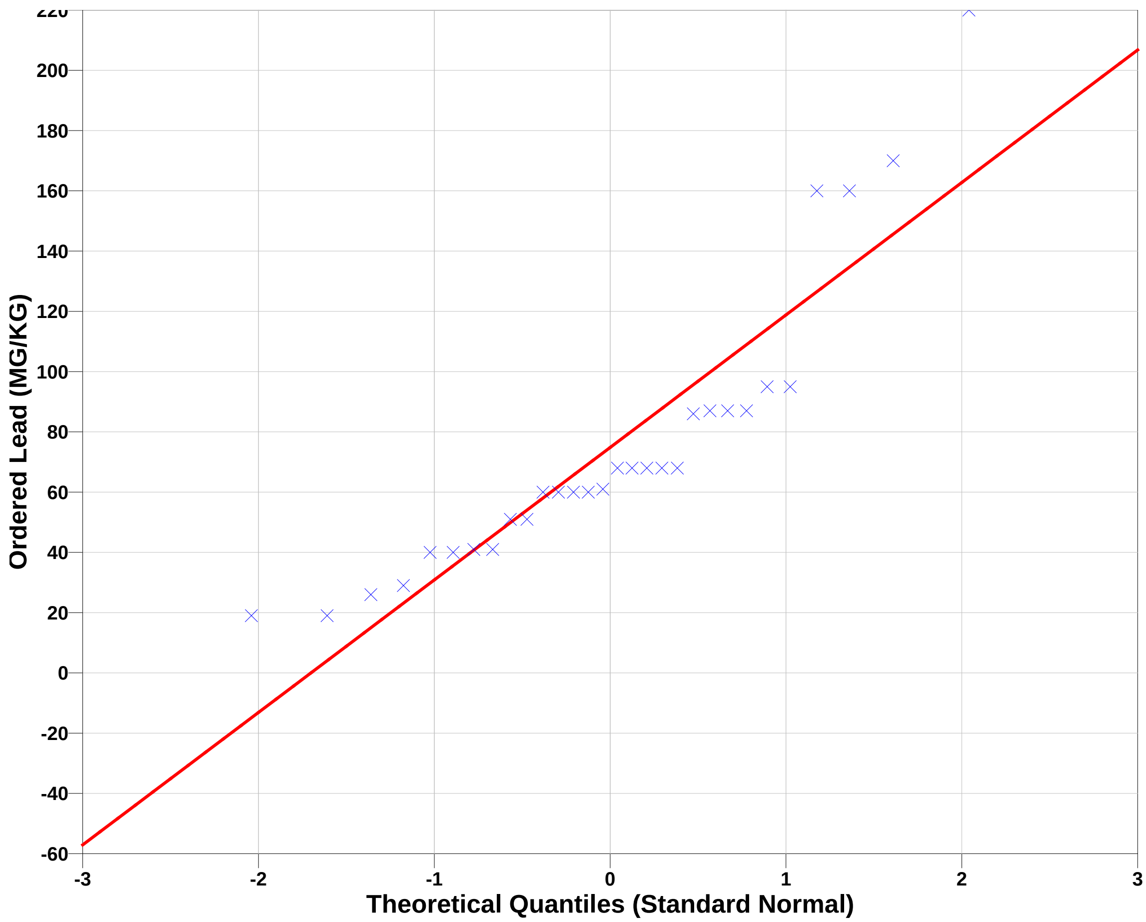
The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.


All Locations
Frequency
10
9
8
7
6
5
4
3
2
1
0
50
100
150
200
Lead (MG/KG)



0
50
100
150
200
250
Lead (MG/KG)



For more information on these three plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Lead

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.8356
Shapiro-Wilk 5% Critical Value	0.927

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	89.395
95% Non-Parametric (Chebyshev) UCL	112.19

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (112.2) may be a more accurate upper confidence limit on the true mean.

MARSSIM Sign Test

The Sign test was performed in accordance with the guidance given in section 8.3.2 of MARSSIM. Each measurement was subtracted from the action level to obtain *n* differences $d_i = AL - X_i$. Any differences of zero were discarded from consideration and the sample size was reduced accordingly. The test statistic S+ was calculated by counting the positive differences. S+ was then compared with the critical value *k*, which was obtained from Table I.3 in Appendix I of MARSSIM.

If $S+ > k$, then the null hypothesis is rejected.

MARSSIM SIGN TEST		
Test Statistic S+	**95% Critical Value**	**Null Hypothesis**
30	19	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, so conclude the site is clean.

CSMRI - Flood Plain Site Characterization, 2011

VSP Analysis of In-situ Samples/Shots From Lab Results, PPM

Uranium, U

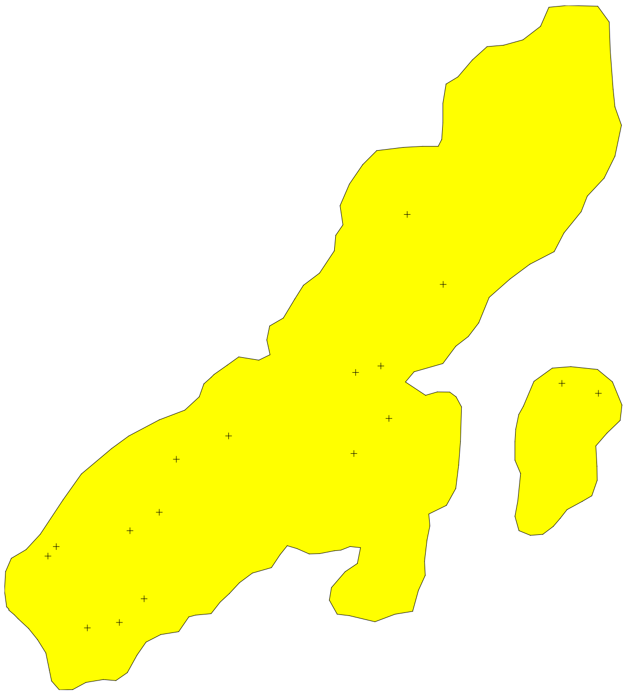
Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	16
Number of samples on map [a]	17
Number of selected sample areas [b]	2
Specified sampling area [c]	13503.31 ft^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.



Area: Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
3075881.4660	1699480.5880	ID_00163	9.4	Unknown	
3075866.8660	1699435.8530	ID_00237	15	Unknown	
3075874.0050	1699437.7110	ID_00236	25	Unknown	
3075830.8970	1699417.9020	ID_00267	8.4	Unknown	
3075866.3580	1699412.9270	ID_00257	5.2	Unknown	
3075876.3060	1699422.8600	ID_00259	11	Unknown	
3075816.0780	1699411.2980	ID_00279	3.1	Unknown	
3075891.6520	1699460.7820	ID_00305	13	Unknown	
3075799.9480	1699365.1180	ID_00387	5.5	Unknown	
3075802.9320	1699391.0760	ID_00354	4.5	Unknown	
3075811.2330	1699396.2960	ID_00353	3.3	Unknown	
3075782.0500	1699386.5720	ID_00375	4.9	Unknown	
3075779.6920	1699383.9000	ID_00374	3.3	Unknown	
3075790.8730	1699363.5770	ID_00422	2.9	Unknown	
3075806.9380	1699371.8120	ID_00388	3.1	Unknown	

Area: Area 2					
X Coord	Y Coord	Label	Value	Type	Historical
3075935.6440	1699429.9500	ID_00384	6.7	Unknown	
3075925.2910	1699432.7910	ID_00381	11	Unknown	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

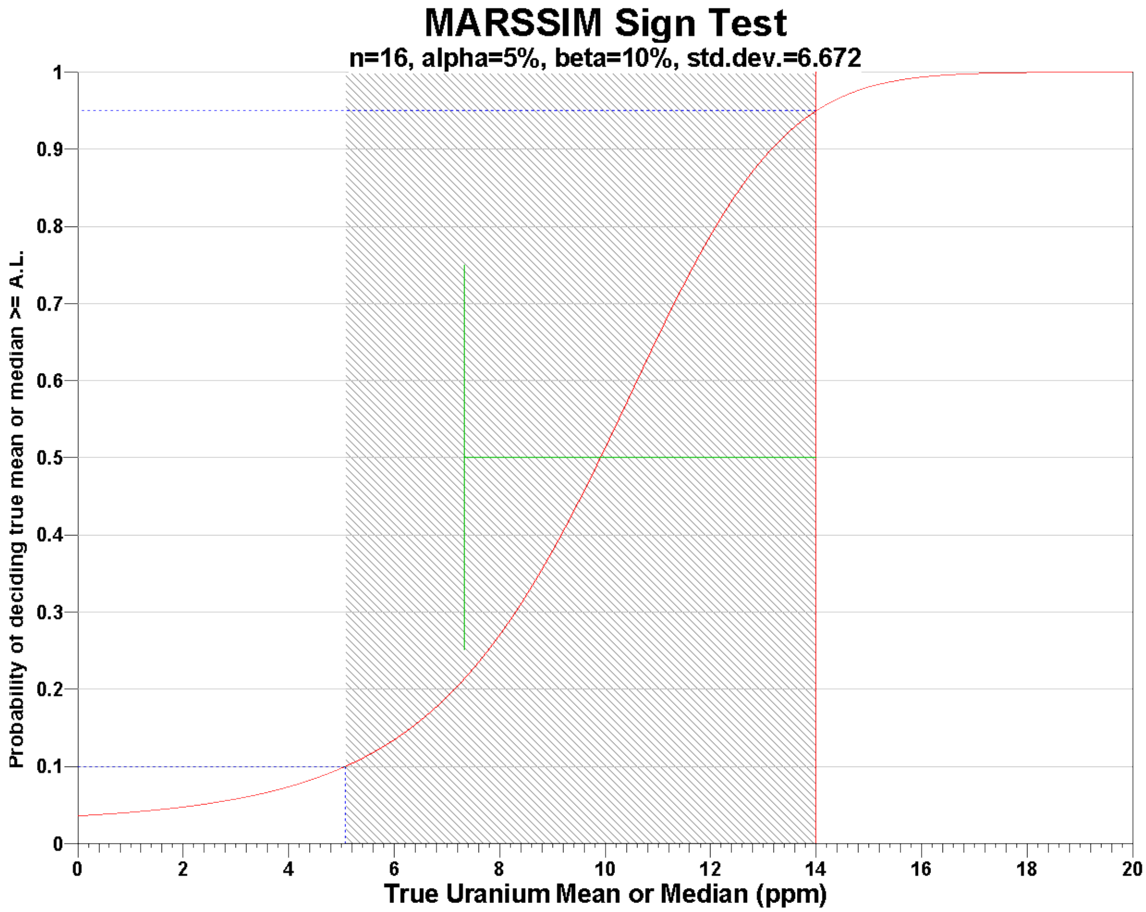
Analyte	n[a]	Parameter

		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Uranium	16	6.672 ppm	8.9267 ppm	0.05	0.1	1.64485	1.28155
9.4	0	9400	9400				
15	0	15000	15000				
25	0	25000	25000				
8.4	0	8400	8400				
5.2	0	5200	5200				
11	0	11000	11000				
3.1	0	3100	3100				
13	0	13000	13000				
5.5	0	5500	5500				
4.5	0	4500	4500				
3.3	0	3300	3300				
4.9	0	4900	4900				
6.7	0	6700	6700				
2.9	0	2900	2900				

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:
1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis
The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=14		α=5		α=10		α=15	
		s=13.344	s=6.672	s=13.344	s=6.672	s=13.344	s=6.672
LBGR=90	β=5	1862	471	1473	374	1236	314
	β=10	1473	374	1130	286	924	234
	β=15	1236	314	924	234	740	188
LBGR=80	β=5	471	124	374	98	314	82
	β=10	374	98	286	76	234	62

	β=15	314	82	234	62	188	50
LBGR=70	**β=5**	214	59	170	47	142	40
	β=10	170	47	130	36	107	30
	β=15	142	40	107	30	86	24

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Data Analysis for Uranium
The following data points were entered by the user for analysis.

Uranium (ppm)										
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	2.9	2.9	3.1	3.1	3.1	3.1	3.1	3.3	3.3	4.5
10	4.9	5.2	5.2	5.5	6.7	6.7	8.4	8.4	9.4	11
20	11	11	11	13	13	15	15	25	25	25

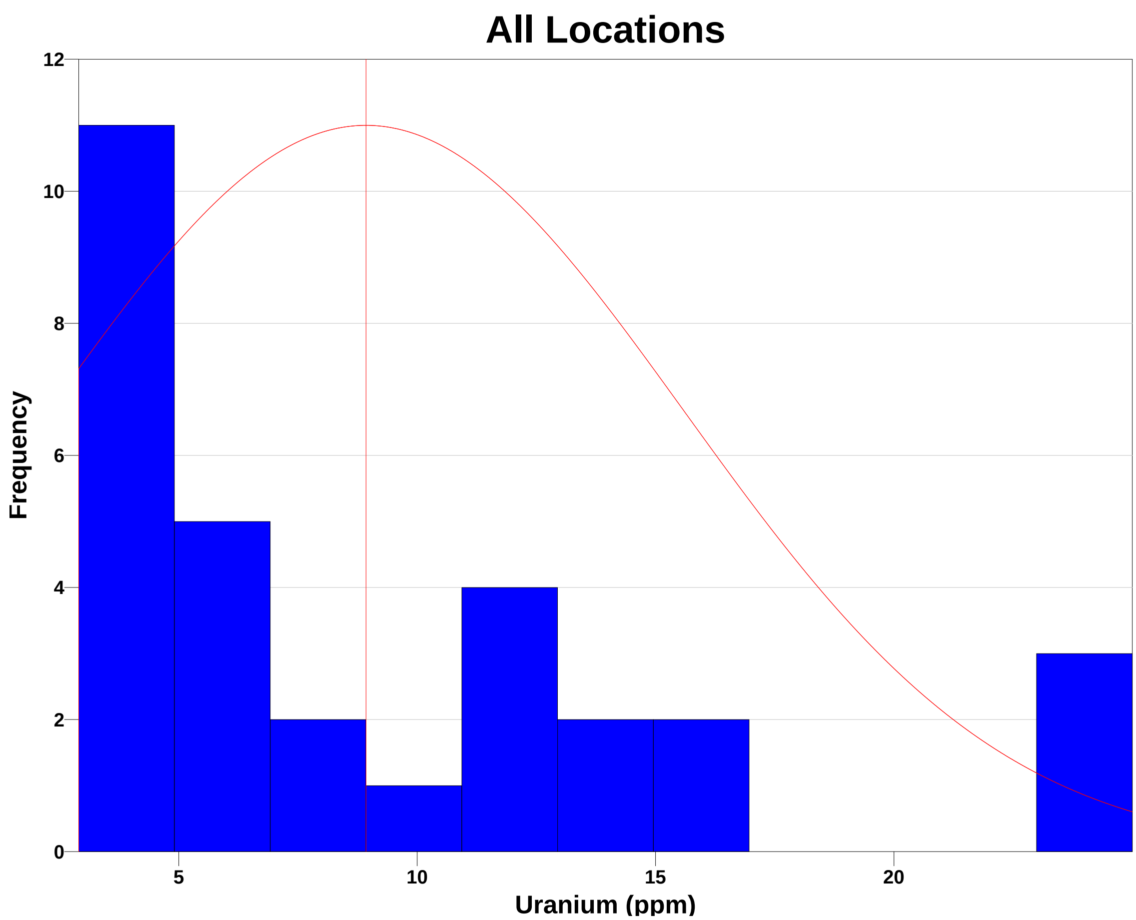
SUMMARY STATISTICS for Uranium								
n	30							
Min	2.9							
Max	25							
Range	22.1							
Mean	8.9267							
Median	6.7							
Variance	44.515							
StdDev	6.672							
Std Error	1.2181							
Skewness	1.3653							
Interquartile Range	8.25							
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
2.9	2.9	3.1	3.25	6.7	11.5	24	25	25

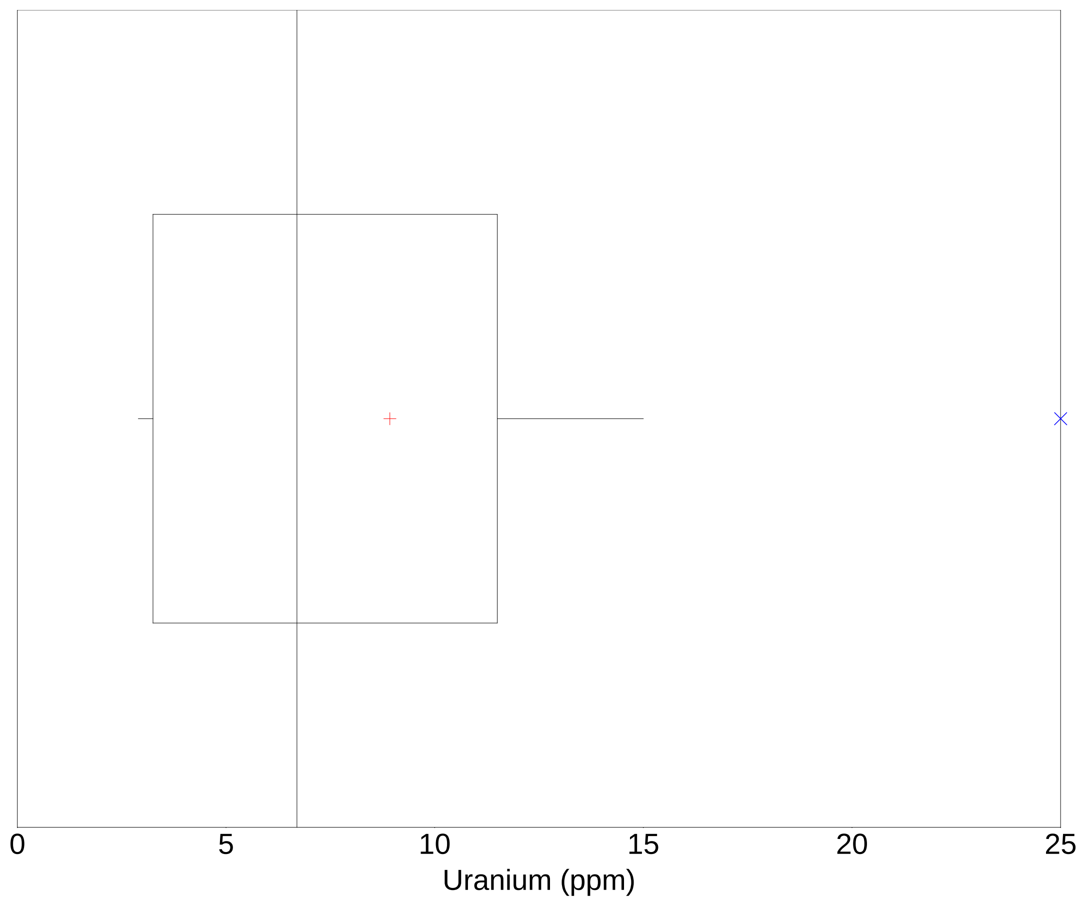
Data Plots
Three graphical displays of the data are shown below: the Histogram, the Box and Whiskers plot, and the Quantile-Quantile (Q-Q) plot.

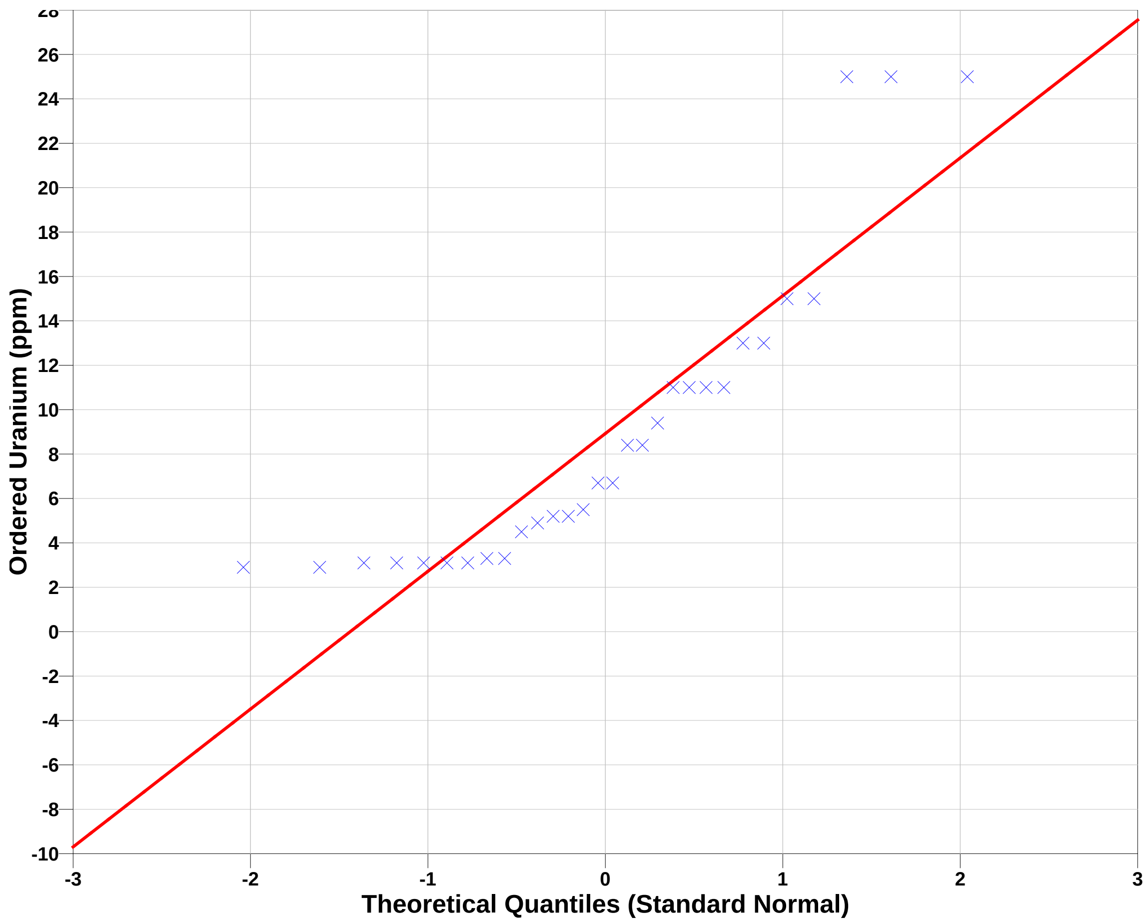
The Histogram is a plot of the fraction of the n observed data that fall within specified data “bins.” A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.




0
5
10
15
20
25
Uranium (ppm)



For more information on these three plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Uranium

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.8074
Shapiro-Wilk 5% Critical Value	0.927

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	10.996
95% Non-Parametric (Chebyshev) UCL	14.236

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (14.24) may be a more accurate upper confidence limit on the true mean.

MARSSIM Sign Test

The Sign test was performed in accordance with the guidance given in section 8.3.2 of MARSSIM. Each measurement was subtracted from the action level to obtain n differences $d_i = AL - X_i$. Any differences of zero were discarded from consideration and the sample size was reduced accordingly. The test statistic S+ was calculated by counting the positive differences. S+ was then compared with the critical value k, which was obtained from Table I.3 in Appendix I of MARSSIM.

If $S+ > k$, then the null hypothesis is rejected.

MARSSIM SIGN TEST		
Test Statistic S+	**95% Critical Value**	**Null Hypothesis**
25	19	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, so conclude the site is clean.

This report was automatically produced* by Visual Sample Plan (VSP) software version 6.0.

