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QUALITY ASSURANCE PROJECT PLAN: Long-Term Operation and Maintenance of Railroad Assets For BNSF Railway Company and Union Pacific Railroad Butte Priority Soils Operable Unit

Kennedy Jenks

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QUALITY ASSURANCE PROJECT PLAN:

Long-Term Operation and Maintenance of Railroad Assets

For BNSF Railway Company
and Union Pacific Railroad
Butte Priority Soils Operable Unit

October 2023

Prepared for

U.S. Environmental Protection Agency, Region 8
Baucus Federal Building
10 West 15th Street, Suite 3200
Helena, Montana 59626

KJ Project No. 2299019.00

Section A: Project Management

A.1 Title and Approval Sheet and Revision Tracking

Title: Long-Term Operation and Maintenance of Railroad Assets, Quality Assurance Project Plan, Butte Priority Soils Operable Unit, October 2023.

Reviewed by:____________________________________ Date: 10/10/2023
Doug Brannan, P.E.
Kennedy Jenks, Railroads' Technical Representative

Reviewed by:____________________________________ Date: __________________
Josh Sales
Kennedy Jenks, Company Quality Assurance Manager

Reviewed by:____________________________________ Date: __________________
Lauren Knickrehm
BNSF Railway Company, Senior Manager Environmental Remediation

Reviewed by:____________________________________ Date: __________________
John DeJong
Union Pacific Railroad Company, Senior Manager Environmental Site Remediation

Approved by:____________________________________ Date: __________________
Nikia Greene
U.S. EPA Region 8, Remedial Project Manager

Approved by:____________________________________ Date: __________________
Daryl Reed
Montana DEQ, Project Officer

Plan is effective on date of approval.

Revision Tracking Table

Revision Date	Section Revised	Changes/Comments
August 2020	--	Original document
May 2022	A.1	Consolidated signature page and added Revision Tracking Table
	A.3	Updated distribution list
	A.4.1, A.4.4, Figure A-1	Updated key individuals
	A.6.1	Updated BRES Schedule to reflect current and future cycles
	A.8.1, Table A-2	Updated Training requirements
	Appendix B, SOP-BPSOU-03	Added Attachment 1 – Butte Hill Revegetation Specifications
	Appendix B, SOP-BPSOU-04	Added Attachment 1 – Furnishing and Installing Aggregate Material
January 2023	A.3	Updated distribution list
	A.4	Updated railroad contacts and project quality assurance manager
	A.6.3	Updated to EPA approved
	B.1.3.1	Updated XRF range from 25% to 35%
	B.2.4	Updated soil sample depth intervals to 0-2 inches, 2-6 inches and 2-12 inches.
	B.4.3	Updated reference to Revision 5, July 2018 (EPA 2018.
	D.1	Update reference to National Functional Guidelines November 2020
	Appendix A, Section A.2	Added additional analysis for cover soil
	Appendix A, Tables A-1 and A-2	Added additional analysis for cover soil
	Appendix A, Section A.4.1	Updated sample collection depth to 1 foot below ground surface

January 2023	Appendix B, SOP-BPSOU-01	Updated XRF use guidelines
	Appendix B, SOP-BPSOU-02	Updated sample depth intervals and clarified sampling for soil cover material intended for use as growth media
	Appendix B, SOP-BPSOU-05	Updated to EPA approved
	Appendix B, SOP-BPSOU-08	Updated sample depth intervals

A.2 Table of Contents

Table of Contents (cont'd)

Table of Contents (cont'd)

List of Tables

Table of Contents (cont'd)

List of Figures

List of Appendices

Acronyms and Abbreviations

ARAR	applicable, relevant, and appropriate requirement
Atlantic Richfield	Atlantic Richfield Company
BHRS	Butte Hill Revegetation Specifications
BMP	best management practice
BNSF	BNSF Railway Company
BPSOU	Butte Priority Soils Operable Unit
BRES	Butte Reclamation Evaluation System
BSBC	Butte Silver Bow County
CAP	corrective action plan
CDM Smith	CDM Smith Federal Programs Corporation
Database System	Railroad Database System
DEQ	Montana Department of Environmental Quality
DMP	Data Management Plan
DOT	U.S. Department of Transportation
DQO	data quality objective
EDD	electronic data deliverable
EPA	U.S. Environmental Protection Agency
FRA	Federal Railway Administration
FTP	file transfer protocol
GIS	geographic information system
GPS	global positioning system
GNSS	global navigation satellite system
H&S	health and safety
HASP	health and safety plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
IATA	International Air Transport Association
ID	identifier or identification
Kennedy Jenks	Kennedy/Jenks Consultants, Inc.
LCS/LCSD	laboratory control sample/laboratory control sample duplicate
MDL	method detection limit
MRL	method reporting limit
MS/MSD	matrix spike/matrix spike duplicate
NPL	National Priorities List
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
PM	project manager
PPE	personal protective equipment
PQL	practical quantitation limit