Software and documentation available at http://vsp.pnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

Stoller

CSMRI - Flood Plain Site Characterization, 2011

VSP Analysis of In-situ Samples/Shots From Lab Results, PPM

Vanadium, V

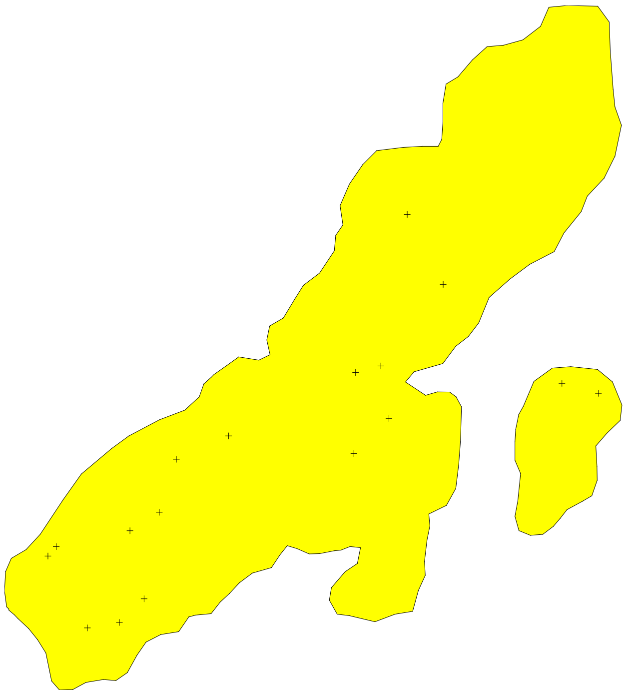
Random sampling locations for comparing a median with a fixed threshold (nonparametric - MARSSIM)

Summary
This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (i.e., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Compare a site mean or median to a fixed threshold
Type of Sampling Design	Nonparametric
Sample Placement (Location) in the Field	Systematic with a random start location
Working (Null) Hypothesis	The median(mean) value at the site exceeds the threshold
Formula for calculating number of sampling locations	Sign Test - MARSSIM version
Calculated total number of samples	11
Number of samples on map [a]	17
Number of selected sample areas [b]	2
Specified sampling area [c]	13503.31 ft^2

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.



Area: Area 1					
X Coord	Y Coord	Label	Value	Type	Historical
3075881.4660	1699480.5880	ID_00163	20	Unknown	
3075866.8660	1699435.8530	ID_00237	23	Unknown	
3075874.0050	1699437.7110	ID_00236	27	Unknown	
3075830.8970	1699417.9020	ID_00267	31	Unknown	
3075866.3580	1699412.9270	ID_00257	14	Unknown	
3075876.3060	1699422.8600	ID_00259	29	Unknown	
3075816.0780	1699411.2980	ID_00279	25	Unknown	
3075891.6520	1699460.7820	ID_00305	25	Unknown	
3075799.9480	1699365.1180	ID_00387	25	Unknown	
3075802.9320	1699391.0760	ID_00354	34	Unknown	
3075811.2330	1699396.2960	ID_00353	36	Unknown	
3075782.0500	1699386.5720	ID_00375	27	Unknown	
3075779.6920	1699383.9000	ID_00374	32	Unknown	
3075790.8730	1699363.5770	ID_00422	54	Unknown	
3075806.9380	1699371.8120	ID_00388	29	Unknown	

Area: Area 2					
X Coord	Y Coord	Label	Value	Type	Historical
3075935.6440	1699429.9500	ID_00384	25	Unknown	
3075925.2910	1699432.7910	ID_00381	19	Unknown	

Primary Sampling Objective

The primary purpose of sampling at this site is to compare a site median or mean value with a fixed threshold. The working hypothesis (or 'null' hypothesis) is that the median(mean) value at the site is equal to or exceeds the threshold. The alternative hypothesis is that the median(mean) value is less than the threshold. VSP calculates the number of samples required to reject the null hypothesis in favor of the alternative one, given a selected sampling approach and inputs to the associated equation.

Selected Sampling Approach
A nonparametric systematic sampling approach with a random start was used to determine the number of samples and to specify sampling locations. A nonparametric formula was chosen because the conceptual model and historical information (e.g., historical data from this site or a very similar site) indicate that typical parametric assumptions may not be true.

Both parametric and non-parametric equations rely on assumptions about the population. Typically, however, non-parametric equations require fewer assumptions and allow for more uncertainty about the statistical distribution of values at the site. The trade-off is that if the parametric assumptions are valid, the required number of samples is usually less than if a non-parametric equation was used.

Locating the sample points over a systematic grid with a random start ensures spatial coverage of the site. Statistical analyses of systematically collected data are valid if a random start to the grid is used. One disadvantage of systematically collected samples is that spatial variability or patterns may not be discovered if the grid spacing is large relative to the spatial patterns.

Number of Total Samples: Calculation Equation and Inputs
The equation used to calculate the number of samples is based on a Sign test (see PNNL 13450 for discussion). For this site, the null hypothesis is rejected in favor of the alternative one if the median(mean) is sufficiently smaller than the threshold. The number of samples to collect is calculated so that if the inputs to the equation are true, the calculated number of samples will cause the null hypothesis to be rejected.

The formula used to calculate the number of samples is:

$$n = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(SignP - 0.5)^2}$$

where

$$SignP = \Phi\left(\frac{\Delta}{s_{total}}\right)$$

$\Phi(z)$ is the cumulative standard normal distribution on $(-\infty,z)$ (see PNNL-13450 for details),
n is the number of samples,
S_{total} is the estimated standard deviation of the measured values including analytical error,
Δ is the width of the gray region,
α is the acceptable probability of incorrectly concluding the site median(mean) is less than the threshold,
β is the acceptable probability of incorrectly concluding the site median(mean) exceeds the threshold,
$Z_{1-\alpha}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\alpha}$ is $1-\alpha$,
$Z_{1-\beta}$ is the value of the standard normal distribution such that the proportion of the distribution less than $Z_{1-\beta}$ is $1-\beta$.

Note: MARSSIM suggests that the number of samples should be increased by at least 20% to account for missing or unusable data and uncertainty in the calculated value of n. VSP allows a user-supplied percent overage as discussed in MARSSIM (EPA 2000, p. 5-33).

The values of these inputs that result in the calculated number of sampling locations are:

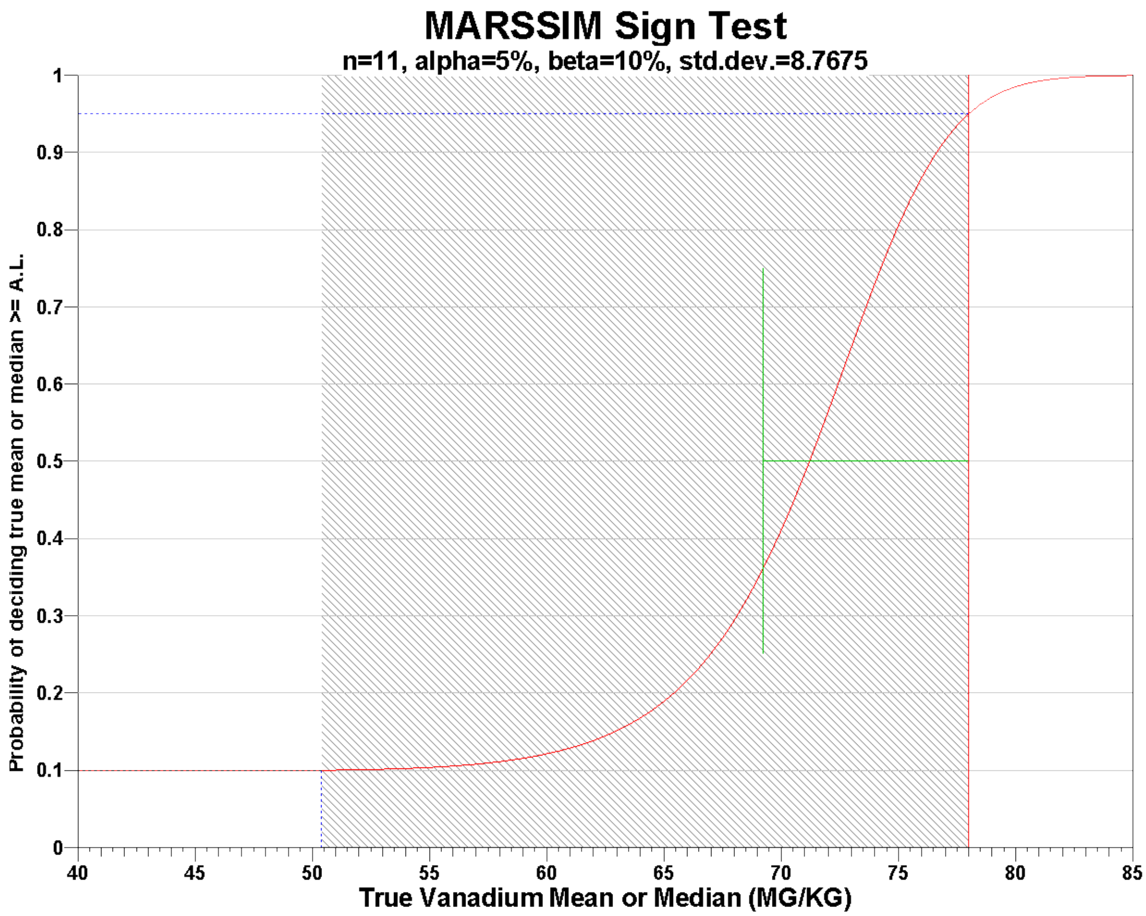
Analyte	n[a]	Parameter

		S	Δ	α	β	$Z_{1-\alpha}$ [b]	$Z_{1-\beta}$ [c]
Vanadium	11	8.7675 MG/KG	27.6 MG/KG	0.05	0.1	1.64485	1.28155

[a] The final number of samples has been increased by the MARSSIM Overage of 20%.
[b] This value is automatically calculated by VSP based upon the user defined value of α.
[c] This value is automatically calculated by VSP based upon the user defined value of β.

The following figure is a performance goal diagram, described in EPA's QA/G-4 guidance (EPA, 2000). It shows the probability of concluding the sample area is dirty on the vertical axis versus a range of possible true median(mean) values for the site on the horizontal axis. This graph contains all of the inputs to the number of samples equation and pictorially represents the calculation.

The red vertical line is shown at the threshold (action limit) on the horizontal axis. The width of the gray shaded area is equal to Δ; the upper horizontal dashed blue line is positioned at 1-α on the vertical axis; the lower horizontal dashed blue line is positioned at β on the vertical axis. The vertical green line is positioned at one standard deviation below the threshold. The shape of the red curve corresponds to the estimates of variability. The calculated number of samples results in the curve that passes through the lower bound of Δ at β and the upper bound of Δ at 1-α. If any of the inputs change, the number of samples that result in the correct curve changes.



Statistical Assumptions
The assumptions associated with the formulas for computing the number of samples are:

1. the computed sign test statistic is normally distributed,
2. the variance estimate, S^2, is reasonable and representative of the population being sampled,
3. the population values are not spatially or temporally correlated, and
4. the sampling locations will be selected probabilistically.

The first three assumptions will be assessed in a post data collection analysis. The last assumption is valid because the gridded sample locations were selected based on a random start.

Sensitivity Analysis

The sensitivity of the calculation of number of samples was explored by varying the standard deviation, lower bound of gray region (% of action level), beta (%), probability of mistakenly concluding that μ > action level and alpha (%), probability of mistakenly concluding that μ < action level. The following table shows the results of this analysis.

Number of Samples							
AL=78		α=5		α=10		α=15	
		s=17.535	s=8.7675	s=17.535	s=8.7675	s=17.535	s=8.7675
LBGR=90	β=5	111	34	88	27	74	23
	β=10	88	27	68	21	56	17
	β=15	74	23	56	17	45	14
LBGR=80	β=5	34	16	27	14	23	11
	β=10	27	14	21	10	17	9
	β=15	23	11	17	9	14	8
LBGR=70	β=5	21	14	16	11	14	10
	β=10	16	11	12	9	11	8
	β=15	14	10	11	8	9	6

s = Standard Deviation
LBGR = Lower Bound of Gray Region (% of Action Level)
β = Beta (%), Probability of mistakenly concluding that μ > action level
α = Alpha (%), Probability of mistakenly concluding that μ < action level
AL = Action Level (Threshold)

Data Analysis for Vanadium

The following data points were entered by the user for analysis.

Vanadium (MG/KG)										
Rank	1	2	3	4	5	6	7	8	9	10
0	14	14	19	19	20	23	23	25	25	25
10	25	25	25	25	25	27	27	27	27	29
20	29	29	29	31	31	32	34	36	54	54

SUMMARY STATISTICS for Vanadium	
n	30
Min	14
Max	54
Range	40
Mean	27.6
Median	26
Variance	76.869
StdDev	8.7675
Std Error	1.6007
Skewness	1.6858

Interquartile Range				5				
Percentiles								
1%	**5%**	**10%**	**25%**	**50%**	**75%**	**90%**	**95%**	**99%**
14	14	19	24.5	26	29.5	35.8	54	54

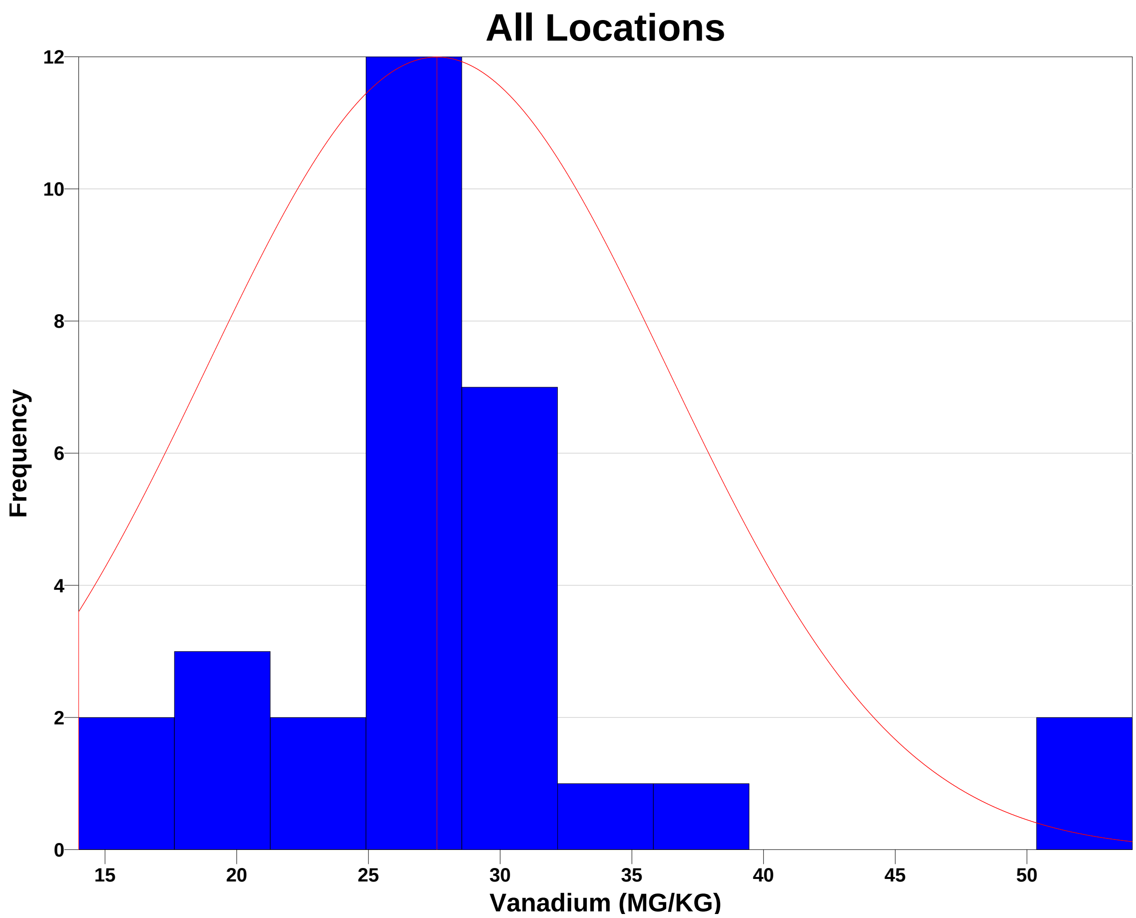
Data Plots

Three graphical displays of the data are shown below: the Histogram, the Box and Whiskers plot, and the Quantile-Quantile (Q-Q) plot.

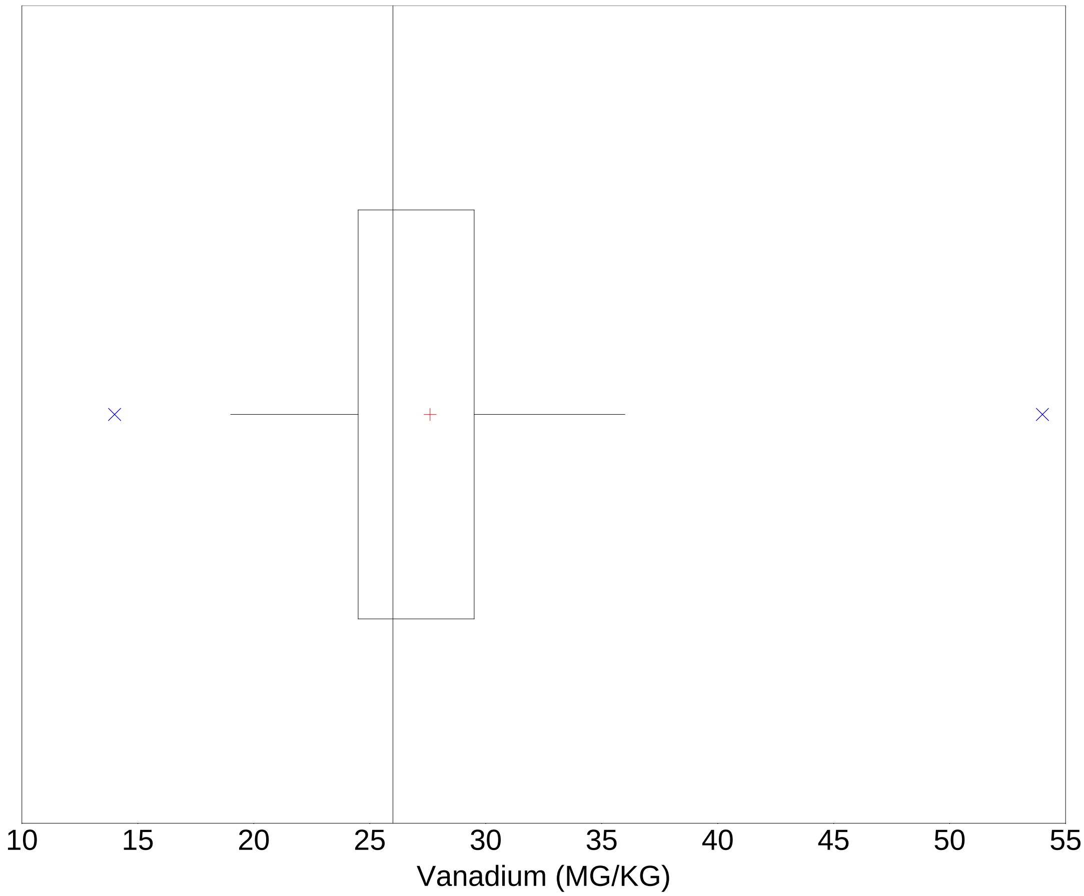
The Histogram is a plot of the fraction of the n observed data that fall within specified data "bins." A histogram is generated by dividing the x axis (range of the observed data values) into "bins" and displaying the number of data in each bin as the height of a bar for the bin. The area of the bar is the fraction of the n data values that lie within the bin. The sum of the fractions for all bins equals one. A histogram is used to assess how the n data are distributed (spread) over their range of values. If the histogram is more or less symmetric and bell shaped, then the data may be normally distributed.

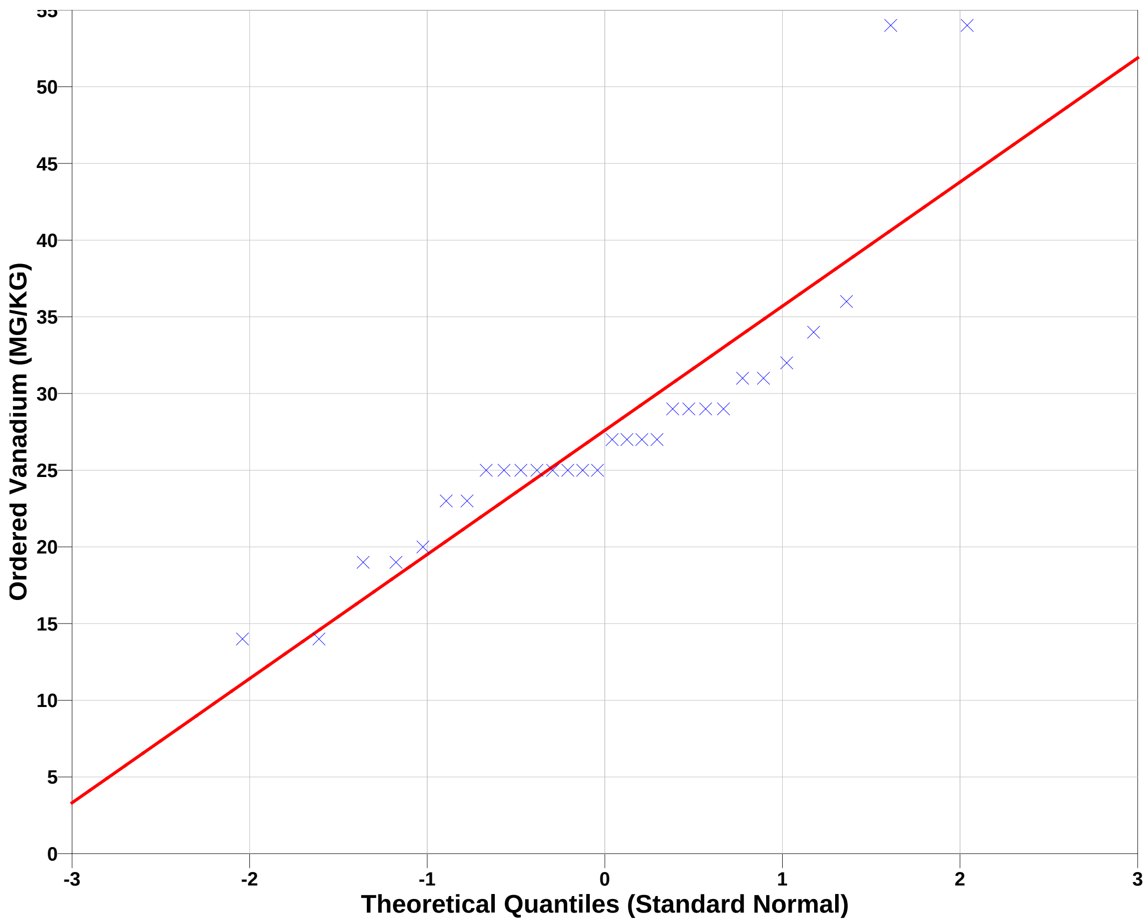
The Box and Whiskers plot is composed of a central box divided by a line, and with two lines extending out from the box, called the "whiskers". The line through the box is drawn at the median of the n data observed. The two ends of the box represent the 25^{th} and 75^{th} percentiles of the n data values, which are also called the lower and upper quartiles, respectively, of the data set. The sample mean (mean of the n data) is shown as a "+" sign. The upper whisker extends to the largest data value that is less than the upper quartile plus 1.5 times the interquartile range (upper quartile minus the lower quartile). The lower whisker extends to the smallest data value that is greater than the lower quartile minus 1.5 times the interquartile range. Extreme data values (greater or smaller than the ends of the whiskers) are plotted individually. A Box and Whiskers plot is used to assess the symmetry of the distribution of the data set. If the distribution is symmetrical, the box is divided into two equal halves by the median, the whiskers will be the same length, and the number of extreme data points will be distributed equally on either end of the plot.