Acronyms and Abbreviations

PRP	potentially responsible party
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
R	recovery
RAL	remedial action level
RBTCRA	Railbed Time Critical Removal Actions
ROD	record of decision
RPD	relative percent difference
RPM	Remedial Project Manager
SAP	sampling and analysis plan
SDG	sample delivery group
SOP	standard operating procedure
UAO	Unilateral Administrative Order
Union Pacific	Union Pacific Railroad
XRF	X-Ray fluorescence

A.3 Distribution List

Copies of this completed and signed quality assurance project plan (QAPP) will be distributed to:

Key Personnel QAPP Recipients	Organization/Position	E-mail Address
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On behalf of the BNSF Railway Company (BNSF) and Union Pacific Railroad (Union Pacific), referred to collectively as the Railroads, copies of this QAPP will be distributed to the individuals above by the Railroads' Technical Representative in electronic format (as indicated above). The Technical Representative will distribute updated copies each time a QAPP revision occurs.

A.4 Project Task Organization

BNSF's Technical Representative will provide the technical staff to complete or oversee long-term operation and maintenance (O&M) activities of the Railroads' assets (defined in Section A.5) for this project. Supporting services may be provided by laboratories and contractors with the Technical Representative's oversight. Figure A-1 presents an organizational chart that shows lines of communication and authority, and reporting responsibilities for this project.

A.4.1 Key Individuals and Responsibilities

The U.S. Environmental Protection Agency (EPA) is the lead regulatory agency for Superfund activities within the Butte Priority Soils Operable Unit (BPSOU). The EPA Region 8 BPSOU Remedial Project Manager (RPM) is Mr. Nikia Greene. He is responsible for overall EPA management, coordination, and technical review of BPSOU with the Montana Department of Environmental Quality (DEQ).

DEQ is the support regulatory agency for Superfund activities at BPSOU. The DEQ Project Officer for these activities is Mr. Daryl Reed.

CDM Smith is the environmental consultant of the EPA and provides technical support, field oversight, and training guidance services. The CDM Smith Project Manager (PM) for BPSOU is Mr. David Shanight.

BNSF and Union Pacific own and operate property contained within BPSOU, and their respective environmental remediation departments manage environmental liability remediation-related issues through their Environmental Remediation department. BNSF oversight and management of BPSOU is assigned to Ms. Lauren Knickrehm, Senior Manager Environmental Remediation. Union Pacific oversight and management of BPSOU is assigned to Mr. John DeJong, Senior Manager Environmental Site Remediation. Together, Ms. Knickrehm and Mr. DeJong are the primary contacts for work pertaining to the Railroads (BNSF and Union Pacific) at the BPSOU.

BNSF and Union Pacific contract with a Technical Representative to provide technical services, project management, and technical representation for work pertaining to the Railroads at BPSOU, including development, maintenance, and application of this QAPP. Mr. Doug Brannan is the Railroads' Technical Representative and the Kennedy/Jenks Consultants, Inc. (Kennedy Jenks) PM for BPSOU.

A.4.2 Project Quality Assurance Managers

As the Project Quality Assurance (QA) Manager, Mr. Doug Brannan, implements the QA program for BPSOU. Mr. Phil Hopper is the Project QA Officer, the primary designee of the Project QA Manager who provides QA support for field and data management staff, and with contractors and laboratories. Mr. Joshua Sales, Kennedy Jenks' QA Manager, is independent of the technical staff and provides an objective review of project data and overall project operations as necessary.

A.4.3 Maintenance of the Quality Assurance Project Plan

Mr. Doug Brannan, the Railroads' Technical Representative, is responsible for maintaining the final approved QAPP and documenting and distributing any revisions as they become available.

A.4.4 Organization Chart

Figure A-1 presents an organizational chart that shows lines of authority and reporting responsibilities for this project.