The Q-Q plot graphs the quantiles of a set of n data against the quantiles of a specific distribution. We show here only the Q-Q plot for an assumed normal distribution. The p^{th} quantile of a distribution of data is the data value, x_p, for which a fraction p of the distribution is less than x_p. If the data plotted on the normal distribution Q-Q plot closely follow a straight line, even at the ends of the line, then the data may be assumed to be normally distributed. If the data points deviate substantially from a linear line, then the data are not normally distributed.



All Locations
Frequency
Vanadium (MG/KG)
0
2
4
6
8
10
12
15
20
25
30
35
40
45
50


10
15
20
25
30
35
40
45
50
55
Vanadium (MG/KG)



For more information on these three plots consult Guidance for Data Quality Assessment, EPA QA/G-9, pgs 2.3-1 through 2.3-12. (http://www.epa.gov/quality/qa-docs.html).

Tests for Vanadium

A goodness-of-fit test was performed to test whether the data set had been drawn from an underlying normal distribution. The Shapiro-Wilk (SW) test was used to test the null hypothesis that the data are normally distributed. The test was conducted at the 5% significance level, i.e., the probability the test incorrectly rejects the null hypothesis was set at 0.05.

NORMAL DISTRIBUTION TEST	
Shapiro-Wilk Test Statistic	0.8176
Shapiro-Wilk 5% Critical Value	0.927

The calculated SW test statistic is less than the 5% Shapiro-Wilk critical value, so we can reject the hypothesis that the data are normal, or in other words the data do not appear to follow a normal distribution at the 5% level of significance. The Q-Q plot displayed above should be used to further assess the normality of the data.

Upper Confidence Limit on the True Mean

Two methods were used to compute the upper confidence limit (UCL) on the mean. The first is a parametric method that assumes a normal distribution. The second is the Chebyshev method, which requires no distributional assumption.

UCLs ON THE MEAN	
95% Parametric UCL	30.32
95% Non-Parametric (Chebyshev) UCL	34.577

Because the data do not appear to be normally distributed according to the goodness-of-fit test performed above, the non-parametric UCL (34.58) may be a more accurate upper confidence limit on the true mean.

MARSSIM Sign Test

The Sign test was performed in accordance with the guidance given in section 8.3.2 of MARSSIM. Each measurement was subtracted from the action level to obtain n differences $d_i = AL - X_i$. Any differences of zero were discarded from consideration and the sample size was reduced accordingly. The test statistic S+ was calculated by counting the positive differences. S+ was then compared with the critical value k, which was obtained from Table I.3 in Appendix I of MARSSIM.

If $S+ > k$, then the null hypothesis is rejected.

MARSSIM SIGN TEST		
Test Statistic S+	**95% Critical Value**	**Null Hypothesis**
30	19	Reject

The test rejected the null hypothesis that the mean value at the site exceeds the threshold, so conclude the site is clean.

This report was automatically produced* by Visual Sample Plan (VSP) software version 6.0.

Software and documentation available at http://vsp.pnl.gov

* - The report contents may have been modified or reformatted by end-user of software.

Risk from Soil Consumption (Residential Scenario)

	Conc$_{soil}$ mg/kg	Consumption Rate[a] kg/da	Expos freq[b] days/yr	Expos dur[b] years	Body wt[b] kg	Averaging time days	Slope factor[c] mg/kg/da^{-1}	Chronic Daily Intake mg/kg/da	Risk[d] (cancer)
BACKGROUND LEVELS									
As	38	1.14E-04	350	70	70	24500	1.5	6.19E-05	9.28E-05
FLOOD PLAIN LEVEL									
As	10	1.14E-04	350	70	70	24500	1.5	1.63E-05	2.44E-05
UPPER TERRACE									
As	14.8	1.14E-04	350	70	70	24500	1.5	2.41E-05	3.62E-05
MAXIMUM MEASUREMENT									
As	780	1.14E-04	350	70	70	24500	1.5	1.27E-03	1.91E-03
REFERENCE LEVELS									
As[e]	1	1.14E-04	350	70	70	24500	1.5	1.63E-06	2.44E-06
As[f]	0.43	1.14E-04	350	70	70	24500	1.5	7.00E-07	1.05E-06

a. Age-adjusted soil ingestion factor from EPA Soil Screenining Guidance (Publication 9355.4-23, July 1996) http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg496.pdf
b. Factors from EPA Risk Assessment Guidance for Superfund, Vol.1, Human Health Evaluation Manual, interim final, December 1989
c. EPA Integrated Risk Information System (IRIS). http://www.epa.gov/iris. Arsenic, inorganic (CASRN 7440-38-2)
d. Risk = CDI * SF.
e. DCGL
f. The Arsenic soil concentration estimated to be equivalent to 1E-06.From the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" website.
http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/

Appendix F
Applicable or Relevant and Appropriate Requirements

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA) requires that any regulations which specify a standard, requirement, criterion, or limitation under any Federal or State environmental law be identified and included with a site feasibility study. Compliance with these applicable or relevant and appropriate requirements (ARARS) is mandatory under CERCLA. The following tables represent the ARARS found for each Remedial Alternative at the CSMRI site including No Action, On-site, and Off-site Disposal to a licensed facility. These tables include a reference to the regulation, the standard specified in the regulation and a determination of whether a regulation or standard is Applicable or Relevant and Appropriate. Applicable requirements give standards which address a specific situation at a CERCLA site whereas relevant and appropriate requirements give standards which address problems or situations similar to a proposed response action or the conditions of the site of concern. These tables are broken into action, chemical, and location specific ARARS.

A majority of the information in these ARAR tables was established during the RAOA for the stockpile material, which were then adapted for the 2004 RIFS, and then updated for the 2007 RIFS. Since then, this set of ARARs has been updated and clarified. Table I provides a summary table of ARARs.

Action-specific ARARS focus on those requirements applicable to the actions associated with each alternative defined. These requirements are items such as regulations governing excavation of impacted material, transportation of impacted material, and/or health and safety of site workers. Tables 1, 2, and 3 list all action specific ARARs.

Chemical-specific ARARS list the requirements associated with each chemical defined as a constituent of concern at the CSMRI site. Tables 4 thru 7 list all chemical specific ARARs associated with soil. A separate table (Table 6) lists the groundwater standards for both alternatives.

Location-specific ARARS list the requirements applicable to the site regardless of the actions taken or chemicals present. These requirements are items such as endangered species present, the location of the Site in a floodplain, and/or historical importance of the site. Tables 8, 9, and 10 list all location specific ARARs.

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Clean Air Act (CAA)	42 U.S.C.A. §§ 7401 to 7671q (40 CFR 50 to 69)	Establishes requirements for air pollution prevention and control	Substantive portions of CAA may be relevant and appropriate to site excavation operations and on-site disposal.	Air	Excavation, on-site disposal	Potentially relevant or appropriate
CAA - National Emission Standards for Hazardous Air Pollutants (NESHAP)	40 CFR 61	Establishes standards for certain HAP emissions from some sources	To the extent the removal activities involve the emission of regulated constituents and activities similar to those addressed in these regulations, they may be relevant and appropriate.	Air	Excavation, on-site disposal	Potentially relevant or appropriate
CAA - Standards of Performance for New Stationary Sources	40 CFR 60	Establishes emission standards for new air emissions	If air pollution sources that are sufficiently similar to those sources covered by these regulations are part of the remedy, the regulations may be relevant and appropriate.	Air	Excavation, on-site disposal	Potentially relevant or appropriate
Colorado Air Quality Control Act	CRS 25-7-101, et seq.	Establishes Colorado requirements for air pollution prevention and control	Portions of Act potentially applicable or relevant and appropriate to site excavation operations and on-site disposal.	Air	Excavation, on-site disposal	Applicable or relevant or appropriate
Common Provision Regulations	5 CCR 1001-2 Section II	Conduct performance tests, emissions monitoring, and record keeping	Substantive requirements are applicable to air emission component of the remedy.	Air	Excavation, on-site disposal	Applicable
Regulation No. 1	5 CCR 1001-3 Regulation No. 1	Establishes emission control regulations for particulates, smoke, CO, sulfur oxides and fugitive particulate emissions.	See following for description of specific provisions.	Air	Excavation, on-site disposal	Applicable
Regulation No. 1	5 CCR 1001-3 Regulation No. 1, Section II.A.1	Comply with opacity limitations.	Less than 20% opacity emitted, specific sources may have other limitations.	Air	Excavation	No – applies to smoke
Regulation No. 1	5 CCR 1001-3 Regulation No. 1, Section III.D	Minimize fugitive particulate emissions.	Applicable to construction activities, storage and handling operations, haul roads and haul trucks, and tailings piles.	Air	Excavation, on site disposal	Applicable
Regulation No. 3	5 CCR 1001-5 Regulation No. 3, Part A Section II; Part B	Construction permit required if emissions exceed 5 TPY PM10 or 10 TPY of TSP. File APEN	Substantive portions are potentially applicable to all sources including earthwork and existing sources unless specifically exempt.	Air	Excavation, on site disposal	Potentially applicable

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
		including estimation of emission rates if threshold exceeded 2 tons.				
Ambient Air Quality Standards	5 CCR 1001-14	Sets ambient standards for total suspended particulates.	Would be applicable if remedy would cause emission of regulated constituents that contribute to a NAAQS violation, including particulates and ozone.	Air	Excavation, on site disposal	Potentially applicable
Jefferson County Health Department Environmental Health – Air Quality Control	*See www.co.jefferson.co.us/health/health_T111_R39.htm*	Fugitive Dust Control Plan	Plan for 25 acres or more of disturbance but individual plans from smaller sites that produce excessive dust possible; all developers must use reasonable controls such as water to prevent fugitive dust emissions.	Air	Excavation	Potentially relevant and appropriate
Occupational Safety and Health Act	29 USC 651-678 (29 CFR 1910.96, 1926)	Regulates worker health and safety.	Independently applicable. Requirements of this act apply to all response actions under the NCP.	NA	All operations	Yes, applicable
Radiation Control	CRS 25-11-101-305	Establishes Colorado requirements for radiation control and safety	Portions of Act applicable or relevant and appropriate to site excavation operations and land disposition.	All Media	Excavation, Land Disposition, Disposal	Yes, applicable or relevant and appropriate
Radiation Control	CRS 25-11-201, et seq., Part 2	Provides procedural requirements for disposal of classified waste at facilities required to be licensed for uranium mill, processing or disposal.	Not applicable or relevant or appropriate because no alternative includes disposal at such facilities in Colorado.	All Media	Excavation, Land Disposition, Disposal	No
Radiation Control - General Provisions	6 CCR 1007-1, Part 1	General provisions (including definitions) for 6 CCR 1007-1.	Provides information about the regulations. Applicable if CSMRI rad license is transferred.	All Media	Excavation, Land Disposition, Disposal	Yes, applicable or relevant and appropriate
Radiation Control – Licensing of Radioactive Material	6 CCR 1007-1, Part 3	Regulations concerning licensing of radioactive materials.	Relevant and appropriate to one off-site facility within the State (Deer Trail). None of the on-site affected materials requires a radioactive materials license. Applicable if CSMRI rad license is transferred.	All Media	Disposal	Potentially relevant and appropriate

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Radiation Control – Standards for Protection Against Radiation	6 CCR 1007-1, Part 4	Establishes standards for protection against radiation hazards.	Substantive portions of license decommissioning standards for unrestricted uses and restricted uses are relevant and appropriate. Applicable if CSMRI rad license is transferred.	All Media	Excavation, Land Disposition, Disposal	Yes, relevant and appropriate
Radiation Control - Notices, Instructions, And Reports To Workers: Inspections	6 CCR 1007-1, Part 10	Notes, instructions, and reports to workers.	Substantive portions are relevant and appropriate. Applicable if CSMRI rad license is transferred.	All Media	Excavation, Land Disposition, Disposal	Yes, relevant and appropriate
Radiation Control – Transportation of Radioactive Material	6 CCR 1007-1, Part 17	Transportation of radioactive materials	Substantive portions are relevant and appropriate. Applicable if CSMRI rad license is transferred.	All Media	Transportation, Disposal	Yes, relevant and appropriate
Radiation Control – Licensing Requirements Milling Facilities	6 CCR 1007-1, Part 18	Licensing requirements for milling facilities and disposition of products of milling operations for uranium, thorium and related materials.	Not applicable to on-site or off-site disposal facilities within the State. Soil cleanup criteria is potentially relevant and appropriate to achieve 5 pCi/g of Ra-226 above background within 15 cm below the surface averaged over areas of 100 square meters and 15 pCi/g of Ra-226 above background averaged over 15 cm thick layers more than 15 cm below the surface. Criterion 6. Groundwater protection will be addressed in OU2, standards provided by Criteria 5 and 7.	All Media	Excavation, Land Disposition, Disposal	Soil cleanup criteria is relevant and appropriate; – otherwise, none of the alternatives includes disposal at a facility regulated by Part 18.
Radiation Control – Licensing Requirements for Land Disposal of Low-Level Radioactive Waste	6 CCR 1007-1, Part 14	Establishes standards for the land disposal of low-level radioactive wastes	Not applicable or relevant and appropriate because on-site impacted materials are not low level radioactive wastes, nor like LLW.	All Media	Excavation, Land Disposition, Disposal	No

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Colorado Environmental Covenant	C.R.S. §25-15-318 – 321	Requires an environmental covenant to ensure continuance of land use restriction if remedy is on-site with restricted uses.	For on-site remedies with restricted uses only	All Media		Applicable
TENORM Guidance	Interim Policy and Guidance Pending Rulemaking for Control and Disposition of Technologically-Enhanced Naturally Occurring Radioactive Materials in Colorado, Rev. 2.1, Final Draft for Comment, February 2007	Guidance re: TENORM Materials	Provides sampling and disposal guidelines for TENORM	All Media		TBC
Atomic Energy Act of 1954, as amended, and Energy Reorganization Act of 1974, as amended.	42 U.S.C. 2011, et seq., 42 U.S.C. 5801, *et seq*.	Establishes requirements for radiation safety	Portions of these laws are potentially relevant and appropriate to site cleanup and/or land disposition.	All Media	Excavation, Land Disposition	Yes, relevant and appropriate
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 19)	10 CFR 19	Establishes standards for protection of workers who will be exposed to 100 mrem (1 mSv) in 1 year.	Remedial alternatives need to limit external and internal exposure from releases to levels that do not exceed 100 mrem/y, or 2 mrem/h per year.	All Media	Excavation, Land Disposition, Disposal	Possibly relevant and appropriate
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 20, 40)	10 CFR 20.1201-8;1301-2; 1402, 1403. 10 CFR 40.42	Establishes standards for protection of the public against radiation arising from the use of regulated materials.	Remedial alternatives need to limit external and internal exposure from releases to levels that do not exceed 100 mrem/y, or 2 mrem/h from external exposure in unrestricted areas. These requirements also establish criteria for closing NRC-licensed sites including a dose standard of 25 mrem/y and ALARA, or 100 mrem/y if institutional controls fail.	All Media	Excavation, Land Disposition, Disposal	Yes, relevant and appropriate

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Clean Water Act (CWA)	33 U.S.C.A. §§ 1251 to 1387 (40 CFR 104 to 135, 230 & 33 CFR 320, 323, 328-330)	Establishes requirements for water pollution prevention and control	Portions of CWA relevant and appropriate to site operations.	Surface Water and potentially groundwater	Excavation, Land Disposition	Yes, relevant and appropriate
Standards for Fill or Excavation in Waters of the United States	33 CFR 320, 323, 328-330	Regulates construction / excavation activities in streams and floodplains for discharges of dredged or fill material into waters of the United States	Portions may be applicable, or relevant and appropriate for portion of Site that is in the Clear Creek flood plain.	Surface Water, Soil	Excavation, Land Disposition	Yes, applicable or relevant and appropriate
Storm Water Discharge Regulations	40 CFR 122.26	Regulates discharges of storm water including runoff water.	Storm-water discharge is covered by the general permit for discharge from small construction or industrial activity sites. Requires a general permit or a site specific discharge permit, Storm-Water Pollution Control Plan, and implementation of Best Management Practices.	Surface Water, Soil	Excavation, Land Disposition	Yes, relevant and appropriate
Safe Drinking Water Act (SDWA)	42 USCA §§ 300f to 300j-26 (40 CFR 141, 143)	Establishes requirements for protection of drinking water.	Portions of the SDWA may be relevant and appropriate to site excavation operations and / or land disposition.	Ground and Surface Water	Excavation, Land Disposition	Yes, relevant and appropriate
National Primary Drinking Water Regulations	40 CFR 141	Establishes primary numerical limits and goals for contaminants to drinking water from public water systems	Maximum Contamination Levels (MCLs) promulgated in 40 CFR 141 are typically used to define site compliance for off-site migration requirements. Improperly conducted excavation operations could affect local waterways.	Ground and Surface Water	Excavation, Land Disposition	Yes, relevant and appropriate
National Secondary Drinking Water Regulations (NSDWRs)	40 CFR 143	NSDWRs are non-federally enforceable guidelines for states to control contaminants that may cause cosmetic effects or aesthetic effects in drinking water.	NSDWRs are non-federally enforceable but may be of concern to public acceptance of drinking water.	Ground and Surface Water	Excavation, Land Disposition	Yes, relevant and appropriate

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Colorado Water Quality Control Act	CRS 25—8-101 thru 803	Establishes Colorado requirements for water pollution prevention and control	Portions of Act may be applicable or relevant and appropriate to the site excavation operations and / or land disposition.	Ground and Surface Water	Excavation, Land Disposition	Yes, both
Basic Standards and Methodologies for Surface Water	5 CCR 1002-31 Regulation 31	Establishes basic standards, anti-degradation standard, and system for classifying state surface waters, and for assigning water quality standards.	Applicable or relevant and appropriate to component of remedy impacting surface water.	Surface Water	Excavation, Land Disposition	Yes, both
Classifications and Numeric Standards for South Platte River Basin tributaries, including Clear Creek	5 CCR 1002-38	Establishes classification and numeric standards to determine allowable concentrations. Discharges to surface waters must comply with basic, narrative, and numeric standards and control regulations to protect classified uses. Used in conjunction with basic standards and methodologies in Regulation 31.	For any surface water discharge identified, compliance is required for Segments 11 and 14 of Clear Creek Basin.	Surface Water	Excavation, Land Disposition	Yes, applicable
Basic Standards for Groundwater	5 CCR 1002-41	Establishes standards and water quality standards for groundwater classifications.	Must comply with substantive narrative and numerical limits.	Groundwater	Excavation, Land Disposition	Yes, applicable
State Discharge Permit Regulations	5 CCR 1002-61	Requires a permit for the discharge of pollutants from a point source into waters of the State, including storm water permits.	Must comply with substantive and administrative requirements.	Surface Water, Groundwater	Excavation, Land Disposition	Yes, applicable

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Storm Sewer Discharge Regulations	5 CCR 1002-65 Regulation 65; CRS 25-8-205	Establishes permit requirements relating to discharges into storm sewers.	Storm sewer regulations are applicable to run-off of pollutants from the site to a storm sewer.	Surface Water	Excavation, Land Disposition	Yes, applicable
Colorado Primary Drinking Water Regulations	5 CCR 1003-1	Establishes maximum numerical limits for contaminants (MCLs) to public drinking water systems.	MCLs are typically used to define site compliance at site boundaries or points of compliance. Improperly conducted excavation operations or on-site remedies could affect local water. Must comply with substantive requirements.	Ground and Surface Water	Excavation, Land Disposition	Yes, relevant and appropriate
Solid Waste Disposal Act (SWDA)	42 U.S.C.A. §§ 6901 to 6992K	Establishes requirements for solid waste and hazardous waste definitions and disposal	Portions of the SWDA are relevant and appropriate for on-site or off-site disposal alternatives.	Soils, Groundwater, Surface Water, Air	Land Disposition, Disposal	Yes, relevant and appropriate
Guidelines For The Storage And Collection Of Residential, Commercial, And Institutional Solid Waste	40 CFR 243	Establishes minimum levels of performance guidelines and requirements for solid waste collection operations.	Potentially relevant and appropriate and TBC to on-site options and off-site disposal facilities. Explicitly excluded are mining, industrial, hazardous, construction, and demolition wastes.	Soils	Land Disposition, Disposal	Potentially relevant and appropriate and TBC
Hazardous Waste Management System	40 CFR 260	Provides definitions of terms, general standards applicable to other parts of hazardous waste regulations	Some portions relevant and appropriate for waste identification and generator provisions.	Soils and Groundwater	Land Disposition, Disposal	Yes, relevant and appropriate
Identification and Listing of Hazardous Waste	40 CFR 261	Identifies those solid wastes that are subject to regulation as hazardous wastes.	Relevant and appropriate for hazardous waste identification.	Soils and Groundwater	Land Disposition, Disposal	Yes, relevant and appropriate
Standards Applicable To Generation of Hazardous Wastes	40 CFR 262	Establishes standards to generators of hazardous wastes.	Not relevant and appropriate because affected materials are not hazardous wastes nor like hazardous wastes, except for hazardous waste identification process in 262.11 which is applicable.	Soils and Groundwater	Land Disposition, Disposal	No
Standards Applicable	40 CFR 264 and 265	Establishes standards for	Not relevant and appropriate because affected	Soils and	Land	No

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
to Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities		owners and operators of hazardous waste treatment, storage and disposal facilities.	materials are not hazardous wastes.	Groundwater	Disposition, Disposal	
Land Disposal Restrictions	40 CFR 268	Identifies hazardous waste materials that cannot be disposed of in a solid waste landfill and defines the circumstances under which an otherwise prohibited waste may be disposed in a solid waste landfill.	Site material is solid waste, not hazardous waste.	Soils	Land Disposition, Disposal	No, relevant and appropriate if wastes exceed characteristic threshold for hazardous waste, which they don't
Solid Wastes Disposal Sites and Facilities Act	CRS 30-20-100.5 to 120	Establishes requirements for solid waste disposal sites.	Portions of the Act are applicable for on-site and off-site disposal alternatives.	All	Land Disposition, Disposal	Yes, applicable
Solid Wastes Disposal Sites and Facilities Regulations	6 CCR 1007-2 Part I, Sections 1-4, and Parts II and III	Establishes minimum standards, closure requirements, site standards and engineering design standards for solid waste and hazardous waste disposal facilities.	Applicable to off-site disposal facilities within the State, and to on-site alternatives for solid wastes. The hazardous waste provisions (Parts II and III) are not applicable nor relevant and appropriate.	All	Land Disposition, Disposal	Applicable with respect to solid waste provisions only (Part I)
Land Disposal Restrictions	6 CCR 1007-3 Part 268	Identifies hazardous waste materials that cannot be disposed of in a solid waste landfill and defines the circumstances under which an otherwise prohibited waste may be land disposed.	Site material is solid waste, not hazardous waste.	Soils	Land Disposition, Disposal	Yes, applicable if wastes exceed characteristic threshold for hazardous waste, which they don't
Colorado Hazardous Waste Regulations,	6 CCR 1007-3, Parts 260, 261, 262.11	Defines hazardous wastes, requires waste	Site materials are not hazardous wastes after application of hazardous waste identification	All	Land Disposition,	Yes, portions are applicable

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Waste Characterization		characterization.	requirements, so substantive requirements are not applicable.		Disposal	and portions not applicable because affected materials are not hazardous wastes
Colorado Hazardous Waste Regulations	6 CCR 1007-3, Parts 264 and 265	Standards for owners and operators of hazardous waste treatment, storage, and disposal facilities.	Not applicable because affected materials are not hazardous wastes, nor relevant or appropriate because not like hazardous wastes.	All	Land Disposition, Disposal	No, materials at Site are not hazardous wastes, nor like hazardous waste
Endangered Species Habitat	U.S. Fish and Wildlife Service – Mountain – Prairie Region - Colorado	Lists endangered species in Colorado	Sufficient data is available, a detailed study is not required to determine if any endangered species are located on site.	NA	Land Disposition, Excavation	Yes, applicable.
Migratory Bird Treaty Act	16 U.S.C. § 703-712; 2 CCR 406-5	Cannot disturb native migratory birds during the breeding season	Restricts work in areas where birds may be nesting	All	Land Disposition, Excavation, Disposal	Yes, applicable
Protection of Fishing Streams	CRS 33-5-101 *et seq.*	Restricts modification of fishing streams	May apply if work will change stream bank or channel	All	Land Disposition, Excavation, Disposal	Yes, applicable
100 Year Floodplain	City of Golden Colorado Municipal Code – Title 19; 2 CCR 408-1 Rule 12	Requirements for obtaining permits associated with specific activities occurring in floodplain hazard areas	Affected soil to the east of the former settling pond is within the Clear Creek 100-year flood plain. State agencies not subject to local permit requirements.	Soil, Surface Water	Land Disposition, Disposal, Excavation	Yes, relevant and appropriate as to substantive requirements

Applicable or Relevant and Appropriate Requirements – Supplements the ARARs provided in Section 8.						
Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Comments	Media	Affected Operations	Applicable or Relevant and Appropriate
Sites of Historical Importance – National Historic Preservation Act	Colorado Office of Archaeology and Historic Preservation – Golden Colorado See www.historycolorado.org/oahp/jefferson-county#golden	Lists Registered Historical Sites in Golden Colorado	Two state historical sites are located near the Colorado School of Mines but not on the Site.	NA	Excavation, Land Disposition	No, because no historical sites are on the Site.

TABLE 1
Action Specific State and Federal Applicable or Relevant and Appropriate Requirements
No Action Alternative

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Colorado Hazardous Waste Regulations, Waste Characterization	6 CCR 1007-3, Parts 260, 261, 262.11	Defines hazardous wastes, requires waste characterization.	Applicable or relevant and appropriate.	Characterization required todetermine if the soil contains characteristic or listed RCRA hazardous waste.	All
Colorado Hazardous Waste Regulations	6 CCR 1007-3, Part 264 and Part 265	Standards for owners and operators of hazardous waste treatment, storage, and disposal facilities. Requirements for managing hazardous waste based upon the mode of management, i.e., container storage, waste piles, impoundments, etc.	Not applicable, nor relevant or appropriate: wastes are not hazardous wastes nor like hazardous wastes.	Potentially applicable if RCRA hazardous wastes are present within the soil. Current data indicates that RCRA wastes are not present so these requirements are not applicable, nor relevant or appropriate because not like hazardous wastes.	All
Land Disposal Restrictions	40 CFR Part 268 6 CCR 1007-3 Part 268	Establishes treatment and prohibition standards for land disposal of selected hazardous wastes.	Potentially Applicable	Potentially applicable to off-site disposal if restricted RCRA wastes are encountered, but none are.	Soil
Radiation Control Act	CRS 25-11-101-305	Establishes state radiation control program.	Portions applicable or relevant and appropriate	Applicability depends on whether license is required or not.	All
Rules and Regulations Pertaining to Radiation Control	6 CCR 1007-1, Part 1	General provisions (including definitions) for 6 CCR 1007-1.	Portions applicable or relevant and appropriate		All Media
Radiation Control Act	CRS 25-11-201, et seq., Part 2	Provides procedural requirements for disposal of classified waste at facilities required to be licensed for uranium mill, processing or disposal.	No	Not applicable or relevant or appropriate because no alternative includes disposal at such facilities in Colorado.	All Media
	6 CCR 1007-1, Part 3	Regulations concerning licensing of radioactive materials.	No	On-site materials do not require a radioactive materials license.	All Media
	6 CCR 1007-1, Part 4	Establishes standards for protection against radiation hazards.	Relevant and Appropriate.	Substantive portions for cleanup are relevant and appropriate.	All Media
	6 CCR 1007-1, Part 10	Notes, instructions, and reports to workers.	Relevant and Appropriate.	Substantive portions are relevant and appropriate.	All Media

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
	6 CCR 1007-1, Part 14	Establishes standards for the land disposal of low-level radioactive wastes	No	Not applicable or relevant and appropriate because on-site impacted materials are not low level radioactive wastes, nor like LLW.	All Media
	6 CCR 1007-1, Part 17	Transportation of radioactive materials	No	Transportation not required for no action.	All Media
	6 CCR 1007-1, Part 18	Licensing and cleanup requirements for milling facilities and the disposition of products of milling operations for uranium, thorium and related materials.	Relevant and Appropriate.	Cleanup criteria relevant and appropriate to on-site issues.	All Media
Colorado Environmental Covenant	C.R.S. §25-15-318 – 321	Requires an environmental covenant to ensure continuance of land use restriction if remedy is on-site with restricted uses.	Applicable	For on-site remedies with restricted uses only	All Media
TENORM Guidance	Interim Policy and Guidance Pending Rulemaking for Control and Disposition of Technologically-Enhanced Naturally Occurring Radioactive Materials in Colorado, Rev. 2.1, Final Draft for Comment, February 2007	Guidance re: TENORM Materials	TBC	Provides sampling and disposal guidelines for TENORM	All Media
Solid Wastes Disposal Sites and Facilities Act	CRS 30-20-100.5 to 120	Establishes requirements for solid waste disposal sites.	Portions Applicable.		All
Solid Wastes Disposal Sites and Facilities Regulations	6 CCR 1007-2, Part I Sections 1-4, and Parts II and III	Establishes minimum standards, closure requirements, site standards and engineering design standards for solid waste disposal facilities.	Applicable for solid waste provisions. Hazardous waste provisions not applicable or relevant or appropriate.	Applicable to on-site disposal.	All
Clean Water Act	33 USC 1251 to 1387	Water pollution prevention.	Portions relevant and appropriate.		Surface Water
Standards for Fill or Excavation in Waters of the United States	33 CFR 320, 323, 328, and 330	Discharges or dredge or fill in waters of the U.S.	Substantive portions potentially relevant and appropriate or applicable.	Substantive portions potentially applicable or relevant and appropriate to fill and excavation in Clear Creek floodplain	Surface Water and Soil

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Storm Water Discharge Regulations	40 CFR 122.26	Regulates discharges of storm water and runoff water.	Relevant and appropriate.	Storm water discharge is covered by the general permit for discharge from construction sites. Utilize Best Available Technology (BAT) and Best Conventional Pollutant Control Technology.	Surface Water and Soil
Colorado Water Quality Control Act	CRS 25-8-101-803	Water pollution prevention.	Applicable or relevant and appropriate.		Surface Water and Groundwater
Basic Standards and Methodologies for Surface Water	5 CCR 1002-31	Establishes basic standards, anti-degradation standard, system for classifying state waters.	Applicable or relevant and Appropriate.	Applicable or relevant or appropriate to component of remedy impacting surface water	Surface Water
Classifications and Numeric Standards, South Platte River Basin, et al.	5 CCR 1002-38	Used in conjunction with basic standards and methodologies in Regulation 31.	Applicable.	For any surface water discharge identified, compliance is required for Segment 11 and 14 of Clear Creek Basin.	Surface Water
State Discharge Permit Regulations	5 CCR 1002-61	Requires a permit for the discharge of pollutants from a point source into waters of the State, including storm water.	Applicable.	Must comply with substantive and administrative requirements.	Surface Water
Storm Sewer Discharge Regulations	5 CCR 1002-65	Establishes requirements relating to discharges into storm sewers.	Applicable.	Storm sewer regulations are applicable to run-off from the site.	Surface Water
Occupational Safety and Health Act	29 USC 651-678 29 CFR 1910.96 29 CFR 1926	Regulates worker health and safety.	Applicable.	Independently applicable. Requirements of this act apply to all response actions under the NCP.	All
Federal Register Vol 64 No. 264 page 68396 Table 3	64 FR 68395-01	Establishes individual radionuclide concentrations deemed compliant with 25 merm/y unrestricted release dose limit in 10 CFR 20.1402	TBC	These interim screening values may be relevant and appropriate if they are used as the soil clean-up criteria	soil
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 19)	10 CFR 19	Establishes standards for protection of workers who will be exposed to 100 mrem (1 mSv) in 1 year.	Possibly relevant and appropriate	Limit to 100 mrem per year.	All

Standard Requirement, Criteria or Limitation	**Citation**	**Description or Requirements**	**Applicable or Relevant and Appropriate**	**Comments**	Media
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 20, 40)	10 CFR 20.1201-8;1301-2; 1402, 1403; 10 CFR 40.42.	Establishes standards for protection of the public against radiation arising from the use of regulated materials. Remedial alternatives need to limit external and internal exposure from releases to levels that do not exceed 100 mrem/y, or 2 mrem/h from external exposure in unrestricted areas. These requirements also establish criteria for closing NRC-licensed sites including a soil remediation standard of 25 mrem/y or 100 mrem/y if institutional controls fail.	Relevant and appropriate	This regulation establishes standards for protection of the public against radiation arising from the use of regulated materials and is relevant and appropriate. Radioactive material from sources not licensed by the NRC are not subject to these regulations, therefore, this standard is applicable because this site is under CERCLA jurisdiction	All
EPA Memorandum, Radiation Risk Assessment at CERCLA Sites: Q&A, OSWER Directive 9200.4-31P		This memorandum provides guidance on conducting risk assessments at radioactively contaminated CERCLA sites. EPA dose limits are to generally achieve risk levels in the 10-4 to 10-6 risk range	TBC	This memorandum is TBC, but is considered by the EPA to be more protective than NRC dose standards, and consistent with CERCLA's risk management requirements.	
EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, Aug. 1997		This memorandum provides guidance on using a risk-based approach to setting exposure limits to less than 15 mrem/yr for NCP compliance.	Applicable or Relevant and Appropriate		Soil
EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, Jul. 22, 1996		This memorandum was the initial discussion that resulted in the recommended 15 mrem/yr dose limit.	TBC		Soil

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, OSWER No. 9200.4-25, Feb. 1998		This memorandum clarifies the use of 40 CFR 192 for the development of radionuclide soil standards.	Applicable or Relevant and Appropriate		Soil

TABLE 2
Action-Specific State and Federal Applicable or Relevant and Appropriate Requirements
On-Site Alternatives

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Clean Air Act	40 CFR 50 to 69	Air pollution control	Relevant and appropriate		Air
New Source Performance Requirements	40 CFR 60	Establishes emission standards for new air emissions	Potentially relevant and appropriate	If temporary air pollution sources that are sufficiently similar to those sources covered by these regulations are part of the remedy, the regulations may be relevant and appropriate	Air
CAA - National Emission Standards for Hazardous Air Pollutants (NESHAP)	40 CFR 61	Establishes standards for certain HAP emissions from some sources	Potentially relevant or appropriate	To the extent the activities involve the emission of regulated constituents and activities similar to those addressed in these regulations, they may be relevant and appropriate.	Air
Colorado Air Quality Control Act	CRS 25-7-101, et seq.	Air pollution control	Applicable		Air
Common Provision Regulations	5 CCR 1001-2 Section II	Conduct performance tests, applicable emissions monitoring, and recordkeeping	Applicable	Substantive requirements are applicable to air emission component of the remedy	Air
Regulation No. 1	5 CCR 1001-3 Regulation No. 1	Establishes emission control regulations for particulates, smoke, carbon monoxide, sulfur oxides and fugitive particulate emissions.	Portions are Applicable	See below for description of specific provisions	Air
Regulation No. 1	5 CCR 1001-3 Regulation No. 1, Section II.A.1	Comply with opacity limitations.	Applicable	Less than 20% opacity emitted, specific sources may have other limitations. Applies only to smoke.	Air
Regulation No. 1	5 CCR 1001-3 Regulation No. 1, Section III.D	Minimize fugitive particulate emissions.	Applicable	Applicable to construction activities, storage and handling operations, haul roads and haul trucks, and tailings piles. Relevant and appropriate to non-specific sources.	Air
Regulation No. 3	5 CCR 1001-5 Regulation No. 3, Part A Section II	File APEN including estimation of emission rates if 2 TPY exceeded.	Applicable	Substantive portions are applicable to all sources including earthwork and existing sources unless specifically exempt.	Air
Ambient Air Quality Standards	5 CCR 1001-14	Sets ambient standards for total suspended particulates, sulfur dioxide, oxidant, carbon monoxide, nitrogen dioxide.	Applicable	Would be applicable if remedy would cause emission of regulated constituents including particulates and ozone that would contribute to NAAQS violation.	Air

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Colorado Hazardous Waste Regulations, Waste Characterization	6 CCR 1007-3, Parts 260, 261, 262.11	Defines hazardous wastes, requires waste characterization.	Applicable or relevant and appropriate	Characterization required to determine if the soil contains characteristic or listed RCRA waste.	All
Colorado Hazardous Waste Regulations, Waste Characterization	6 CCR 1007-3, Part 264 and Part 265	Standards for owners and operators of hazardous waste treatment, storage, and disposal facilities. Requirements for managing hazardous waste based upon the mode of management, i.e., container storage, waste piles, impoundments, etc.	Not applicable, not relevant and appropriate	Potentially applicable if RCRA hazardous wastes are present within the soil. Current data indicates that RCRA wastes are not present so these requirements are not applicable, nor relevant or appropriate because not like hazardous wastes.	All
Land Disposal Restrictions	40 CFR Part 268 6 CCR 1007-3 Part 268	Establishes treatment and prohibition standards for land disposal of selected hazardous wastes.	Not Applicable	Potentially applicable to off-site disposal if restricted RCRA wastes are encountered, which they were not.	Soil
Radiation Control	CRS 25-11-101-305	Radiation control.			
Rules and Regulations Pertaining to Radiation Control	6 CCR 1007-1, Part 1	General provisions (including definitions) for 6 CCR 1007-1.	Portions applicable or relevant and appropriate.		All Media
Radiation Control	CRS 25-11-201, et seq., Part 2	Provides procedural requirements for disposal of classified waste at facilities required to be licensed for uranium mill, processing or disposal.	No	Not applicable or relevant or appropriate because no alternative includes disposal at such facilities in Colorado.	All Media
	6 CCR 1007-1, Part 3	Regulations concerning licensing of radioactive materials.	Not applicable or relevant or appropriate	No license required for on-site disposal.	All Media
	6 CCR 1007-1, Part 4	Establishes standards for protection against radiation hazards.	Relevant and Appropriate.	Substantive cleanup portions are relevant and appropriate.	All Media
	6 CCR 1007-1, Part 10	Notes, instructions, and reports to workers.	Relevant and Appropriate.	Substantive portions are relevant and appropriate.	All Media
	6 CCR 1007-1, Part 14	Establishes standards for the land disposal of low-level radioactive wastes	No	Not applicable or relevant and appropriate because on-site impacted materials are not low level radioactive wastes, nor like LLW.	All Media
	6 CCR 1007-1, Part 17	Transportation of radioactive materials	Relevant and Appropriate.	Substantive portions are relevant and appropriate.	All Media

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
	6 CCR 1007-1, Part 18	Licensing and cleanup requirements for milling facilities and the disposition of products of milling operations for uranium, thorium and related materials.	Relevant and appropriate.	Substantive portions related to cleanup are relevant and appropriate.	All Media
Colorado Environmental Covenant	C.R.S. §25-15-318 - 321	Requires an environmental covenant to ensure continuance of land use restriction if remedy is on-site with restricted uses.	Applicable	For on-site remedies with restricted uses only	All Media
TENORM Guidance	Interim Policy and Guidance Pending Rulemaking for Control and Disposition of Technologically-Enhanced Naturally Occurring Radioactive Materials in Colorado, Rev. 2.1, Final Draft for Comment, February 2007	Guidance re: TENORM Materials	TBC	Provides sampling and disposal guidelines for TENORM	All Media
Solid Wastes Disposal Sites and Facilities Act	CRS 30-20-100.5 to 120	Establishes requirements for solid waste disposal sites.	Portions applicable.		All
Solid Wastes Disposal Sites and Facilities Regulations	6 CCR 1007-2, Part I, Sections 1-4, and Parts II and III	Establishes minimum standards, closure requirements, site standards and engineering design standards for solid waste disposal facilities.	Applicable for solid waste provisions. Hazardous waste provision not applicable or relevant or appropriate.	Potentially applicable to on-site disposal.	Soil
Clean Water Act	33 USC 1251 to 1387	Water pollution prevention	Portions relevant and appropriate.		Surface Water
Standards for Fill or Excavation in Waters of the United States	33 CFR 320, 323, 328, and 330	Discharges of dredge or fill in waters of the U.S.	Substantive portions potentially relevant and appropriate or applicable.	Substantive portions potentially applicable or relevant and appropriate to fill and excavation in Clear Creek floodplain.	Surface Water
Storm Water Discharge Regulations	40 CFR 122.26	Regulates discharges of storm water and runoff water.	Relevant and appropriate.	Storm water discharge is covered by the general permit for discharge from construction sites. Utilize Best Available Technology (BAT) and Best Conventional Pollutant Control Technology.	Surface Water and Soil

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Colorado Water Quality Control Act	CRS 28-8-101-803	Water pollution prevention.	Applicable or relevant and appropriate.		Surface Water and Groundwater
Basic Standards and Methodologies for Surface Water	5 CCR 1002-31	Establishes basic standards, anti-degradation standard, system for classifying state waters.	Applicable or Relevant and Appropriate	Applicable or relevant or appropriate to component of remedy impacting surface water	Surface Water
Classifications and Numeric Standards, South Platte River Basin, et al.	5 CCR 1002-38	Used in conjunction with basic standards and methodologies (Section 3.1.0)	Applicable	For any surface water discharge identified, compliance is required for Segment 11 and 14 of Clear Creek Basin.	Surface Water
State Discharge Permit Regulations	5 CCR 1002-61	Requires a permit for the discharge of pollutants from a point source into waters of the State.	Applicable	Must comply with substantive and administrative requirements.	Surface Water
Storm Sewer Discharge Regulations	5 CCR 1002-65	Establishes requirements relating to discharges into storm sewers.	Applicable	Storm sewer regulations are applicable to run-off from the site.	Surface Water
Occupational Safety and Health Act	29 USC 651-678 29 CFR 1910.96 29 CFR 1926	Regulates worker health and safety.	Applicable	Independently applicable. Requirements of this act apply to all response actions under the NCP.	All
Federal Register Vol 64 No. 264 page 68396 Table 3	64 FR 68395-01, Dec. 7, 1999, NCR Supplemental Information to License Termination Rule	Establishes individual radionuclide concentrations deemed compliant with 25 merm/y unrestricted release dose limit in 10 CFR 20.1402 for surface soils, but not for sites with subsurface and groundwater contamination.	TBC	These interim screening values may be relevant and appropriate if they are used as the surface soil clean-up criteria with ALARA.	Surface soil
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 19)	10 CFR 19	Establishes standards for protection of workers who will be exposed to 100 mrem (1 mSv) in 1 year.	Possibly relevant and appropriate	Limit to 100 mrem per year.	All

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 20, 40)	10 CFR 20.1201-8;1301-2; 1402, 1403 10 CFR 40.42	Establishes standards for protection of the public against radiation arising from the use of regulated materials. Remedial alternatives need to limit external and internal exposure from releases to levels that do not exceed 100 mrem/y, or 2 mrem/h from external exposure in unrestricted areas. These requirements also establish criteria for closing NRC-licensed sites including a soil remediation standard of 25 mrem/y or 100 mrem/yr if institutional controls fail.	Relevant and appropriate	This regulation establishes standards for protection of the public against radiation arising from the use of regulated materials and is relevant and appropriate. Radioactive material from sources not licensed by the NRC are not subject to these regulations, therefore, this standard is not applicable.	All
EPA Memorandum, Radiation Risk Assessment at CERCLA Sites: Q&A, OSWER Directive 9200.4-31P		This memorandum provides guidance on conducting risk assessments at radioactively contaminated CERCLA sites. EPA dose limits are to generally achieve risk levels in the 10-4 to 10-6 risk range, which equates to 15 mrem/yr TEDE standard.	TBC	This memorandum is TBC, but is considered by the EPA to be more protective than NRC dose standards and consistent with NCP requirements.	All
Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Rev 1 August 2000	NUREG-1575; EPA 402-R-97-016	Guidance for radiological surveys to demonstrate compliance with cleanup criteria.	TBC		All
EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, Aug. 1997		This memorandum provides guidance on using a risk-based approach to setting exposure limits to less than 15 mrem/yr for NCP compliance.	Applicable or Relevant and Appropriate		Soil

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, Jul. 22, 1996		This memorandum was the initial discussion that resulted in the recommended 15 mrem/yr dose limit.	TBC		Soil
EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, OSWER No. 9200.4-25, Feb. 1998		This memorandum clarifies the use of 40 CFR 192 for the development of radionuclide soil standards.	Applicable or Relevant and Appropriate		Soil

TABLE 3
Action-Specific State and Federal Applicable or Relevant and Appropriate Requirements
Compliance Evaluation for Off-Site Alternatives

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Clean Air Act	40 CFR 50 to 69	Air pollution control.	Relevant and appropriate			
New Source Performance Requirements	40 CFR 60	Establishes emission standards for new air emissions	Potentially relevant and appropriate	If temporary air pollution sources that are sufficiently similar to those sources covered by these regulations are part of the remedy, the regulations may be relevant and appropriate.	Air	None of the off-site RA alternatives will use new air emission sources that are sufficiently similar to those sources covered by the regulations. Therefore, this standard is not applicable or relevant and appropriate.
Colorado Air Quality Control Act	CRS 25-7-101-512					
Common Provision Regulations	5 CCR 1001-2, Section II	Conduct performance tests, applicable emissions monitoring, and recordkeeping	Applicable	Substantive requirements are applicable to air emission component of the remedy.	Air	Perimeter air monitoring as set forth in Section 4.1.3 will be a component of the off-site RA alternatives during construction. This monitoring satisfies the performance testing required by the Air Quality Control Division for stationary sources. The results of the perimeter air monitoring will be recorded and maintained on-site or at another suitable location.
Regulation No. 1	5 CCR 1001-3, Regulation No. 1	Establishes emission control regulations for particulates, smoke, carbon monoxide, sulfur oxides and fugitive particulate emissions.	Portions are Applicable	See below for description of specific provisions.	Air	See below for attainment of specific provisions.
Regulation No. 1	5 CCR 1001-3, Regulation No. 1, Section II.A.1	Comply with opacity limitations.	Applicable	Less than 20% opacity emitted, specific sources may have other limitations.	Air	None of the off-site RA alternatives include an air emissions source which would require monitoring for opacity limitations.