A.5 Problem Definition and Background

A.5.1 Site Background

BPSOU is one of the remedial operable units identified by EPA within the Butte Area portion of the Silver Bow Creek/Butte Area National Priorities List (NPL) site within and near Butte, Montana. The Butte Area NPL had an extensive history of metals mining, ore processing, and waste disposal and was designated as a Superfund site in 1983. In 1992, EPA named potentially responsible parties (PRPs) for BPSOU and included Atlantic Richfield Company (Atlantic Richfield), Butte-Silver Bow County (BSBC), Inland Properties Incorporated, and Rarus Railway Company, as well as BNSF and Union Pacific (jointly termed the Railroads).[1]

BPSOU characterization efforts on the Union Pacific and/or BNSF properties (railroad property) began during the 1990s, and remediation efforts termed Railbed Time Critical Removal Actions (RBTCRA) occurred in the 2000s. The EPA administrative order for the RBTCRA was issued in 2000. RBTCRA construction activities on railroad property were essentially completed by 2004. The construction activities included removal of mining-related materials with high metals concentrations, placement and capping of the removed materials in a railroad repository, and capping mining-related materials with low metals concentrations in place with either engineered (rock) caps or vegetated caps. Surface drainage control improvements termed stormwater best management practices (BMPs) were also designed and constructed during the RBTCRA to maintain drainage on railroad property and to protect the caps from erosion.

In 2006, the BPSOU Record of Decision (ROD) was issued calling for long-term management of ecological risk and human health risk in BPSOU related to arsenic and lead (EPA 2006a). In 2011, EPA issued a Unilateral Administrative Order (UAO) for performance of the remedial actions pursuant to the 2006 BPSOU ROD. With respect to the Railroads as "Group 2 Respondents," the 2011 UAO resulted in construction of additional railroad stormwater BMPs, implementation of inspection programs for maintaining caps and stormwater BMPs, and development of a data management framework for railroad caps and stormwater BMPs O&M data. These programs are further discussed in Section A.5.2, and a regulatory timeline from 2000 to present is provided as Figure A-2.

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[1] Rarus Railway Company and its assets and data management are not part of this BNSF and Union Pacific Railroad QAPP.

The Butte Reclamation Evaluation System (BRES) was developed by EPA and put into use after the development of EPA's 2006 BRES Manual (CDM Smith 2006) for the inspection and maintenance of caps within BPSOU. The Railroads produced a Stormwater BMP O&M Plan (Kennedy Jenks 2023a) for O&M of stormwater BMPs on railroad property. Together, the caps and stormwater BMPs comprise the Union Pacific and/or BNSF assets (herein termed railroad assets) within BPSOU, shown on Figures A-3 through A-8.

A.5.2 Reason for this Project

For the purposes of this QAPP, this project is a long-term O&M of the above-defined railroad assets which is managed under the Railroads' BRES and stormwater BMPs programs. The reason for this project is to meet the intent of the above-described 2006 BPSOU ROD and the 2011 BPSOU UAO for the long-term management of ecological risk and human health risk.

The process of collecting, providing quality assurance review, storing, and using railroad asset data generated under the BRES and stormwater BMPs programs is detailed in the *Final Revised Data Management Plan, BNSF and Union Pacific Railroad Assets within Butte Priority Soils Operable Unit* (DMP) (Kennedy Jenks 2023b). Summaries regarding the two O&M programs are provided below.

A.5.2.1 BRES Program

During RBTCRA activities, vegetated and engineered (rock) caps were constructed over mining-related materials with metal concentrations that exceeded site action levels. BRES serves as a program to assist in the conditions evaluation and maintenance of the caps. On behalf of the Railroads, the Technical Representative oversees and implements the BRES program, conducting formal evaluations of Railroad BRES cap sites on a 4-year cycle to confirm the caps are functioning as designed. Evaluation of the sites happens according to the BRES O&M program, which is further described in the *Draft Operations and Maintenance Plan, BNSF Railway Company and Union Pacific Railroad Company, Railroad Non-Track Areas* (Draft Non-Track Areas O&M Plan) (Kennedy Jenks 2011a) and the *Draft Operations and Maintenance Plan, Active Railroad Lines* (Draft Active Tracks O&M Plan) (Kennedy Jenks 2011b)[2]. Additional details regarding the 4-year cycle are described in the *Butte Reclamation Evaluation System (BRES) Operation and Maintenance (O&M) Program Frequency Modification Plan* (BRES Frequency Modification Plan, Kennedy Jenks 2017).