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Regulation No. 1	5 CCR 1001-3, Regulation No. 1, Section III.D	Minimize fugitive particulate emissions.	Applicable, Relevant and Appropriate	Applicable to construction activities, storage and handling operations, haul roads and haul trucks, and tailings piles. Relevant and appropriate to non-specific sources.	Air	For all of the off-site RA alternatives. fugitive particulate emissions will be minimized during remediation by implementing the dust control procedures identified in Section 4.1.3. In addition, fugitive particulate emissions from storage and handling operations will be minimized by covering soil stockpiles with geotextile when not in use and implementing the dust control procedures set forth in Section 4.1.3.
Regulation No. 3	5 CCR 1001-5, Regulation No. 3, Part A Section II	File APEN including estimation of emission rates, if 2 TPY exceeded.	Applicable	Substantive portions are applicable to all sources including earthwork and existing sources unless specifically exempt.	Air	File APEN, if necessary.
Ambient Air Quality Standards	5 CCR 1001-14	Sets ambient standards for total suspended particulates, sulfur dioxide, oxidant, carbon monoxide, nitrogen dioxide.	Applicable	Would be applicable if remedy would cause emission of regulated constituents.	Air	Emission of regulated constituents other than small amounts of total suspended particulates is not anticipated during the implementation of any of the off-site RA alternatives. Dust control measures set forth in Section 4.1.3 will be used to attain the requirements of this regulation.
Hazardous Materials Transportation Safety and Security Reauthorizatoni Act of 2005	49 U.S.C. 5101 *et seq.*					
Transportation Regulations	49 CFR Parts 107, 171 to 174, and 177	Regulates transportation of hazardous materials. Part 173 is specific to Class 7 radioactive materials.	Not applicable or relevant and appropriate.	Wastes at Site are not Class 7 radioactive materials or like them.	Soils, Solids	N/A

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Colorado Hazardous Waste Regulations, Waste Characterization	6 CCR 1007-3, Parts 260, 261, 262.11	Defines hazardous wastes, requires waste characterization.	Applicable or relevant and appropriate.	Characterization required to determine if the soil contains characteristic or listed RCRA waste.	Soils	Soils have already been adequately characterized for the presence of RCRA hazardous wastes. Additional characterization activities are not required to meet these regulations for any of the off-site RA alternatives.
Colorado Hazardous Waste Regulations, Waste Characterization	6 CCR 1003-3, Part 264 and Part 265	Standards for owners and operators of hazardous waste treatment, storage, and disposal facilities. Requirements for managing hazardous waste based upon the mode of management, i.e., container storage, waste piles, impoundments, etc.	Not applicable or relevant and appropriate.	Potentially applicable if RCRA hazardous wastes are present within the soil.	Soils	Current data indicates that RCRA hazardous wastes are not present so these requirements are not applicable to any of the off-site RA alternatives.
Land Disposal Restrictions	40 CFR Part 268 6 CCR 1007-3, Part 268	Establishes treatment and prohibition standards for land disposal of selected hazardous wastes.	No		Soil	No RCRA wastes have been encountered.
Radiation Control	CRS 25-11-101 to 305	Radiation control.				
Rules and Regulations Pertaining to Radiation Control	6 CCR 1007-1, Part 1, All Sections with emphasis on 1.5, 1.6., and 1.7	General provisions (including definitions, exemptions, recordkeeping, and inspections).	Portions applicable or relevant and appropriate		All Media	The pertinent requirements (primarily administrative) set forth in these regulations will be met for each of the off-site RA alternatives within the State.

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
	CRS 25-11-201, et seq., Part 2	Provides procedural requirements for disposal of classified waste at facilities required to be licensed for uranium mill, processing or disposal.	No	Not applicable or relevant or appropriate because no alternative includes disposal at such facilities in Colorado.	All Media	
	6 CCR 1007-1, Part 3	Regulations concerning licensing of radioactive materials.	Portions relevant and appropriate	Relevant and appropriate to only one off-site disposal facility within the State (Clean Harbors).	All Media	Waste does not need a license.
	6 CCR 1007-1, Part 4	Establishes standards for protection against radiation hazards.	Relevant and Appropriate	Substantive cleanup portions are relevant and appropriate.	All Media	Substantive requirements of this standard will be met for each of the off-site alternatives including meeting permissible doses, levels, and concentration standards through the use of PPE, environmental monitoring, and dosimetry programs.
	6 CCR 1007-1, Part 10	Notes, instructions, and reports to workers.	Relevant and Appropriate	Substantive requirements are relevant and appropriate.	All Media	The pertinent requirements will be met for each of the off-site alternatives within the State.
	6 CCR 1007-1, Part 17	Transportation of radioactive materials	Relevant and Appropriate	Substantive portions are relevant and appropriate.	All Media	Packaging and transportation of radioactive materials will meet these standards for all of the off-site RA alternatives.
	6 CCR 1007-1, Part 18	Licensing requirements for milling facilities and the disposition of products of milling operations for uranium, thorium and related materials.	Not applicable or relevant and appropriate	Not applicable.	All Media	N/A to off-site alternatives.

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Colorado Environmental Covenant	C.R.S. §25-15-318 - 321	Requires an environmental covenant to ensure continuance of land use restriction if remedy is on-site with restricted uses.	Applicable	For on-site remedies with restricted uses only	All Media	
TENORM Guidance	Interim Policy and Guidance Pending Rulemaking for Control and Disposition of Technologically-Enhanced Naturally Occurring Radioactive Materials in Colorado, Rev. 2.1, Final Draft for Comment, February 2007	Guidance re: TENORM Materials	TBC	Provides sampling and disposal guidelines for TENORM	All Media	
Solid Wastes Disposal Sites and Facilities Act	CRS 30-20-100.5 to 120	Solid waste disposal sites				
Solid Wastes Disposal Sites and Facilities Regulations	6 CCR 1007-2, Part I, Sections 1-4, Parts II and III	Establishes minimum standards, closure requirements, site standards and engineering design standards for solid waste disposal facilities.	Applicable for solid waste provisions.	Applicable to off-site disposal facilities within the State.	All Media	For off-site RA alternatives which include disposal at a licensed solid waste disposal facility within the State. Will consider only lawful facilities.
Clean Water Act	33 USC 1251 to 1376	Water pollution prevention.				
Standards for Fill or Excavation in Waters of the United States	33 CFR 320, 323, 328, and 330		Applicable or relevant and appropriate		Surface Water	None of the off-site RA alternatives will include fills or excavations.

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Storm Water Discharge Regulations	40 CFR 122.26	Regulates discharges of storm water and runoff water.	Applicable	Storm water discharge is covered by the General Permit for Discharge from Construction Sites. Utilize Best Available Technology (BAT) and Best Conventional Pollutant Control Technology.	Surface Water	For all of the off-site RA alternatives, storm water discharge is covered by the General Permit for Discharge from Construction Sites. The substantive requirements of the general permit will be met by implementing storm water controls such as berms, silt fences, and retention basins as necessary to reduce the pollutants in storm water discharges for each of the off-site RA alternatives.
Colorado Water Quality Control Act	CRS 25-8-101-703	Water pollution prevention.	Applicable or relevant and appropriate			
Basic Standards and Methodologies for Surface Water	5 CCR 1002-31	Establishes basic standards, anti-degradation standard, system for classifying state waters.	Applicable or Relevant and Appropriate	Applicable or relevant and appropriate to component of remedy impacting surface water.	Surface Water	The substantive requirements of the section will be met by implementing storm water controls such as berms, silt fences, and retention basins as necessary to reduce the pollutants in storm water discharges for each of the off-site RA alternatives.
Classifications and Numeric Standards, South Platte River Basin, et al.	5 CCR 1002-38	Used in conjunction with basic standards and methodologies (Section 3.1.0)	Applicable	For any surface water discharge identified, compliance is required for Segments 11 and 14 of Clear Creek Basin.	Surface Water	The substantive requirements of the section will be met by implementing storm water controls such as berms, silt fences, and retention basins as necessary to reduce the pollutants in storm water discharges for each of the off-site RA alternatives.
State Discharge Permit Regulations	5 CCR 1002-61	Requires a permit for the discharge of pollutants from a point source into waters of the State.	Potentially Applicable	Must comply with substantive requirements.	Surface Water	The substantive requirements of the section will be met by implementing storm water controls such as berms, silt fences, and retention basins as necessary to reduce the pollutants in storm water discharges for each of the off-site RA alternatives.

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Storm Sewer Discharge Regulations	5 CCR 1002-65	Establishes requirements relating to discharges into storm sewers.	Applicable	Storm sewer regulations are applicable to run-off from the site.	Surface Water	The substantive requirements of the section will be met by implementing storm water controls such as berms, silt fences, and retention basins as necessary to reduce the pollutants in storm water discharges for each of the off-site RA alternatives.
Occupational Safety and Health Act	29 USC 651-678 29 CFR 1910.96 29 CFR 1926	Regulates worker health and safety.	Applicable	Independently applicable. Requirements of this act apply to all response actions under the NCP.	All	The Safety, Health and Emergency Response Plan sets forth the health and safety program to be implemented during the RA. Adherence to this plan satisfies these standards.
Federal Register Vol 64 No. 264 page 68396 Table 3	64 FR 68395-01	Establishes individual radionuclide concentrations deemed compliant with 25 merm/y unrestricted release dose limit in 10 CFR 20.1402	TBC	These interim screening values may be relevant and appropriate if they are used as the soil clean-up criteria	Soil	Perform dose modeling on site conditions to determine if individual radionuclide concentrations meet 25 mrem/yr and ALARA.
Primary Drinking Water Regulations	5 CCR 1003-1	Establishes drinking water standards for community water systems	Relevant and appropriate	Groundwater at Site not a community water system, but contributes to Clear Creek that is a source of drinking water	Groundwater	Substantive requirements will be met at points of compliance
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 19)	10 CFR 19	Establishes standards for protection of workers who will be exposed to 100 mrem (1 mSv) in 1 year.	Possibly relevant and appropriate	Remedial alternatives need to limit external and internal exposure from releases to levels that do not exceed 100 mrem/y, or 2 mrem/h per year.	All	Excavation, Land Disposition, Disposal

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Nuclear Regulatory Standards for Protection Against Radiation – (10 CFR 20, 40)	10 CFR 20.1201-8;1301-2; 1402, 1403; 10 CFR 40.42	Establishes standards for protection of the public against radiation arising from the use of regulated materials. Remedial alternatives need to limit external and internal exposure from releases to levels that do not exceed 100 mrem/y, or 2 mrem/h from external exposure in unrestricted areas. These requirements also establish criteria for closing NRC-licensed sites including a soil remediation standard of 25 mrem/y and 100 mrem/y if institutional controls fail.	Relevant and appropriate	This regulation establishes standards for protection of the public against radiation arising from the use of regulated materials and is relevant and appropriate. Radioactive material from sources not licensed by the NRC are not subject to these regulations, therefore, this standard is not applicable. No facility accepting site wastes will have an NRC license.	Soil	Confirmation sampling to show compliance with DCGLs.
EPA Memorandum, Radiation Risk Assessment at CERCLA Sites: Q&A, OSWER Directive 9200.4-31P		This memorandum provides guidance on conducting risk assessments at radioactively contaminated CERCLA sites. EPA dose limits are to generally achieve risk levels in the 10-4 to 10-6 risk range	TBC	This memorandum is TBC, but is considered by the EPA to be more protective than NRC dose standards, and consistent with NCP requirements.		Confirmation sampling to show compliance with DCGLs.

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Multi-Agency Radiation Survey and Site Investigation (MARSSIM) December 19999	NUREG-1575 EPA 402-R-97-016	Guidance for radiological surveys to demonstrate compliance with cleanup criteria	TBC		All	MARSSIM was followed.
EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, Aug. 1997		This memorandum provides guidance on using a risk-based approach to setting exposure limits to less than 15 mrem/yr for NCP compliance.	Applicable or Relevant and Appropriate		Soil	Confirmation sampling.
EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, Jul. 22, 1996		This memorandum was the initial discussion that resulted in the recommended 15 mrem/yr dose limit.	TBC		Soil	Confirmation sampling.
EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, OSWER No. 9200.4-25, Feb. 1998		This memorandum clarifies the use of 40 CFR 192 for the development of radionuclide soil standards.	Applicable or Relevant and Appropriate		Soil	Confirmation sampling.

TABLE 4
Chemical Specific State and Federal Applicable or Relevant and Appropriate Requirements
No Action Alternative

Standard Requirement, Criteria or Limitation	Description or Requirements	Citation	Applicable or Relevant and Appropriate	Comments	Media
Radium-226	Less than or equal to 5 pCi/g Ra-226 above background within 15 cm of the surface averaged over 100 square meter area. Less than or equal to 15 pCi/g above background within subsequent 15 cm layers of soil averaged over 100 square meter area.	40 CFR 192.12(a); 6 CCR 1007-1, Part 18, Criterion 6.	Relevant and Appropriate	Standard for clean-up of land at inactive uranium processing sites.	Soils
Radium- 226	7.0E-01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Thorium- 228	4.7E+00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Uranium- 234	1.3E+01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Uranium- 238	1.4E+01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils

Standard Requirement, Criteria or Limitation	Description or Requirements	Citation	Applicable or Relevant and Appropriate	Comments	Media
Thorium- 230	1.8E-00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Thorium- 232	1.1E-00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Thorium-230	Clean-up level calculated using initial Ra-226 concentration and assuming period for Th-230 ingrowth; depth of backfill may be considered.	Generic protocol for excavation of Th-230, DOE, January 15, 1989	TBC	DOE standard modified by EPA's January 16, 1992 letter. To be considered for excavation of clay liner under the waste pile.	Soils
Radon Decay Products	Objectives of remedial action to achieve an annual average not to exceed 0.02 WL. In any case, not to exceed 0.03 WL.	40 CFR 192.12(b)(1)	Relevant and Appropriate	Standard for clean-up of inactive uranium processing sites. Relevant and appropriate if occupied or habitable buildings planned for site.	Air
Radiation	Gamma radiation shall not exceed background levels by more than 20 microR per hour.	40 CFR 192.12(b)(2)	Relevant and Appropriate	Standard for clean-up of inactive uranium processing sites. Relevant and appropriate if occupied or habitable buildings planned for site.	Soils
Radiation	Standards for protection against radiation.	10 CFR 20 6 CCR 1007-1 Part 4	Relevant and Appropriate	Substantive portions are relevant and appropriate.	All Media
Radiation Dose	25 mrem/y TEDE above background plus ALARA	10 CFR 20.1402; 6 CCR 1007-1, 4.61.2	Relevant and Appropriate	For unrestricted use cleanup.	All
Radiation Dose	25 mrem/y TEDE above background plus ALARA, plus 100 mrem/y TEDE if institutional controls fail.	10 CFR 20.1403; 6 CCR 1007-1, 4.61.3	Relevant and Appropriate	For restricted use cleanup.	All
Radiation Dose	15 mrem/yr TEDE above background	EPA Memo, OSWER Directive 9200.4-31P, Radiation Risk Assessment at CERCLA Sites	TBC	For CERCLA compliant cleanup	All

Standard Requirement, Criteria or Limitation	Description or Requirements	Citation	Applicable or Relevant and Appropriate	Comments	Media
Radiation Dose	15 mrem/yr	EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, Aug. 1997	Applicable or Relevant and Appropriate	This memorandum provides guidance on using a risk-based approach to setting exposure limits to less than 15 mrem/yr for NCP compliance.	Soil
Radiation Dose	15 mrem/yr	EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, Jul. 22, 1996	TBC	This memorandum was the initial discussion that resulted in the recommended 15 mrem/yr dose limit.	Soil
Radiation Dose		EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, OSWER No. 9200.4-25, Feb. 1998	Applicable or Relevant and Appropriate	This memorandum clarifies the use of 40 CFR 192 for the development of radionuclide soil standards.	Soil
Radiation Dose	10^{-4} - 10^{-6} cancer risk	40 CFR 300.430(e)(2)	Applicable	For CERCLA compliant cleanup	All
Radiation Dose	ICRP Publication 30 provides recommended Annual Limits on Intake and Derived Air Concentrations designed to limit the intake of radioactive materials by workers.	ICRP 30	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this international guidance is to be considered.	All Media
Radiation Dose	Federal Guidance Report No. 11 provides Annual Limits on Intake and Derived Air Concentrations to be implemented by federal agencies to limit the intake of radioactive materials by workers.	Federal Guidance Report No. 11	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this Federal guidance is to be considered.	All Media
Air Pollutants	National Emission Standards for Hazardous Air Pollutants (NESHAP)	40 CFR 61, 6 CCR 1007-1 part 4; OSWER 9200.4-25	Relevant and Appropriate	To the extent the remedial activities involve the emission of regulated constituents and activities similar to those addressed in these regulations, they may be relevant and appropriate.	Air

Standard Requirement, Criteria or Limitation	Description or Requirements	Citation	Applicable or Relevant and Appropriate	Comments	Media
Arsenic	Less than 0.39 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Land use. Due to high background levels, a higher limit is applied.	Soil
Lead (inorganic)	Less than 400 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Landuse	Soil
Mercury (compounds) Mercury (elemental)	Less than 23 mg/kg 13 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Landuse	Soil
Vanadium	390 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC		Soil
Molybdenum	390 mg/kg	EPA Region 9 Memorandum, Region 9 Regional Screening Levels (formerly PRGs), updated as of June 2011	TBC		Soil

TABLE 5
Chemical-Specific State and Federal Applicable or Relevant and Appropriate Requirements
On-Site Alternatives

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media
Radium-226	Less than or equal to 5 pCi/g above background within 15 cm of the surface averaged over 100 square meter area. Less than or equal to 15 pCi/g above background within subsequent 15 cm layers of soil averaged over 100 square meter area.	40 CFR 192.12(a) 6 CCR 1007-1, Part 18, Criterion 6.	Relevant and Appropriate	Standard for clean-up of land at inactive uranium processing sites.	Soils
Radium- 226	7.0E-01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Thorium- 228	4.7E+00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Uranium- 234	1.3E+01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Uranium- 238	1.4E+01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Thorium- 230	1.8E-00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media
Thorium- 232	1.1E-00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils
Radon Decay Products	Objectives of remedial action to achieve an annual average not to exceed 0.02 WL. In any case, not to exceed 0.03 WL.	40 CFR 192.12(b)(1)	Relevant and Appropriate	Standard for clean-up of inactive uranium processing sites. Relevant and appropriate if occupied or habitable buildings planned for site.	Air
Radiation	Gamma radiation shall not exceed background levels by more than 20 microR per hour.	40 CFR 192.12(b)(2)	Relevant and Appropriate	Standard for clean-up of inactive uranium processing sites. Relevant and appropriate if occupied or habitable buildings planned for site.	Soils
Radiation	Standards for protection against radiation.	10 CFR 20 6 CCR 1007-1 Part 4	Relevant and Appropriate	Substantive portions are relevant and appropriate.	All Media
Radiation Dose	25 mrem/y TEDE above background plus ALARA	10 CFR 20.1402; 6 CCR 1007-1, 4.61.2	Relevant and Appropriate	For unrestricted use cleanup.	All
Radiation Dose	25 mrem/y TEDE above background plus ALARA, plus 100 mrem/y TEDE if institutional controls fail.	10 CFR 20.1403; 6 CCR 1007-1, 4.61.3	Relevant and Appropriate	For restricted use cleanup.	All
Radiation Dose	15 mrem/yr TEDE above background	EPA Memo, OSWER Directive 9200.4-31P, Radiation Risk Assessment at CERCLA Sites	TBC	For CERCLA compliant cleanup	All
Radiation Dose	15 mrem/yr	EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, Aug. 1997	Applicable or Relevant and Appropriate	This memorandum provides guidance on using a risk-based approach to setting exposure limits to less than 15 mrem/yr for NCP compliance.	Soil
Radiation Dose	15 mrem/yr	EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, Jul. 22, 1996	TBC	This memorandum was the initial discussion that resulted in the recommended 15 mrem/yr dose limit.	Soil

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media
Radiation Dose		EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, OSWER No. 9200.4-25, Feb. 1998	Applicable or Relevant and Appropriate	This memorandum clarifies the use of 40 CFR 192 for the development of radionuclide soil standards.	Soil
Radiation Dose	10^{-4} - 10^{-6} cancer risk	40 CFR 300.430(e)(2)	Applicable	For CERCLA compliant cleanup	All
Radiation Dose	ICRP Publication 30 provides recommended Annual Limits on Intake and Derived Air Concentrations designed to limit the intake of radioactive materials by workers.	ICRP 30	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this international guidance is to be considered.	All Media
Radiation Dose	Federal Guidance Report No. 11 provides Annual Limits on Intake and Derived Air Concentrations to be implemented by federal agencies to limit the intake of radioactive materials by workers.	Federal Guidance Report No. 11	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this Federal guidance is to be considered.	All Media
Air Pollutants	National Emission Standards for Hazardous Air Pollutants (NESHAP)	40 CFR 61	Relevant and Appropriate	To the extent the remedial activities involve the emission of regulated constituents and activities similar to those addressed in these regulations, they may be relevant and appropriate.	Air
Arsenic	Less than 0.39 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Land use. Due to high background levels, a higher limit is applied.	Soil
Lead (inorganic)	Less than 400 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Landuse	Soil

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media
Mercury (compounds) Mercury (elemental)	Less than 23 mg/kg 13 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Landuse	Soil
Vanadium	390 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC		Soil
Molybdenum	390 mg/kg	EPA Region 9 Memorandum, Region 9 Regional Screening Levels (formerly PRGs), updated as of June 2011	TBC		Soil

TABLE 6
Chemical-Specific State and Federal ARARs for Groundwater
Compliance Evaluations On-site Alternatives

Contaminant	Standard	Applicable or R&A	Comments	Method of Attainment
Ra-226 and Ra-228	5 pCi/l	Applicable	Statewide standard [1](also MCL), MCLG - Zero	Sampling performed for likely chemicals on a screening basis and then confirmation sampling/monitoring for chemicals of concern.
Th-230 and Th-232	60 pCi/l	Applicable	Statewide standard [1]	
Gross Alpha	15 pCi/l[2]	Applicable	Statewide standard [1](also MCL), MCLG - Zero	
Beta/Photon Emitters	4 mrem/year[3]	Applicable	Statewide standard [1](also MCL), MCLG - Zero	
Uranium	30 µg/l	R&A	Human health Standard[1], MCL, MCLG - Zero	
Trichloroethylene	0.005 mg/l	Applicable	Statewide standard [1](also MCL), MCLG - Zero	
Tetrachloroethylene	0.005 mg/l	Applicable	Statewide standard [1](also MCL), MCLG - Zero	
Arsenic	0.01 mg/l	Applicable	Human health standard [1], MCL, MCLG - Zero	
Barium	2.0 mg/l	Applicable	Human health standard [1], MCL	
Cadmium	0.005 mg/l	Applicable	Human health standard[1], MCL	
Cyanide (Free)	0.20 mg/l	R&A	Human health standard[1], MCL	
Chromium	0.1 MG/L	Applicable	Human health standard[1], MCL	
Fluoride	4.0 mg/l	R&A	Human health standard[1], MCL	
Lead	0.05 mg/l	Applicable	human health standard, Action Level, MCLG - Zero	
Mercury	0.002 mg/l	Applicable	Human health standard[1], MCL	
Molybdenum	0.035 mg/l	Applicable	Human health standard[1], Action level	
Nitrate	10.0 mg/l	R&A	Human health standard[1], MCL	
Nitrite	1.0 mg/l	R&A	Human health standard[1], MCL	
Selenium	0.05 mg/l	Applicable	Human health standard[1], MCL	
Silver	0.05 mg/l	Applicable	Human health standard[1], Action level	

[1] 5 CCR 1002-41.5(C)(2) and Tables A, 1, 2, and 3. This is the GW standard 5 CCR 1002-41; primary and secondary drinking water standard is found at 5 CCR 1003-1.
[2] Excludes contributions from radon and uranium
[3] Applicable only to man-made radionuclides

Contaminant	Standard	Applicable or R&A	Comments	Method of Attainment
Chloride	250 mg/l	R&A	Secondary drinking water[1]	
Copper	1.0 mg/l	R&A	Secondary drinking water[1]	
Iron	0.3 mg/l	R&A	Secondary drinking water[1]	
Manganese	0.05 mg/l	R&A	Secondary drinking water[1]	
Sulfate	250 mg/l	R&A	Secondary drinking water[1]	
Zinc	2.0 mg/l	Applicable	Agricultural standard[1]	
Aluminum	5.0 mg/l	R&A	Agricultural standard[1], Secondary drinking water is 0.05-0.2 mg/l	
Beryllium	0.004 mg/l	R&A	Human health standard[1], MCL	
Cobalt	0.05 mg/l	R&A	Agricultural standard[1]	
Nickel	0.20 mg/l	R&A	Agricultural standard[1]	
Vanadium	0.1 mg/l	R&A	Agricultural standard[1]	

TABLE 7
Chemical-Specific State and Federal Applicable or Relevant and Appropriate Requirements
Compliance Evaluation for Off-Site Alternatives

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media	Method of Attainment
Radium-226	Less than or equal to 5 pCi/g above background within 15 cm of the surface averaged over 100 square meter area. Less than or equal to 15 pCi/g above background within subsequent 15 cm layers of soil averaged over 100 square meter area.	40 CFR 192.12(a) 6 CR 1007-1, Part 18, Criterion 18	Relevant and Appropriate	Standard for clean-up of land at inactive uranium processing sites.	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Thorium-230	Clean-up level calculated using initial Ra-226 concentration and assuming period for Th-230 ingrowth; depth of backfill may be considered.	Generic protocol for excavation of Th-230, DOE, January 15, 1989	TBC	DOE standard modified by EPA's January 16, 1992 letter. To be considered for excavation of clay liner under the waste pile.	Soils	Confirmatory sampling will performed to meet standard from Federal Register Vol 64 No. 264 page 68395-01 Table 3
Radium- 226	7.0E-01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Thorium- 228	4.7E+00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media	Method of Attainment
Uranium- 234	1.3E+01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Uranium- 238	1.4E+01 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Thorium- 230	1.8E-00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Thorium- 232	1.1E-00 pCi/g	Federal Register Vol 64 No. 264 page 68395-01 Table 3	TBC	Establishes individual radionuclide concentrations deemed compliant with 25 mrem/y unrestricted release dose limit in 10 CFR 20.1402. These interim screening values may be relevant if they are used as the soil clean-up criteria	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Radon Decay Products	Objectives of remedial action to achieve an annual average not to exceed 0.02 WL. In any case, not to exceed 0.03 WL.	40 CFR 192.12(b)(1)	Relevant and Appropriate	Standard for clean-up of inactive uranium processing sites. Relevant and appropriate if occupied or habitable buildings planned for site.	Air	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media	Method of Attainment
Radiation	Gamma radiation shall not exceed background levels by more than 20 microR per hour.	40 CFR 192.12(b)(2)	Relevant and Appropriate	Standard for clean-up of inactive uranium processing sites. Relevant and appropriate if occupied or habitable buildings planned for site.	Soils	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Radiation	Standards for protection against radiation.	10 CFR 20 6 CCR 1007-1 Part 4	Relevant and applicable	Substantive cleanup portions are relevant and appropriate.	All Media	Requirements of this standard will be met on-site for each of the off-site RA alternatives including meeting permissible doses, levels, and concentration standards through the use of PPE, environmental monitoring, and dosimetry programs.
Radiation Dose	25 mrem/y TEDE above background plus ALARA	10 CFR 20.1402; 6 CCR 1007-1, 4.61.2	Relevant and Appropriate	For unrestricted use cleanup.	All	Sampling to meet DCGLs
Radiation Dose	25 mrem/y TEDE above background plus ALARA, plus 100 mrem/y TEDE if institutional controls fail.	10 CFR 20.1403; 6 CCR 1007-1, 4.61.3	Relevant and Appropriate	For restricted use cleanup.	All	Sampling and Institutional controls
Radiation Dose	15 mrem/yr TEDE above background	EPA Memo, OSWER Directive 9200.4-31P, Radiation Risk Assessment at CERCLA Sites	TBC	For CERCLA compliant cleanup	All	Sampling to meet DCGLs
Radiation Dose	15 mrem/yr	EPA Memorandum, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination, OSWER No. 9200.4-18, Aug. 1997	Applicable or Relevant and Appropriate	This memorandum provides guidance on using a risk-based approach to setting exposure limits to less than 15 mrem/yr for NCP compliance.	Soil	Confirmation sampling

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media	Method of Attainment
Radiation Dose	15 mrem/yr	EPA Memorandum, Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates, Jul. 22, 1996	TBC	This memorandum was the initial discussion that resulted in the recommended 15 mrem/yr dose limit.	Soil	Confirmation sampling
Radiation Dose		EPA Memorandum, Use of Soil Cleanup Criteria in 40 CFR 192 as Remediation Goals for CERCLA Sites, OSWER No. 9200.4-25, Feb. 1998	Applicable or Relevant and Appropriate	This memorandum clarifies the use of 40 CFR 192 for the development of radionuclide soil standards.	Soil	Confirmation sampling
Radiation Dose	10^{-4} - 10^{-6} cancer risk	40 CFR 300.430(e)(2)	Applicable	For CERCLA compliant cleanup	All	Sampling to meet DCGLs and institutional controls, if necessary.
Radiation Dose	ICRP Publication 30 provides recommended Annual Limits on Intake and Derived Air Concentrations designed to limit the intake of radioactive materials by workers.	ICRP 30	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this international guidance is to be considered.	All Media	The appropriate selection of respiratory protection procedures will meet the criteria set forth in this guidance for all of the off-site RA alternatives.
Radiation Dose	Federal Guidance Report No. 11 provides Annual Limits on Intake and Derived Air Concentrations to be implemented by federal agencies to limit the intake of radioactive materials by workers.	Federal Guidance Report No. 11	TBC	To the extent that workers may have radioactive material intakes due to the presence of site wastes, this Federal guidance is to be considered.	All Media	The appropriate selection of respiratory protection procedures will meet the criteria set forth in this guidance for all of the off-site RA alternatives.

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media	Method of Attainment
Air Pollutants	National Emission Standards for Hazardous Air Pollutants (NESHAP)	40 CFR 61	Relevant and Appropriate	To the extent the remedial activities involve the emission of regulated constituents and activities similar to those addressed in these regulations, they may be relevant and appropriate.	Air	Perimeter air monitoring (including radionuclides) and dust control measures as set forth in Section 4.1.3 will be a component of all of the off-site RA alternatives to ensure that the potentially relevant and appropriate NESHAPs are being met.
Arsenic	Less than 0.39 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Landuse	Soil	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative. Due to higher background levels, a higher limit is applied.
Lead (inorganic)	Less than 400 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Landuse	Soil	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.

Contaminant	Standard	Citation	Applicable or Relevant and Appropriate or TBC	Comments	Media	Method of Attainment
Mercury (compounds) Mercury (elemental)	Less than 23 mg/kg 13 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC	Represents most conservative state cleanup standard for Residential/Unrestricted Landuse	Soil	Confirmatory sampling will be performed to ensure that this standard is attained on-site for each off-site RA alternative.
Vanadium	390 mg/kg	Colorado Department of Public Health and Environment, Hazardous Materials and Waste Division – Colorado Soil Evaluation Values (CSEV Table) July 2011	TBC		Soil	Same as above
Molybdenum	390 mg/kg	EPA Region 9 Memorandum, Region 9 Regional Screening Levels (formerly PRGs), updated as of June 2011	TBC		Soil	Same as above

TABLE 8
Location Specific State and Federal Applicable or Relevant and Appropriate Requirements
No Action Alternative

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Endangered Species Habitat	U.S. Fish and Wildlife Service – Mountain – Prairie Region - Colorado	Lists endangered species in Colorado	Applicable	Orchid found on-site.	All
Migratory Bird Treaty Act	16 U.S.C. § 703-712; 2 CCR 406-5	Restricts work in areas where birds may be nesting	Applicable	Cannot disturb native migratory birds during the breeding season	All
Protection of Fishing Streams	CRS 33-5-101 *et seq.*	Restricts modification of fishing streams	Applicable	May apply if work will change stream bank or channel	All
100 Year Floodplain	City of Golden Colorado Municipal Code – Title 19; 2 CCR 408-1 Rule 12	Requirements for obtaining permits associated with specific activities occurring in floodplain hazard areas	Relevant and Appropriate.	Affected soils left onsite may lie in floodplain of Clear Creek. Substantive requirements only.	Soils/ Water
Sites of Historical Importance	Colorado Office of Archaeology and Historic Preservation – Golden Colorado. See www.historycolorado.org/oahp/jefferson-county#golden	Lists Registered Historical Sites in Golden Colorado	Relevant and Appropriate	Two state historical sites are located near the Colorado School of Mines but not on the actual property.	All

TABLE 9
Location-Specific Applicable or Relevant and Appropriate Requirements
Off-Site Remedial Action Alternatives

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media
Endangered Species Habitat	U.S. Fish and Wildlife Service – Mountain – Prairie Region - Colorado	Lists endangered species in Colorado.	Applicable	Orchid found on-site	All
Migratory Bird Treaty Act	16 U.S.C. § 703-712; 2 CCR 406-5	Restricts work in areas where birds may be nesting	Applicable	Cannot disturb native migratory birds during the breeding season	All
Protection of Fishing Streams	CRS 33-5-101 *et seq.*	Restricts modification of fishing streams	Applicable	May apply if work will change stream bank or channel	All
100 Year Floodplain	City of Golden Colorado Municipal Code – Title 19;; 2 CCR 408-1 Rule 12	Requirements for obtaining permits associated with specific activities occurring in floodplain hazard areas.	Relevant and Appropriate.	Permits may need to be obtained for offsite removal of materials residing in Clear Creek floodplain. Portion of site is located in the 100 year floodplain of Clear Creek. Substantive requirements only.	Soils/ Water
Sites of Historical Importance	Colorado Office of Archaeology and Historic Preservation – Golden Colorado. See www.historycolorado.org/oahp/jefferson-county#golden	Lists Registered Historical Sites in Golden Colorado.	Relevant and Appropriate	Two state historical sites are located near the Colorado School of Mines but not on the actual property, therefore RA will not occur on historical site.	All

TABLE 10
Location-Specific State and Federal Applicable or Relevant and Appropriate Requirements
Compliance Evaluation for Off-Site Alternatives

Standard Requirement, Criteria or Limitation	Citation	Description or Requirements	Applicable or Relevant and Appropriate	Comments	Media	Method of Attainment
Endangered Species Habitat	U.S. Fish and Wildlife Service – Mountain – Prairie Region - Colorado	Lists endangered species in Colorado	Applicable		All	Perform study to determine whether endangered species habitat exists onsite. Orchid found on-site.
Migratory Bird Treaty Act	16 U.S.C. § 703-712; 2 CCR 406-5	Restricts work in areas where birds may be nesting	Applicable	Cannot disturb native migratory birds during the breeding season	All	
Protection of Fishing Streams	CRS 33-5-101 *et seq.*	Restricts modification of fishing streams	Applicable	May apply if work will change stream bank or channel	All	
100 Year Floodplain	City of Golden Colorado Municipal Code – Title 19; 2 CCR 408-1 Rule 12	Requirements for obtaining permits associated with specific activities occurring in floodplain hazard areas	Relevant and Appropriate.	Permits may need to be obtained for offsite removal of materials residing in Clear Creek floodplain. Portion of site is located in the 100 year floodplain of Clear Creek.	Soils/ Water	Maintain site controls in accordance with specified regulations, substantive requirements only. Off-site facilities are not located in Golden.
Sites of Historical Importance	Colorado Office of Archaeology and Historic Preservation – Golden Colorado. See www.historycolorado.org/oahp/jefferson-county#golden	Lists Registered Historical Sites in Golden Colorado	Relevant and Appropriate	Two state historical sites are located near the Colorado School of Mines but not on the actual property, therefore RA will not occur on Historical Site		No historical sites are located on off-site facility being considered.

CSMRI - Alternative 4 - Solidify and Engineered Cap

					TASK 1 Mobilization/Demob		TASK 2 Construct onsite facilities		TASK 3 Solidification		TASK 4 Place back on site		TASK 5 Closure Report			TASK 6 Construct Cap		TASK 7 Stabilize Site		TASK 8 Long term O&M		Hrs / UnitsTotal	EXT
	Labor Category	Individual	$ / Hr		Hrs	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT		
1	Principal		$180.00		16	$2,880.00	40	$7,200.00	40	$7,200.00	10	$1,800.00	16		$2,880.00	20	$3,600.00	12	$2,160.00	0	$0.00	154	$27,720.00
2	Proj Mgr		$107.00		80	$8,560.00	40	$4,280.00	160	$17,120.00	20	$2,140.00	80		$8,560.00	120	$12,840.00	40	$4,280.00	0	$0.00	540	$57,780.00
3	Proj Engineer		$107.00		80	$8,560.00	20	$2,140.00	20	$2,140.00	20	$2,140.00	60		$6,420.00	120	$12,840.00	40	$4,280.00	0	$0.00	360	$38,520.00
4	RSO/HSO		$107.00		80	$8,560.00	40	$4,280.00	160	$17,120.00	20	$2,140.00	60		$6,420.00	120	$12,840.00	40	$4,280.00	0	$0.00	520	$55,640.00
5	Rad Technician		$96.00		40	$3,840.00	20	$1,920.00	160	$15,360.00	20	$1,920.00	240		$23,040.00	120	$11,520.00	40	$3,840.00	0	$0.00	640	$61,440.00
6	Site Supervisor		$96.00		80	$7,680.00	40	$3,840.00	160	$15,360.00	20	$1,920.00	160		$15,360.00	120	$11,520.00	40	$3,840.00	0	$0.00	620	$59,520.00
7	Operator 1		$80.00		80	$6,400.00	40	$3,200.00	120	$9,600.00	60	$4,800.00	0		$0.00	120	$9,600.00	40	$3,200.00	0	$0.00	460	$36,800.00
8	Operator 2		$80.00		80	$6,400.00	40	$3,200.00	120	$9,600.00	40	$3,200.00	0		$0.00	240	$19,200.00	40	$3,200.00	0	$0.00	560	$44,800.00
9	Labor		$45.00		80	$3,600.00	40	$1,800.00	120	$5,400.00	40	$1,800.00	0		$0.00	240	$10,800.00	40	$1,800.00	0	$0.00	560	$25,200.00
10	Flagger		$45.00		0	$0.00	40	$1,800.00	120	$5,400.00	20	$900.00	0		$0.00	240	$10,800.00	40	$1,800.00	0	$0.00	460	$20,700.00
11	Administrative		$45.00		40	$1,800.00	20	$900.00	80	$3,600.00	4	$180.00	40		$1,800.00	40	$1,800.00	12	$540.00	0	$0.00	236	$10,620.00
12																							
13																							
14																							
15																							
	Total Hrs				656		380		1260		274		656			1500		384		0		5110	
	Labor Totals					$58,280.00		$34,560.00		$107,900.00		$22,940.00			$64,480.00		$117,360.00		$33,220.00		$0.00		$438,740.00
					TASK 1		TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 8			
		Unit	Rate	MU	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
	Subcontractors																						
16	Engineering	Hr	$150.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	40	$6,600.00	12	$1,980.00	0	$0.00	52	$8,580.00
17	Surveying	Hr	$150.00	10%	0	$0.00	20	$3,300.00	0	$0.00	22	$3,630.00	0		$0.00	80	$13,200.00	24	$3,960.00	0	$0.00	146	24090
18	Drafting	Hr	$75.00	10%	40	$3,300.00	20	$1,650.00	0	$0.00	12	$990.00	0		$0.00	32	$2,640.00	0	$0.00	0	$0.00	104	8580
19	Geotechnical (pilot study)	Hr	$150.00	10%	0	$0.00	0	$0.00	40	$6,600.00	0	$0.00	0		$0.00	40	$6,600.00	0	$0.00	0	$0.00	80	13200
20	Waste Transp 1	CY	12.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
21	Annual inspection and report	each	5,000.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	80	$440,000.00	80	440000
22	5 year inspection and report	each	10,000.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	20	$220,000.00	20	220000
23	Waste Disposal 2	each	5,000.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
24	Lab Analysis	each	5,000.00	10%	0	$0.00	0	$0.00	0.25	$1,375.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0.25	1375
25	Gamma Spec /	week	450.00	10%	0	$0.00	1	$495.00	2	$990.00	2	$990.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	5	2475
26	GW Monitoring (assume 100 years monitoring)	year	193,480.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
27	Utility Relocation	LS	0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
28	Revegitation	acre	1,500.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	5	$8,250.00	0	$0.00	5	8250
29	Traffic Control	week	1,475.00	10%	0	$0.00	1	$1,622.50	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	1622.5
30	Storm Water	LS	2,300.00	10%	0	$0.00	1	$2,530.00	0	$0.00	1	$2,530.00	0		$0.00	1	$2,530.00	1	$2,530.00	0	$0.00	4	10120
	Subcontrs Totals					$3,300.00		$9,597.50		$8,965.00		$8,140.00			$0.00		$31,570.00		$16,720.00		$660,000.00	497.25	$738,292.50
					TASK 1		TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 8			
		Unit	Cost	MU	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
	Equip/Supp													0									
31	Communications	Week	$187.50	10%	2	$412.50	1	$206.25	4	$825.00	0	$0.00	0		$0.00	6	$1,237.50	2	$412.50	0	$0.00	15	$3,093.75
32	Vehicle Cost	Week	$218.75	10%	4	$962.50	1	$240.63	4	$962.50	0	$0.00	0		$0.00	6	$1,443.75	2	$481.25	0	$0.00	17	4090.625
33	PPE	Week	$406.25	10%	1	$446.88	3	$1,340.63	8	$3,575.00	0	$0.00	0		$0.00	9	$4,021.88	2	$893.75	0	$0.00	23	10278.125
34	Tools / Equip	LS	$4,350.00	10%	0	$0.00	2	$9,570.00	2	$9,570.00	0	$0.00	0		$0.00	3	$14,355.00	1	$4,785.00	0	$0.00	8	38280
35	Mileage as of 3/12/07	Miles	$0.485	10%	1000	$533.50	500	$266.75	1000	$533.50	0	$0.00	0		$0.00	2000	$1,067.00	500	$266.75	0	$0.00	5000	2667.5
36	Air Monitoring	Week	$650.00	10%	2	$1,430.00	2	$1,430.00	2	$1,430.00	0	$0.00	0		$0.00	3	$2,145.00	1	$715.00	0	$0.00	10	7150
37	Stormwater Mgt.	LS	$2,000.00	10%	0.5	$1,100.00	0.25	$550.00	0.25	$550.00	0	$0.00	0		$0.00	0.5	$1,100.00	1	$2,200.00	0	$0.00	2.5	$5,500.00
38	Licenses / Permits	LS	$5,000.00	10%	2	$11,000.00		$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	2	11000
39	Dozer	hour	$80.00	10%	80	$7,040.00	40	$3,520.00	0	$0.00	0	$0.00	0		$0.00	120	$10,560.00	40	$3,520.00	0	$0.00	280	24640
40	Loader 1	hour	$69.00	10%	0	$0.00	0	$0.00	120	$9,108.00	0	$0.00	0		$0.00	40	$3,036.00	0	$0.00	0	$0.00	160	12144
41	Loader 2	hour	$69.00	10%	0	$0.00	0	$0.00	120	$9,108.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	120	9108
42	Excavator	hour	$71.00	10%	80	$6,248.00	40	$3,124.00	40	$3,124.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	160	12496
43	Grader	hour	$25.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	80	$2,200.00	20	$550.00	0	$0.00	100	2750
44	Water Truck	hour	$25.00	10%	80	$2,200.00	40	$1,100.00	120	$3,300.00	0	$0.00	0		$0.00	80	$2,200.00	40	$1,100.00	0	$0.00	360	9900
45	Equip Trailer	week	$437.50	10%	0	$0.00	0	$0.00	2	$962.50	0	$0.00	0		$0.00	3	$1,443.75	0	$0.00	0	$0.00	5	2406.25
46	Reagent Silo	Week	$1,500.00	10%	2	$3,300.00	0	$0.00	4	$6,600.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	6	9900
47	Portland (fob site)	ton	$40.00	10%	0	$0.00	0	$0.00	1000	$44,000.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1000	44000
48	Compactor	hour	$90.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	80	$7,920.00	0	$0.00	0	$0.00	80	7920
49	Volvo 30 ton offroad dump	hour	$92.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
50	Maintenance	Week	$1,500.00	10%	2	$3,300.00	1	$1,650.00	2	$3,300.00	0	$0.00	0		$0.00	3	$4,950.00	0	$0.00	0	$0.00	8	13200
51	Fuel	Week	$3,937.50	10%	2	$8,662.50	1	$4,331.25	2	$8,662.50	0	$0.00	0		$0.00	3	$12,993.75	1	$4,331.25	0	$0.00	9	38981.25
52	Rad Instrument	Week	$206.25	10%	2	$453.75	1	$226.88	2	$453.75	0	$0.00	0		$0.00	3	$680.63	1	$226.88	0	$0.00	9	2041.875
53	Cap Materials	CY	$16.75	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	5000	$92,125.00	0	$0.00	0	$0.00	5000	92125
54	Decon Equipment	Week	$125.00	10%	2	$275.00	1	$137.50	2	$275.00	0	$0.00	0		$0.00	3	$412.50	1	$137.50	0	$0.00	9	1237.5
55	Utilites	Week	$55.00	10%	2	$121.00	1	$60.50	2	$121.00	0	$0.00	0		$0.00	3	$181.50	0	$0.00	0	$0.00	8	484
56	Office Trailer	week	$150.00	10%	2	$330.00	1	$165.00	2	$330.00	0	$0.00	0		$0.00	3	$495.00	1	$165.00	0	$0.00	9	1485
	Generator	week	$250.00	10%	2	$550.00	1	$275.00	2	$550.00	0	$0.00	0		$0.00	3	$825.00	1	$275.00	0	$0.00	9	2475
	Pug Mill	ton	$4.50	10%	0	$0.00	0	$0.00	19850	$98,257.50	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	19850	98257.5
	Golden Water Permit	gallon	$0.01	10%	2000	$22.00	1000	$11.00	100000	$1,100.00	0	$0.00	0		$0.00	25000	$275.00	10000	$110.00	0	$0.00	138000	1518
	Mob / Demob	each	$2,750.00	10%	1	$3,025.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	3025
	Equip/ Supp Totals					$51,412.63	0	$28,205.38		$206,698.25		$0.00			$0.00		$165,668.25		$0.00		$0.00	170260.5	$472,154.38
						$112,992.63		$72,362.88		$323,563.25		$31,080.00			$64,480.00		$314,598.25		$49,940.00		$660,000.00	TOTAL	$1,649,186.88

FEASIBILITY STUDY Updated Estimated Cost

UPDATED	CSMRI - Alternative 1 - No Further Action	CSMRI - Alternative 2 - Solid Waste Disposal	CSMRI - Alternative 3 - Onsite Disposal Cell	CSMRI - Alternative 4 - Solidify and Engineered Cap
COST (000's)				
Mobilization/demob	$0	$52	$96	$113
Construction Cost	$0	$88	$987	$669
Equipment Cost	$0	$34	included in construction	included in construction
Reclamation Cost	$0	$15	$61	$50
Disposal Cost	$0	$68	$0	$0
Engineering Cost	$0	$0	$66	$72
Long Term O & M OU2 (Present Value)	$0	$0	$660	$660
Closure Report	na	$32	$57	$64
Repair (Present Value)	$0	$0	$0	$0
Total (000's)	$0	$289	$1,926	$1,629
Rank	1	2	4	3