A.5.2.2 Stormwater BMPs Program

Surface drainage components (or stormwater BMPs) are located within the Railroads' right-of-way and properties in BPSOU. Stormwater BMPs include ditches, inlets, manholes, conveyance pipes, sediment basins, and other BMPs that collect, convey, and control the flow of stormwater. Proper maintenance of BMPs is necessary to allow operation as designed. To identify maintenance needs, stormwater BMPs are inspected according to the criteria outlined in the *Final Interim Operation and Maintenance Plan, Railroad Stormwater Best Management Practices within the Butte Priority Soils Operable Unit* (Stormwater BMPs O&M Plan, Kennedy Jenks 2023a).

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[2] In its letter to BNSF dated 18 July 2018, EPA requested the Railroads combine these two 2011 draft reports into one BRES O&M plan for the Railroads' BRES sites. This combined report is being drafted.

A.5.2.3 Primary Objectives of Project QAPP

The primary objectives of the project QAPP are to:

1. Sample and revegetate vegetated caps in accordance with BRES guidance (CDM Smith 2006) and confirm concentrations of metals in imported cover soil are less than applicable remedial action levels (RALs) from the 2006 BPSOU ROD.
2. Verify selection and application of appropriate, quality surface materials during O&M of railroad assets with rock surfaces, and confirm concentrations of metals in finer-grained quarry source material (e.g., backfill) are less than applicable RALs from the 2006 BPSOU ROD.
3. Verify metals concentrations and visible characteristics of accumulated solid media, and evaluate appropriate placement or disposal location(s) based on applicable metals RALs from the 2006 BPSOU ROD and/or other characteristics.

This QAPP was prepared by Kennedy Jenks on behalf of the Railroads and contains the QA process to meet the above primary objectives for the O&M of railroad assets.[3]

A.5.3 Decisions, Actions, and Expected Outcomes

Collected under the BRES and stormwater BMPs programs, data regarding railroad asset operating conditions are used to make decisions regarding the potential need for corrective action plans (CAPs)/maintenance plans[4], and evaluation of expected outcomes. This process is described below in the context of the primary objectives from Section A.5.2.

A.5.3.1 Vegetated BRES Caps and Primary Objective 1

In the case of vegetated caps, reduced desirable vegetated cover caused by expanding barren conditions and/or the presence of undesirable vegetation can trigger mitigation requirements under BRES guidance (CDM Smith 2006). Where barren areas are present, it may be necessary to conduct site-specific sampling of the vegetated cap cover soil to evaluate soil condition/health prior to CAP preparation. With adequate site-specific data, standard CAPs can be prepared and implemented such as revegetation and/or reseeding in accordance with the EPA-approved 2006 Butte Hill Revegetation Specifications (BHRS), as well as weed removal and weed suppression. Source material for cover soil to be imported would be tested to verify concentrations of metals are below applicable RALs from the 2006 BPSOU ROD. The expected outcome is to re-evaluate the conditions of the mitigated vegetated cap after three growing seasons, per BRES guidance (CDM Smith 2006).

A.5.3.2 Rock Surface Assets and Primary Objective 2

Rock surface railroad assets include BRES engineered rock caps (made of various rock materials: Type 2, 3, 3A, 4, and 8) and rock-constructed erosion protection stormwater BMPs

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[3] EPA requested the Railroads prepare a QAPP and provided CDM Smith's *Quality Assurance Project Plan: Silver Bow Creek and Blacktail Creek Pore Water and Sediment Sampling, Silver Bow Creek/Butte Area Superfund Site* (CDM Smith 2016). CDM Smith's QAPP was adapted to develop this QAPP.

[4] CAPs is a BRES Program term, and "maintenance plan" is typical of the stormwater BMPs program.

(made primarily of Type 2 and Type 3 rock materials). If conditions observed during O&M activities indicate the design intent of a rock surface railroad asset is not being met based on professional judgement, the decision may be made to implement a CAP requiring import of additional rock material. The CAP will specify application of appropriate, quality materials meeting project gradation and testing requirements, sourced from a quarry where concentrations of metals are below applicable RALs from the 2006 BPSOU ROD. The expected outcome of CAP implementation is the restored railroad asset will operate as designed.