CSMRI - Alternative 1 - No Further Action

					TASK 1 Mobilization		TASK 2 Construction Cost		TASK 3 Equipment Cost		TASK 4 Land Development		TASK 5 Disposal Cost			TASK 6 Engineering Cost		TASK 7 Operations and Maintenance		TASK 8 Demobilization		Hrs / UnitsTotal	EXT
	Labor Category	Individual	$ / Hr		Hrs	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT		
1	Principal		$180.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
2	Proj Mgr		$107.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
3	Proj Engineer		$107.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
4	RSO/HSO		$107.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
5	Rad Technician		$96.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
6	Site Supervisor		$96.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
7	Operator 1		$80.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
8	Operator 2		$80.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
9	Labor		$45.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
10	Flagger		$45.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
11	Administrative		$45.00		0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
12																							
13																							
14																							
15																							
	Total Hrs				0		0		0		0		0			0		0		0		0	
	Labor Totals					$0.00		$0.00		$0.00		$0.00			$0.00		$0.00		$0.00		$0.00		$0.00
					TASK 1		TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 8			
		Unit	Rate	MU	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
	Subcontractors																						
16	Engineering	Hr	$0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
17	Surveying	Hr	$0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
18	Drafting	Hr	$0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
19	Geotechnical	Hr	$0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
20	Waste Transp 1	CY	6.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
21	Waste Transp 2	CY	198.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
22	Waste Disposal 1	CY	9.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
23	Waste Disposal 2	CY	95.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
24	Lab Analysis	each	0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
25	Gamma Spec /	week	0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
26	Quaterly GW Monitoring	year	193,480.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
27	Utility Relocation	LS	0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
28	Demolition	CY	0.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
29	Traffic Control	week	1,475.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
30	Storm Water	LS	2,300.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
	Subcontrs Totals					$0.00		$0.00		$0.00		$0.00			$0.00		$0.00		$0.00		$0.00	0	$0.00
					TASK 1		TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 8			
		Unit	Cost	MU	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
	Equip/Supp													0									
31	Communications	Week	$187.50	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
32	Vehicle Cost	Week	$218.75	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
33	PPE	Week	$406.25	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
34	Tools / Equip	LS	$4,350.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
35	Mileage as of 3/12/07	Miles	$0.485	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
36	Air Monitoring	Week	$650.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
37	Stormwater Mgt.	LS	$2,000.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
38	Licenses / Permits	LS	$5,000.00	10%	0	$0.00		$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
39	Dozer	Week	$5,700.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
40	Loader 1	Week	$2,455.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
41	Loader 2	Week	$2,887.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
42	Excavator	Week	$5,700.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
43	Grader	Week	$2,829.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
44	Water Truck	Week	$3,675.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
45	Equip Trailer	Week	$437.50	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
46	Crane	Week	$2,575.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
47	Scraper	Week	$5,750.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
48	Complactor	Week	$2,070.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
49	Backhoe	Week	$975.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
50	Maintenance	Week	$1,500.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
51	Fuel	Week	$3,937.50	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
52	Rad Instrument	Week	$206.25	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
53	Decon Equipment	Week	$125.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
54	Utilites	Week	$55.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
55	Mob / Demob	each	$2,750.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
	Equip/ Supp Totals					$0.00	0	$0.00		$0.00		$0.00			$0.00		$0.00		$0.00		$0.00	0	$0.00
						$0.00		$0.00		$0.00		$0.00			$0.00		$0.00		$0.00		$0.00	TOTAL	$0.00

	TASK 2 Construction Cost		TASK 3 Equipment Cost		TASK 4 Land Development		TASK 5 Disposal Cost			TASK 6 Engineering Cost		TASK 7 Closure Report Cost		TASK 8Long Term O&M		Hrs / UnitsTotal	EXT
EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT		
$360.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	4	$720.00	0	$0.00	6	$1,080.00
$8,560.00	20	$2,140.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	60	$6,420.00	0	$0.00	160	$17,120.00
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
$3,424.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	32	$3,424.00
$12,672.00	65	$6,240.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	112	$10,752.00	0	$0.00	309	$29,664.00
$9,600.00	65	$6,240.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	136	$13,056.00	0	$0.00	301	$28,896.00
$640.00	65	$5,200.00	40	$3,200.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	113	$9,040.00
$640.00	65	$5,200.00	40	$3,200.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	113	$9,040.00
$1,800.00	0	$0.00	40	$1,800.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	80	$3,600.00
$360.00	65	$2,925.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	73	$3,285.00
$1,080.00	8	$360.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	16	$720.00	0	$0.00	48	$2,160.00
	353		120		0		0			0		328		0		1235	
$39,136.00		$28,305.00		$8,200.00		$0.00			$0.00		$0.00		$31,668.00		$0.00		$107,309.00
	TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 1			
EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
$6,600.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	40	6600
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	1	$16,500.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	16500
$0.00	5	$3,300.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	5	3300
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	1	$5,500.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	5500
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	0	$0.00		$0.00	2200		$67,760.00	0	$0.00	0	$0.00	0	$0.00	2200	67760
$0.00	0	$0.00	0	$0.00	1	$15,400.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	15400
$1,622.50	1	$1,622.50	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	2	3245
$0.00	160	$17,600.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	160	17600
$8,222.50		$44,522.50		$0.00		$15,400.00			$67,760.00		$0.00		$0.00		$0.00	2410	$135,905.00
	TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 1			
EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
								0									
$206.25	8	$1,650.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	9	$1,856.25
$0.00	8	$1,925.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	8	1925
$0.00	4	$1,787.50	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	4	1787.5
$0.00	1	$4,785.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	4785
$0.00	500	$275.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	500	275
$0.00	1	$797.50	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	797.5
$0.00	1	$2,200.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	$2,200.00
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	50	$6,600.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	50	6600
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	40	$6,600.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	40	6600
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	40	$2,200.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	40	2200
$0.00	0	$0.00	0.25	$120.31	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0.25	120.3125
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0

$0.00	0	$0.00	1	$1,650.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	1650
$0.00	0	$0.00	1	$4,331.25	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	4331.25
$0.00	0	$0.00	50	$1,650.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	50	1650
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	5	$302.50	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	5	302.5
$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
$0.00	4	$1,100.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	4	1100
$1,650.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	1650
$0.01	10000	$110.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	10001	110.011
$3,025.00	0	$0.00	1	$3,025.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	2	6050
$4,881.26	0	$14,932.50		$26,176.56		$0.00			$0.00		$0.00		$0.00		$0.00	10719.25	$45,990.32
$52,239.76		$87,760.00		$34,376.56		$15,400.00			$67,760.00		$0.00		$31,668.00		$0.00	TOTAL	$289,204.32

CSMRI - Alternative 3 - Onsite Disposal Cell

					TASK 1 Mobilization/Demob		TASK 2 Construct On-Site Facilities and Engineering		TASK 3 Construct Cell		TASK 4 Place Soil in Cell		TASK 5 Closure Report			TASK 6 Construct Cap		TASK 7 Site stabilization		TASK 8 Long Term O&M		Hrs / UnitsTotal	EXT
	Labor Category	Individu	$ / Hr		16	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT	EXT	Hrs	EXT	Hrs	EXT	Hrs	EXT		
1	Principal		$180.00		40	$7,200.00	40	$7,200.00	40	$7,200.00	0	$0.00	16		$2,880.00	40	$7,200.00	0	$0.00	0	$0.00	176	$31,680.00
2	Proj Mgr		$107.00		40	$4,280.00	20	$2,140.00	80	$8,560.00	8	$856.00	80		$8,560.00	80	$8,560.00	30	$3,210.00	0	$0.00	338	$36,166.00
3	Proj Engineer		$107.00		40	$4,280.00	20	$2,140.00	80	$8,560.00	40	$4,280.00	60		$6,420.00	80	$8,560.00	20	$2,140.00	0	$0.00	340	$36,380.00
4	RSO/HSO		$107.00		40	$4,280.00	20	$2,140.00	80	$8,560.00	40	$4,280.00	60		$6,420.00	80	$8,560.00	20	$2,140.00	0	$0.00	340	$36,380.00
5	Rad Technician		$96.00		40	$3,840.00	20	$1,920.00	80	$7,680.00	40	$3,840.00	160		$15,360.00	80	$7,680.00	20	$1,920.00	0	$0.00	440	$42,240.00
6	Site Supervisor		$96.00		80	$7,680.00	20	$1,920.00	80	$7,680.00	40	$3,840.00	160		$15,360.00	80	$7,680.00	20	$1,920.00	0	$0.00	480	$46,080.00
7	Operator 1		$80.00		40	$3,200.00	40	$3,200.00	120	$9,600.00	80	$6,400.00	0		$0.00	80	$6,400.00	40	$3,200.00	0	$0.00	400	$32,000.00
8	Operator 2		$80.00		40	$3,200.00	40	$3,200.00	80	$6,400.00	40	$3,200.00	0		$0.00	80	$6,400.00	40	$3,200.00	0	$0.00	320	$25,600.00
9	Labor		$45.00		80	$3,600.00	20	$900.00	80	$3,600.00	4	$180.00	0		$0.00	80	$3,600.00	8	$360.00	0	$0.00	272	$12,240.00
10	Flagger		$45.00		0	$0.00	20	$900.00	80	$3,600.00	40	$1,800.00	0		$0.00	8	$360.00	0	$0.00	0	$0.00	148	$6,660.00
11	Administrative		$45.00		0	$0.00	20	$900.00	20	$900.00	8	$360.00	40		$1,800.00	40	$1,800.00	0	$0.00	0	$0.00	128	$5,760.00
12																							
13																							
14																							
15																							
	Total Hrs				440		280		820		340		576			728		198		0		3382	
	Labor Totals					$41,560.00		$26,560.00		$72,340.00		$29,036.00			$56,800.00		$66,800.00		$18,090.00		$0.00		$311,186.00
					TASK 1		TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 8			
		Unit	Rate	MU	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
	Subcontractors																						
16	Engineering	Hr	$150.00	10%	0	$0.00	40	$6,600.00	20	$3,300.00	0	$0.00	0		$0.00	40	$6,600.00	0	$0.00	0	$0.00	100	$16,500.00
17	Surveying	Hr	$175.00	10%	40	$7,700.00	20	$3,850.00	20	$3,850.00	20	$3,850.00	0		$0.00	40	$7,700.00	12	$2,310.00	0	$0.00	152	29260
18	Drafting	Hr	$75.00	10%	40	$3,300.00	20	$1,650.00	12	$990.00	0	$0.00	0		$0.00	32	$2,640.00	12	$990.00	0	$0.00	116	9570
19	Geotechnical	Hr	$150.00	10%	40	$6,600.00	12	$1,980.00	0	$0.00	0	$0.00	0		$0.00	20	$3,300.00	0	$0.00	0	$0.00	72	11880
20	GCL Liner (installed)	SY	3.50	10%	160	$616.00	0	$0.00	5000	$19,250.00	0	$0.00	0		$0.00	4400	$16,940.00	0	$0.00	0	$0.00	9560	36806
21	HDPE Liner (installed)	SY	2.50	10%	160	$440.00	0	$0.00	5000	$13,750.00	0	$0.00	0		$0.00	5000	$13,750.00	0	$0.00	0	$0.00	10160	27940
22	Geotextile Liner (installed)	SY	2.50	10%	160	$440.00	0	$0.00	5000	$13,750.00	0	$0.00	0		$0.00	5000	$13,750.00	0	$0.00	0	$0.00	10160	27940
23	GDN Liner (installed)	SY	4.00	10%	160	$704.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	5000	$22,000.00	0	$0.00	0	$0.00	5160	22704
24	Lab Analysis (geotech)	each	3,000.00	10%	1	$3,300.00	0	$0.00	0.25	$825.00	0.5	$1,650.00	0		$0.00	0.5	$1,650.00	0	$0.00	0	$0.00	2.25	7425
25	annaul cell inspection and report	each	5,000.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	80	$440,000.00	80	440000
21	5 year inspection and report	each	10,000.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	20	$220,000.00	20	220000
26	GW Monitoring (assume 100 years monitoring)	year	193,480.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
27	Rock Supplier Cushion Materials and top soil (fob site)	ton	14	10%	0	$0.00	0	$0.00	6000	$92,400.00	0	$0.00	0		$0.00	6000	$92,400.00	0	$0.00	0	$0.00	12000	184800
27	Rock Supplier Biota Barrier Materials (fob site)	ton	16	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	2500	$44,000.00	0	$0.00	0	$0.00	2500	44000
28	QA Engineer	hour	100.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
29	Traffic Control	week	1,475.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	2	$3,245.00	0	$0.00	0	$0.00	2	3245
30	Storm Water	LS	2,300.00	10%	0	$0.00	1	$2,530.00	1	$2,530.00	0	$0.00	0		$0.00	100	$253,000.00	10	$25,300.00	0	$0.00	112	283360
	Subcontrs Totals					$23,100.00		$16,610.00		$150,645.00		$5,500.00			$0.00		$480,975.00		$28,600.00		$660,000.00	50196.25	$1,365,430.00
					TASK 1		TASK 2		TASK 3		TASK 4		TASK 5			TASK 6		TASK 7		TASK 8			
		Unit	Cost	MU	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	QTY	EXT	EXT	QTY	EXT	QTY	EXT	QTY	EXT		
	Equip/Supp													0									
31	Communications	Week	$187.50	10%	1	$206.25	2	$412.50	4	$825.00	2	$412.50			$0.00	6	$1,237.50	1	$206.25	0	$0.00	16	$3,300.00
32	Vehicle Cost	Week	$218.75	10%	1	$240.63	2	$481.25	4	$962.50	4	$962.50	0		$0.00	9	$2,165.63	1	$240.63	0	$0.00	21	5053.125
33	PPE	Week	$406.25	10%	1	$446.88	2	$893.75	4	$1,787.50	2	$893.75	0		$0.00	3	$1,340.63	1	$446.88	0	$0.00	13	5809.375
34	Tools / Equip	LS	$4,350.00	10%	1	$4,785.00	1	$4,785.00	2	$9,570.00	2	$9,570.00	0		$0.00	3	$14,355.00	0	$0.00	0	$0.00	9	43065
35	Mileage as of 3/12/07	Miles	$0.485	10%	1000	$533.50	500	$266.75	1000	$533.50	1000	$533.50	0		$0.00	1500	$800.25	500	$266.75	0	$0.00	5500	2934.25
36	Air Monitoring	Week	$650.00	10%	1	$715.00	1	$715.00	2	$1,430.00	2	$1,430.00	0		$0.00	3	$2,145.00	1	$715.00	0	$0.00	10	7150
37	Stormwater Mgt.	LS	$2,000.00	10%	0.5	$1,100.00	0.25	$550.00	0.5	$1,100.00	0.25	$550.00	0		$0.00	1	$2,200.00	1	$2,200.00	0	$0.00	3.5	$7,700.00
38	Licenses / Permits	LS	$5,000.00	10%	1	$5,500.00		$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	1	5500
39	Dozer	hour	$80.00	10%	8	$704.00	8	$704.00	80	$7,040.00	80	$7,040.00	0		$0.00	80	$7,040.00	40	$3,520.00	0	$0.00	296	26048
40	Loader 1	hour	$69.00	10%	8	$607.20	40	$3,036.00	80	$6,072.00	80	$6,072.00	0		$0.00	80	$6,072.00	40	$3,036.00	0	$0.00	328	24895.2
41	Loader 2	hour	$69.00	10%	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	0	0
42	Excavator	hour	$71.00	10%	8	$624.80	40	$3,124.00	80	$6,248.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	128	9996.8
43	Grader	hour	$25.00	10%	8	$220.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	40	$1,100.00	0	$0.00	48	1320
44	Water Truck	hour	$25.00	10%	8	$220.00	40	$1,100.00	80	$2,200.00	80	$2,200.00	0		$0.00	80	$2,200.00	40	$1,100.00	0	$0.00	328	9020
45	Equip Trailer	week	$437.50	10%	0	$0.00	1	$481.25	2	$962.50	1	$481.25	0		$0.00	2	$962.50	0	$0.00	0	$0.00	6	2887.5
48	Compactor	hour	$90.00	10%	0	$0.00	0	$0.00	2	$198.00	2	$198.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	4	396
49	Volvo 30 ton offroad dump	hour	$92.00	10%	16	$1,619.20	0	$0.00	80	$8,096.00	160	$16,192.00	0		$0.00	80	$8,096.00	0	$0.00	0	$0.00	336	34003.2
50	Maintenance	Week	$1,500.00	10%	1	$1,650.00	1	$1,650.00	0	$0.00	2	$3,300.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	4	6600
51	Fuel	Week	$3,937.50	10%	1	$4,331.25	1	$4,331.25	2	$8,662.50	2	$8,662.50	0		$0.00	3	$12,993.75	0	$0.00	0	$0.00	9	38981.25
52	Rad Instrument	Week	$206.25	10%	1	$226.88	1	$226.88	2	$453.75	2	$453.75	0		$0.00	3	$680.63	0	$0.00	0	$0.00	9	2041.875
53	Decon Equipment	Week	$125.00	10%	4	$550.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	3	$412.50	6	$825.00	0	$0.00	13	1787.5
54	Utilites	Week	$55.00	10%	2	$121.00	1	$60.50	2	$121.00	2	$121.00	0		$0.00	3	$181.50	1	$60.50	0	$0.00	11	665.5
55	Office Trailer	week	$150.00	10%	2	$330.00	0.5	$82.50	2	$330.00	2	$330.00	0		$0.00	3	$495.00	0.5	$82.50	0	$0.00	10	1650
56	Generator	week	$250.00	10%	2	$550.00	0	$0.00	2	$550.00	2	$550.00	0		$0.00	3	$825.00	0.5	$137.50	0	$0.00	9.5	2612.5
57	Golden Water Permit	gallon	$0.01	10%	2	$0.02	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	2	0.022
58	Mob / Demob	each	$2,750.00	10%	2	$6,050.00	0	$0.00	0	$0.00	0	$0.00	0		$0.00	0	$0.00	0	$0.00	0	$0.00	2	6050
	Equip/ Supp Totals					$31,331.60	0	$22,900.63		$57,142.25		$59,952.75			$0.00		$64,202.88		$13,937.00		$0.00	7103.5	$240,804.58
						$95,991.60		$66,070.63		$280,127.25		$94,488.75			$56,800.00		$611,977.88		$60,627.00		$660,000.00	TOTAL	$1,917,420.58

The DiVito Dream Makers....

Jerry Golden
Licensed partner to Joe DiVito

April 16, 2007

Linn D. Havelick, CIH
Director, Environmental Health & Safety
Colorado School of Mines
Golden, CO 80401

Dear Linn,

The information you requested is included in the enclosed table.
The data for the table was obtained from Metrolist which is the real estate listing service for the greater metro Denver area. The JFW area is for Jefferson County West, of which the city of Golden is located approximately in the center. The data contains over 90% of all resale homes (private sales and "for sale by owner" are not included) and only includes a small percentage of new homes. The large fluctuations in the raw land average prices can be explained by the relatively low number of properties included in the data. Also the varying size of the lots in not considered, one could be for a ¼ acre lot whereas another could be for a 5 acre lot.

I hope this information is helpful, if not let me know and I can pull the data directly from the public records and we can then tabulate more specifically to your needs. This would take a little more time however.

Sincerely,

Jerry Golden
REALTOR

RE/MAX ALLIANCE
5440 Ward Road, Suite 110
Arvada, CO 80002-1817
Direct: 303-456-2116
Fax: 303-420-5232
Toll Free: 800-221-5716
Jerry@JerryGolden.com
www.JerryGolden.com

AVERAGE PRICE OF RESIDENCES AND RAW LAND

		2003		2004			2005			2006		
		Count	Average $	Count	Average $	% Change	Count	Average $	% Change	Count	Average $	% Change
Residential	JFW	751	364918	795	376686	3.22%	732	382583	1.57%	711	400888	4.78%
	Metro Denver	36677	277856	41682	289971	4.36%	41365	307529	6.06%	39208	317112	3.12%
Land	JFW	20	257079	41	237911	-7.46%	19	182257	-23.39%	14	291811	60.11%
	Metro Denver	796	156250	1170	203012	29.93%	1390	183579	-9.57%	1281	222264	21.07%

Metrolist is the source of the data which is deemed reliable, but not guaranteed.

CSMRI Site Proposed Plan – Flood Plain Soil

Proposed Plan for CSMRI Site

This Proposed Plan identifies the Preferred Alternative (offsite disposal at a solid waste landfill – Alternative 2) for cleaning up soil at the flood plain portion of the former CSMRI facility, Golden, Colorado (Site) and provides the rationale for its selection. The Plan also includes summaries of other alternatives that were evaluated for use at the Site. This document was prepared by the State of Colorado acting by and through the Board of Trustees of Colorado School of Mines (the State) for review and comment by the Colorado Department of Public Health and Environment (CDPHE), the local community, and other stakeholders. The State, in consultation with CDPHE, will select a final remedy after reviewing and considering all of the information submitted during a 30-day public comment period. The State, in consultation with CDPHE, may modify the Preferred Alternative or select another response action presented in this Plan based on new information or public comments. Therefore, the public is encouraged to review and comment on the alternatives presented in this Proposed Plan.

The State is issuing this Proposed Plan as part of its public participation responsibilities under Section 300.430(f)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) process. The Proposed Plan summarizes information that can be found in greater detail in the Flood Plain Remedial Investigation/ Feasibility Study (RI/FS) report and other documents contained in the Administrative Record file for this Site. The State encourages the public to review these documents to gain a more comprehensive understanding of the Site and investigation activities that have been conducted at the Site.

Site History

Numerous mineral research projects were conducted at the Site from 1912 until approximately 1987. Some of these projects involved investigating methods to extract metals and radionuclides from mineral ores. The research projects utilized 17 buildings on the Site that were razed in the mid-1990s. A settling pond, located between the building complex and Clear Creek, was used to store research wastewater. Wastewater was transferred to the settling pond through a system of sumps and floor drains in the buildings.

Important Dates and Information

Public Comment Period:
November 8, 2011 through December 7, 2011
The State will accept written comment on the Proposed Plan during the public comment period. Comments should be addressed to Linn Havelick, Director Environmental Projects (see last page of this document for address and email information).

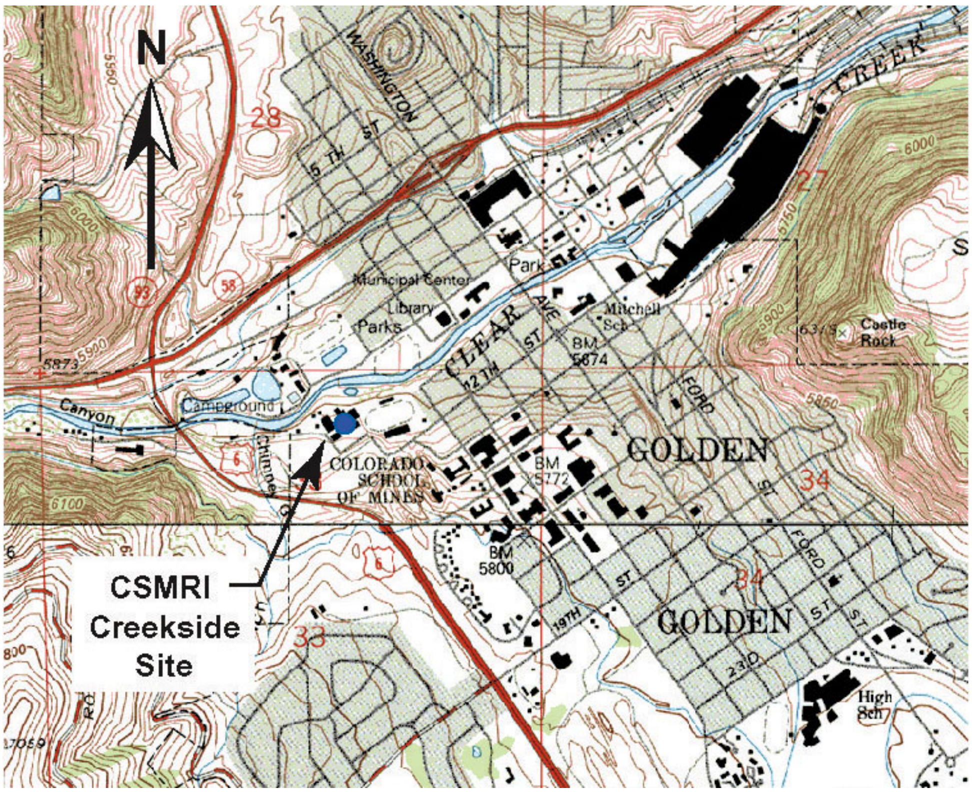
Public Meeting:
November 30, 2011 – 7:00 p.m. to 8:00 p.m.
The State will hold a public meeting to explain the Proposed Plan and all of the alternatives presented in the Feasibility Study. Oral and written comments also will be accepted at the meeting. The meeting will be held at General Research Building, Room 201, 1310 Maple Street on the campus of the Colorado School of Mines, Golden, Colorado. An open house will be hosted at the same location by the State just prior to the public meeting between 5:00 p.m. and 7:00 p.m.

For more information, see www.is.mines.edu/ehs/CSMRI/CSMRI2007.htm and the Administrative Record at the following location: CSMRI Site Investigation and Cleanup
Arthur Lakes Library
Library Circulation Desk
Colorado School of Mines
1400 Illinois Street
Golden, Colorado 80401
(303) 273-3911
Hours: Mon -Thu 7:30 a.m. to midnight;
Fri 7:30 a.m. to 6:00 p.m.;
Sat 9:00 a.m. to 5:00 p.m.;
Sun 11:00 a.m. to midnight

In January 1992, a water main owned by the City of Golden broke on the Site and began discharging a large volume of water into the settling pond. The U.S. Environmental Protection Agency (EPA) responded in February 1992 and performed a number of activities to stabilize conditions at the Site, including:

- excavating and stockpiling contaminated pond material (the Stockpile - 20,000 cubic yards of sediment and soil) and,
- closure of the settling pond

After site stabilization, the State of Colorado acting by and through Colorado School of Mines implemented the preferred disposal option of disposal of the stockpile at a local solid waste landfill. The State has been investigating and cleaning up the Site in consultation with CDPHE since then. In November/December 2002, all remaining concrete and asphalt were demolished and shipped to a local landfill and a recycling plant.



Site Location Map

Site Characteristics

Between December 2002 and January 2006, New Horizons Environmental Consultants, Inc. and The S.M. Stoller Corporation investigated soils in areas not investigated by EPA.

In 2006 Stoller created two soil stockpiles for excavated investigation materials.

The selected remedial alternative of offsite disposal at local landfills was implemented by the State in 2007.

Groundwater was then monitored in both the upper terrace and the downgradient lower terrace for two years. Groundwater monitoring results showed an isolated dissolved uranium groundwater plume located at the lower terrace. This area had been the subject of the EPA cleanup between 1992 and 1997. The EPA cleanup of the former pond was based on Ra-226 in soils, not uranium; and the cleanup standard for Ra-226 was higher in 1992 than the cleanup standard used for the upper terrace area in 2007. The eastern flood plain area had been subject to ongoing groundwater monitoring. New wells installed in the western flood plain area showed the uranium contamination was significantly more extensive then previously demonstrated by the eastern wells.

CDPHE requested an investigation and cleanup plan to address the groundwater contamination. Stoller characterized the flood plain in two phases. The first phase, which was a preliminary characterization effort primarily using test pits, indicated that the area containing the highest uranium values and the suspected source of the groundwater contamination was on the western side of the flood plain.

The second phase of investigation was implemented at the end of September 2010. It delineated elevated uranium concentrations in soil suspected to be the sources of contamination, especially the uranium plume contamination, through excavation, sampling, and analysis. The characterization effort began near well CSMRI-8, an area known to contain CSMRI process contaminant fill material, and continued until clean areas were reached. Table 1 presents the Constituents of Potential Concern and the Tentative Derived Concentration Guideline Levels (DCGLs) used during the investigation, also known as cleanup standards for soil. These were the same cleanup goals used for the upper terrace soil cleanup, except that the vanadium level was lowered at the request of CDPHE and uranium was added.

A total 1,400 cubic yards of excavated soil were excavated, transported and stockpiled on a lined staging area just above the lower terrace in an upper terrace area.

The Site was separated into two operable units (one for soil and one for groundwater) for the following reasons: (1) contaminated soil has been excavated from the pond area and temporarily stockpiled on the upper terrace for final disposition, (2) the soil stockpile is ready for final disposition, and (3) contaminated groundwater needs to be monitored for two years before further decisions about the groundwater may be made. Operable Unit 1 (OU1) is the soil in the former pond area, including the soil stockpiled on the upper terrace, and Operable Unit 2 (OU2) is the contaminated groundwater beneath the Site. OU2 will be addressed in a separate RI/FS at a later date. Separation into two operable units allows for the stockpiled soil to be disposed of now without waiting for the completion of the two-year monitoring period.

Table 1
COPCs and Tentative Site DCGLs

Constituent	Tentative DCGL
Metals	**mg/kg**
Arsenic	39
Lead	400
Mercury (total)	23
Molybdenum	390
Uranium	14
Vanadium	78
Radioisotopes	**picoCuries/gram**
Radium 226	4.14
Radium 228	4.6
Thorium 228	6.47
Thorium 230	11.53
Thorium 232	3.88
Uranium 234	254.9
Uranium 235	4.97
Uranium 238	21.8

Characterization work yielded the following information about the flood plain soil:

- The volume of contaminated soil on the flood plain is 1,400 cubic yards.
- The contaminants identified on the flood plain include uranium, arsenic, lead, mercury, vanadium, radium-226, thorium-230, uranium-234, uranium-235, and uranium-238.

One soil stockpile was established for materials excavated during the investigation. The stockpile is currently staged in a lined containment area and stabilized with a soil tackifier to eliminate the risk of airborne dust. The stockpile contains approximately 1,400 cubic yards of material with a mean concentration of 15 mg/kg uranium, 411 mg/kg lead, and 20.56 pCi/g Ra-226. No other COCs exceed the tentative Site cleanup goals.

Scope of the Action

The proposed remedial alternative for offsite disposal at a landfill is intended to be the final cleanup for soil at the Site. Groundwater will be addressed separately in the future after the current two-year groundwater monitoring program ends. The clay pits area, the softball field area, and the upper terrace at the Site are considered closed. Site soil above cleanup levels is currently located in the onsite stockpile. CDPHE has determined that the remaining Site soils are below the tentative DCGLs. The remedial alternatives are designed to address the existing stockpile. After cleanup, the Site will be returned to beneficial uses. An environmental covenant requiring radon mitigation systems for residential buildings constructed on the Site will also be a part of the remedy, as well as a covenant to restrict beneficial uses of groundwater.

Summary of Site Risks/Hazards

Acceptable exposures to known or suspected carcinogens are generally those that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. This translates to between one person in 10,000 or one person in 1,000,000 developing cancer because of exposure to the material. A baseline risk assessment was performed to evaluate human health risks for various scenarios. These risk scenarios were applied to three Site conditions: the soils on the flood plain area pre-excavation, the flood plain area post-excavation, and the soils stockpile managed on the upper terrace. Of the materials found on Site, the radionuclides radium, thorium, and uranium are known carcinogens along with the metal arsenic (lead and mercury are suspected carcinogens but currently there is insufficient information to predict levels of risk for these metals). EPA uses the 10^{-6} risk level as the point of departure for determining remediation goals. However, the upper boundary of the risk range is not a discrete line at $1x10^{-6}$. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions.

The affected material (primarily metals) also presents other health concerns that are not associated with cancer. Noncarcinogens are evaluated by their systemic effect on target organs or systems. EPA defines acceptable human exposure levels (including sensitive subgroups) as those that do not cause adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety. This acceptable exposure level is best approximated by a hazard index (HI) of 1. If a HI is less than 1, adverse effects usually are not expected. As the HI increases beyond 1, the possibility of adverse health effects also increases.

Detailed information about possible health effects from the metals and radionuclides found on Site may be found at a number of websites including those listed below:

http://www.atsdr.cdc.gov/toxpro2.html
http://www.epa.gov/iriswebp/iris/index.html
http://www.intox.org/databank/pages/chemical.html

Human Health Risks/Hazards

The baseline risk assessment indicated that leaving the affected material in place would result in a risk to an onsite urban resident in the range of $9.73 x10^{-5}$ to $9.77 x 10^{-5}$ (depends on location of residence). A recreational user, student athlete, or groundskeeper would experience a risk in the range of $1.13 x 10^{-7}$ to $5.72 x 10^{-6}$ (assumes limited access to Site).

Control or offsite disposal of the affected material would result in a significant reduction in risk to an on-site resident (for details see Section 8 of the RI/FS).

Environmental Risks/Hazards

Because of the extensive previous investigation operations and the current short-term management of the stockpile, there are minimal current risks to the environment from soil remaining in the flood plain (groundwater will be addressed separately). However, without control of the stockpile, the Site would be a long-term source of metals and radionuclide to the underlying groundwater, which eventually flows into Clear Creek.

The Preferred Alternative identified in this Proposed Plan, or one of the other active measures considered in the Proposed Plan, is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

Remedial Action Objectives

The Remedial Action Objectives (RAOs) for the Site include:

- Eliminate or minimize the pathway for dermal contact, inhalation, and ingestion of site-specific radionuclides to human receptors, in order to achieve a level of protection in compliance with the NCP levels of acceptable cancer risk (10^{-4} to 10^{-6}).
- Develop receptor-specific soil cleanup levels to limit unacceptable radiation doses for the radionuclides found in the affected material (i.e., soil).
- Minimize risk associated with radon gas either by source excavation or by requiring the installation of radon mitigation systems in any structures constructed on Site.
- Prevent long-term dermal, inhalation, and ingestion exposures to trace metal affected materials with concentrations greater than the CDPHE proposed Residential/Unrestricted Land-Use Standards or that generate HIs greater than 1.
- Prevent offsite migration of affected material that could result in the exposures described above. This includes the groundwater pathway.
- Implement remedial measures that limit groundwater and surface-water concentrations to the groundwater protection standard and the maximum contaminant levels (MCLs) at the points of compliance and to non-zero maximum contaminant level goals (MCLGs), established under the Safe Drinking Water Act and under Colorado law. Although the affected groundwater is not a current drinking water supply it eventually enters Clear Creek, which is used by downstream users for drinking water. Uranium is the primary groundwater contaminant of concern.
- Implement remedial actions that reduce exposures from ionizing radiation to levels that are as low as reasonably achievable (ALARA).
- Comply with soil-, location- and action-specific Applicable or Relevant and Appropriate Requirements (ARARs). (See Section 8.1 and Appendix I of RI/FS for ARAR discussion).

Summary of Remedial Alternatives

Alternative 1 – No Further Action

Estimated Capital Cost: $0
Estimated Present Worth Cost: $0
Estimated Construction Timeframe: NA
Estimated Time to Achieve Remedial Action Objectives: Not achieved, until natural attenuation is achieved, 100 years used for comparison.

Alternative 1 provides a comparative baseline against which other alternatives can be evaluated. Under Alternative 1 two site conditions were evaluated (pre-excavation flood plain soil, and the post-excavation flood plain soil and stockpile). The site condition carried through the alternatives evaluation is the case where the affected soils would remain in the lined stockpile which represents the current state of the Site.

A major weakness in the no-further action alternative is the failure to provide adequate protection of human health and the environment. Contaminants would not be adequately controlled to limit migration.

Alternative 1 has an additional cost associated with the loss of property value. Appraisal information indicates that without site cleanup, the land value decreases by up to $367,000. The estimated value for present worth is based on the value when considered for its highest and best use (i.e., residential development).

Alternative 2 Offsite disposal at solid-waste landfill

Estimated Capital Cost: $289,000
Estimated Operation and Maintenance (Present Value)
Cost: $0
Estimated Present Worth Cost: $0
Estimated Construction Timeframe: 2 months
Estimated Time to Achieve RAOs: Upon Completion
(Soil only assumes natural attenuation of groundwater which is a separate OU)

Alternative 2 involves the load-out and transportation of the stockpile to an approved landfill.

Estimated transport times were determined assuming the closest solid waste landfill for alternative 2. Foothills Landfill on Colorado Highway 93 is approximately 8 miles north of the Site. Transportation times will increase if other facilities are selected.

Upon completion of the offsite disposal, all of the property would be available for residential and other use with an environmental covenant. Backfill material may be required to bring the Site to a useable elevation and for stormwater control and safety.

Because all of the affected material would be taken from the Site, Alternative 2 would not experience the loss in property value associated with the other alternatives. The Foothills Landfill is the least expensive and the most administratively reliable landfill option and is thus the preferred landfill for disposal.

Alternatives 3 – Onsite disposal cell with engineered cap
Estimated Capital Cost $1,926,000
Estimated Operation and Maintenance (Present Value) Cost: $660,000
Estimated Present Worth Cost: $367,000
Estimated Construction Timeframe: 6-8 months
Estimated Time to Achieve RAOs:
RAOs only partially achieved, monitoring required for at least 100 years

Alternative 3 requires the construction of an engineered disposal cell without solidification. An area above groundwater fluctuations would be selected for the construction of the cell. Allowing a material depth of 10 feet and a 4:1 slope into the cell to allow for equipment movement, the footprint of the cell would be about 1 acre. Geotechnical testing would be required to verify proper placement of the cell and a clay sub-liner would be installed. A geosynthetic liner will be installed over the clay to ensure containment. The affected material will then be moved from the stockpile and placed in the cell. When all material is relocated to the cell, a clay cap (3 feet thick) will be installed over the material.

Again, institutional controls would be required for the cell to ensure the integrity of the cap and to monitor groundwater in the vicinity of the cell. O&M would include annual inspections and reporting with more robust inspections every five years. Limited groundwater monitoring may be required to monitor the natural attenuation of current uranium concentrations and radionuclide activities; however, groundwater will be covered under a separate RI/FS. Backfill could be required to bring the Site to a useable elevation and to provide stormwater control.

Alternative 3 has the additional cost associated with the loss of property value. Although a remediation process is completed, the land value may still decrease by up to $367,000. The estimated present worth cost would be $1.6M if the land value loss were included

Alternative 4 – Onsite solidification with engineered cap
Estimated Capital Cost: $1,629,000
Estimated Operation and Maintenance (Present Value)
Cost: $660,000
Estimated Present Worth Cost: $367,000
Estimated Construction Timeframe: 6-8 months
Estimated Time to Achieve Remedial Action Objectives: RAOs only partially achieved, monitoring required for at least 100 years

Alternative 4 will require segregation by soil type. Some crushing of cobbles may be required. An area at a high enough elevation to remain above groundwater fluctuations will be selected for final placement of the solidified material. Operational reagent such as concrete, cement kiln dust, or fly ash will be stockpiled onsite, and a batch processor will be brought in to mix the materials. A water supply also will be required. Batches of material will be placed in lifts, and solidification will be verified with test cores.

Alternative 4 would require the mixing of the stockpile to produce a uniform distribution of activity in the resulting soil pile.

After the solidification of the structure has been confirmed, a clay cap (3 feet in thickness) will be constructed over the structure to limit leaching effects. The structure and cap footprint would require institutional controls on about 1 acre of land. Long-term cap maintenance in the vicinity of the solidified matrix would be required. O&M would include annual inspections and reporting with more robust inspections every five years. The remaining property would be available for unrestricted use although a limited groundwater monitoring program currently ongoing would continue to monitor the current metal concentrations and radionuclide activities. Some backfill would be required to bring the Site to a useable elevation and to provide stormwater control.

Alternative 4 will require a pilot test to determine the appropriate mixture of concrete, fly ash, and soil. After the proper mixture is determined, stockpiled materials can be treated and moved into the cell.

Alternative 4 has the additional cost associated with the loss of property value. Although a remediation process is completed, the land value may still decrease by up to $367,000. The estimated present worth cost would be $1.3M if the land value loss were included.

Evaluation of the Alternatives

Nine criteria are used to evaluate the different remediation alternatives individually and against each other in order to select a remedy. The nine criteria fall into three groups. The first group, the threshold criteria, includes overall protection of human health and the environment and compliance with the ARARs. If an alternative does not meet these criteria, it is not eligible for future consideration. The second group, the balancing criteria, includes long-term effectiveness and permanence, reduction of toxicity, mobility, or volume through treatment, short-effectiveness, implementability, and cost. These criteria are weighed against each other to determine a preferred option. The last group, the modifying criteria, includes State and community acceptance. The modifying criteria are often used to make a final selection.

The following sections profile the relative performance of each of the alternatives against the other alternatives. The nine evaluation criteria are individually discussed in the following sections. Detailed discussion of the alternative evaluation can be found in Sections 7 and 8 of the RI/FS.

- *Overall protection of human health and the environment,*

Alternative 1, the no-further action alternative, does not provide adequate protection of human health and the environment because it does not adequately address the exposure pathways.

Alternatives 2, 3, and 4 effectively address the direct exposure pathways by either preventing access to the material using caps and a variety of containment options or by taking the material away from the Site. A short-term groundwater-monitoring program will be required for Alternative 2 because of residual metals and radionuclides remaining in the groundwater system, but that will be addressed separately in the future. The solidified matrix or disposal cell associated with Alternatives 3 and 4 would require long-term groundwater monitoring.

Alternative 2 would provide the most protection to human health and the environment in the vicinity of the Site because there are remaining concerns with Alternatives 3 and 4 if institutional controls fail or engineering controls fail.

- *Compliance with ARARs*

Alternative 1 does not meet the ARARs that have been identified for the Site. Alternatives 3 and 4 is compliant with ARARs, except for reducing doses to less than 100 mrem/yr if institutional controls fail, by consolidating and containing the affected material onsite. Alternative 2 complies with ARARs and has the least uncertainty associated with the site-specific ARARs.

- *Long-term effectiveness and permanence*

Alternative 1 has no long-term effectiveness or permanence because the material would remain in place and be a continuing source of hazard and risk to human health and the environment. This alternative would have the largest remaining risk for the Site and surrounding area.

The remaining alternatives would sufficiently address residual risk. The alternatives that involve a cap would have a degree of uncertainty associated with long-term permanence. Cap breakdown could result in significant risks to

human health and the environment. The provision in 40 CFR §192.02 requires the control measures to be effective for 1,000 years (at least 200 years) when certain radionuclides are involved. Long-term effectiveness of caps can be compromised by failure to implement institutional controls and the lack of maintenance. In addition to human activities, freeze-thaw cycles, vegetation, and burrowing animals can compromise cap material. The literature refers to problems with the mobility of uranium in carbonates (Alternative 4). The magnitude of this effect would be site-specific but could be problematic in the long term.
.
Alternative 2, offsite disposal, has the least uncertainty associated with long-term effectiveness and permanence.

- *Reduction of toxicity, mobility, or volume through treatment*

Alternative 4 is the only alternative that addresses the material through treatment. Toxicity and mobility are addressed because the matrix prevents material migration and reduces toxicity through reduced bioavailability. Properly maintained, the solidified matrix would be expected to remain intact for an extended period of time. While treatment associated with Alternative 4 does reduce the toxicity (through lessening bioavailability) and mobility of the material, the volume of material would actually increase.

Alternative 4 uses a cap to address toxicity and mobility by limiting contact and infiltration but the volume is not reduced. Alternative 2 produces no net reduction in metals or radionuclides, just relocation.

- *Short-term effectiveness*

All alternatives except Alternative 1 (no-further action) involve some short-term risk to workers and the surrounding community. A low to moderate risk would be associated with the truck traffic required to move equipment or material (i.e., traffic accidents). Access to State Highway 6 would limit the risk to the immediate neighborhood but could affect the local county (or counties).

Worker exposure would be the greatest for Alternative 4 because of the mixing and grinding operations. Alternatives 2 and 3 would have less risk. Worker risks would be mitigated by material handling equipment and safety equipment.

Alternative 2 has the highest short-term risk for the surrounding community because of the number of loads of affected soil. The risk applies only to traffic accidents, not to exposure to affected soils. The remaining alternatives would have a lesser effect on the community because of limited transportation operations.

- *Implementability*

Alternative 1, no-further action is relatively easy to implement technically. However, the administrative feasibility for this alternative is low because of the need to take action.

Alternatives 2 through 4 are technically feasible. Each alternative involves standard construction and earth-moving techniques. Alternative 4 has the most uncertainty because a concrete/soil mixture would need to be determined. Proper installation of a disposal cell can be problematic (Alternative 4). Alternatives 3 and 4 are sensitive to weather conditions especially during the winter months. Administrative feasibility for Alternatives 2 thorough 4 is medium to high.

- *Cost*

The least expensive alternative is Alternative 2 (see Section 8 of the RI/FS). If the value of the land is considered, both versions of Alternative 2 have significantly less cost than the other alternatives because they allow all future uses of the property.

- *State acceptance*

In preliminary discussions with CDPHE, the offsite disposal alternative (Alternative 2) was the preferred alternative. The State prefers Alternative 2.

- *Community acceptance*

Comments received during a community outreach meeting conducted in September 2010 indicated support of the offsite disposal plan (Alternative 2).

Summary of the Preferred Alternative

The Preferred Alternative for cleaning up the Site is to dispose of the 1,400 yards of soil in the stockpile at the Highway 93 Foothills landfill. The preferred alternative meets the threshold criteria and provides the best balance of tradeoffs among the other alternatives with respect to the balancing and modifying criteria. The preferred alternative was selected over the other alternatives because it is expected to achieve substantial and long-term risk reduction for the Site. The alternative also allows residential future use of the property, which is the most protective and preferred type of cleanup. Alternative 2 reduces the risk from the soil within a reasonable timeframe and at reasonable cost (compared to the other alternatives).

Based on the information available at this time, the Preferred Alternative will be protective of human health and the environment, comply with the ARARs, be cost effective, and provide a long-term effective and permanent solution. The Preferred Alternative can change in response to public comment or new information.

Community Participation

The State provides information regarding the cleanup of the Site to the public through public meetings, the Administrative Record file for the Site, a web site, and announcements published in the *Denver Post* and the *Golden Transcript.* The State encourages the public to gain a more comprehensive understanding of the Site and the remedial activities and investigations that have been conducted at the Site.

The dates for the public comment period, the date location and time of the public meeting, and the locations of the Administrative Record files, are provided on the front page of this Proposed Plan.

For further information about the Site please contact:

Mr. Linn Havelick
Director of Environmental Projects
Colorado School of Mines
Chauvenet Hall, Rm. 194
1015 14th Street
Golden, CO 80401
lhavelick@mines.edu
Phone: 303-273-3998
FAX: 303-384-2081
Website: http://www.is.mines.edu/ehs/CSMRI/CSMRI2007.htm