A.5.3.3 Accumulated Solid Media Management and Primary Objective 3

Solid media accumulation applies to the stormwater BMPs program with removal trigger criteria included in the Stormwater BMPs O&M Plan (Kennedy Jenks 2023a). Accumulated solid media will be tested to evaluate appropriate disposal or final placement. It will be tested for metals and screened using applicable RALs from the 2006 BPSOU ROD. Additional testing may be conducted as appropriate based on field observations. Using testing results, a CAP will be prepared for disposal or final placement. The expected outcome is the accumulated solid media would be removed from railroad asset(s), taken to a landfill or capped within railroad property using either a vegetated cap or engineered rock cap design for surface erosion protection, and the railroad asset(s) from which the solid media is removed would be restored to its design operation.

A.5.4 Regulatory Information, Applicable Criteria and Action Limits

At BPSOU, the EPA has developed RALs for contaminated solid media that are applicable to the railroad assets. These RALs define the condition when remedial action is needed for metals contamination in solid media (EPA 2006a). The RALs for lead and arsenic in solid media are summarized in Table A-1.

Table A-1: Solid Media Action Levels

Constituent	Solid Media	Action Levels(a)	Land Use
Lead	Soil	1,200 mg/kg(b)	Residential
	Soil	2,300 mg/kg	Non-Residential
Arsenic	Soil	250 mg/kg	Residential
	Soil	500 mg/kg	Commercial
	Soil	1,000 mg/kg	Recreational

Notes:
(a) Action Levels from ROD Solid Media, Table D-1 (EPA 2006a).
(b) mg/kg = milligrams per kilogram.

A.6 Project/Task Description

A.6.1 Summary of Work to be Performed

The Project is long-term O&M of railroad assets and the work to be performed is implementation of the BRES and stormwater BMPs programs. Summaries of the BRES and stormwater BMPs programs were presented in above Sections A.5.2.1 and A 5.2.2, respectively. Application of this Project QAPP and the primary objectives is dependent on railroad asset conditions identified during routine O&M activities.

A.6.2 Work Schedule

The work schedule for performing tasks associated with this QAPP follows EPA-approval of CAPs proposed by the Railroads in the BRES and stormwater BMPs programs.

A.6.2.1 BRES Schedule

The first BRES 4-year cycle was from 2013 through 2016, the second from 2017 through 2020; the third 4-year cycle began in 2021, and the fourth will begin in 2025. As initially presented in BRES Frequency Modification Plan (Kennedy Jenks 2017), the BRES schedule for the current and upcoming 4-year cycles is as follows:

	Cycle 3				Cycle 4			
BPSOU RBTCRA Groups	2021	2022	2023	2024	2025	2026	2027	2028
Middle Yard Sites	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season
Mainline East Sites	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season
Lower Yard Sites	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season
Mainline West & Newcome Branch Sites	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season	Evaluation & Corrective Action	1st Growing Season	2nd Growing Season	3rd Growing Season

Under the above schedule, evaluation of all four geographic subgroups takes place during the first year of the cycle (here shown as 2021 and 2025). Additionally, if feasible, the Railroads implement applicable CAPs within the same calendar year as the inspection (dependent on contractor availability, weather, and EPA comments); otherwise CAPs would be implemented the second year of the cycle (here shown as 2022 and 2026). Typically, during the second, third, and fourth years of the 4-year evaluation cycle, sites would be left dormant allowing for three complete growing seasons between corrective action and re-evaluation per final BRES guidance (CDM Smith 2006).

A.6.2.2 Stormwater BMPs Schedule

The Railroads' first formal stormwater BMPs inspection was conducted in 2015. Stormwater BMPs inspections are conducted annually with implementation of O&M repairs/construction following EPA approval of scope/CAPs proposed by the Railroads.

A.6.3 Geographical Locations

The Railroads' BRES and stormwater BMP assets are divided geographically into five distinct groups (Middle Yard, Mainline East, Lower Yard, Mainline West, and Newcome Branch) as presented on Figure A-3, overview map, and as identified in the BRES schedule table in

Section A.6.2.1 above. Figures A-4 through A-8 present detailed overviews of each of the five geographic groups, respectively.

Other relevant geographic locations include import source material locations. Solid media import sample locations will vary depending on contractor sourcing, and locations will be approved by EPA.

A.6.4 Resources and Time Constraints

Potential resource constraints in implementing the objectives of this QAPP may include:

1. Locating cover soil material meeting the EPA-approved 2006 BHRS within the Butte region.
2. Securing revegetation/reclamation contractor with BHRS experience who possesses all required, current Federal Railway Administration (FRA) worker certifications and trainings.
3. Locating rock cover material meeting the original 2000 RBTCRA specifications within the Butte region.

Resource constraints are not anticipated for accumulated solid media management.

Potential time constraints in implementing the objectives of this QAPP may include:

- Seasonal weather conditions:
    - Winter conditions (constrains objectives 1 and 3, and possibly 2 depending on nature of work to implemented and availability of import source material; additionally, limited daylight).
    - Spring wet-weather conditions (constrains objective 3 as accumulated sediment may be submerged, and working within active conveyance feature may pose a health and safety risk).
    - Summer dry conditions with occasional thunderstorms (constrains implementation of objective 1, requiring additional care and water application with potential risk of erosion during heavy thunderstorm).
- Regulatory review and negotiation to select CAPs for implementation.
- Contractor availability during peak construction season.

A.7 Data Quality Objectives for Measurement Data

Data quality objectives (DQOs) are statements that define the type, quality, quantity, purpose, and use of data to be collected. The evaluation of BRES and stormwater railroad assets is closely tied to the DQOs, which serve as the basis for decisions regarding the need for corrective measures. The EPA has developed a seven-step process for establishing DQOs to confirm that data collected during a field sampling program will be adequate to support reliable site-specific decision-making (EPA 2001, 2006).

Appendix A provides the detailed implementation of the seven-step DQO process associated with this QAPP.

A.7.1 Precision

Precision is an appraisal of the reproducibility of a set of measurements. Precision can be better defined as the variability of a group of measurements compared to their average value. Variability for environmental monitoring programs contains a geospatial component, and analytical component, and a field component. Precision applicable to the work associated with this QAPP pertains to geospatial measurements.

Precision related to asset boundaries is the degree to which site boundaries can be determined on a geographic scale. During site evaluations, field personnel will be equipped with a sub-meter global navigation satellite system (GNSS) receiver paired with an Apple iPad tablet (or equivalent) running ArcGIS Collector software as described in the Global Positioning System (GPS) Coordinate Collection and Handling standard operating procedure (SOP) (Appendix B). Field personnel can walk the extent of BRES caps and stormwater BMPs, can pinpoint the location of observations or CAPs, and can pin photographs of said locations to an online asset map database as necessary.

Precision related to field solid media sampling and solid media import sampling is the amount of variance between individual measurements of the same property taken under similar conditions. Precision is quantitative and most often expressed in terms of relative percent difference (RPD). Field duplicate samples for metals analysis will be collected to provide a measure of overall variability of field-related sources. Laboratory-related variability is measured through laboratory quality control (QC) samples such as laboratory duplicates. Laboratory analytical data will be evaluated for precision using field duplicates, laboratory duplicates, matrix spikes/matrix spike duplicates (MS/MSDs), and laboratory control sample/laboratory control sample duplicates (LCS/LCSDs), as applicable.

Analytical precision will be evaluated by the analyses of MSD and laboratory duplicate samples, which can be mathematically expressed as the RPD between duplicate sample analyses. RPD is calculated using the following equation:

$$\mathrm{RPD} = \frac{(\mathrm{S} - \mathrm{D})}{\left(\frac{(\mathrm{S}+\mathrm{D})}{2}\right)} * 100$$

Where:

RPD = Relative percent difference

S = First sample value

D = Second (duplicate) sample value.

The frequency of the performance of MSD and laboratory duplicate samples, where applicable, is usually one per batch (which typically consists of up to 20 samples) for each sample matrix received.

Field duplicate samples will be submitted blind to the laboratory as a means to determine field variability. Precision quantities for field duplicates will be calculated for analyses with method reporting limits of the same order of magnitude and with detected concentrations greater than or equal to five times the method reporting limits.

Laboratory-related variability is measured through laboratory QC samples such as laboratory duplicates. Laboratory analytical data will be evaluated for precision using field duplicates, laboratory duplicates, MS/MSDs, and LCS/LCSDs, as applicable.

A.7.2 Bias and Accuracy

Accuracy is the degree of agreement between a measured value (e.g., field sample) with the true or expected value. As it pertains to site boundaries, accuracy will be assessed by field personnel equipped with a sub-meter GPS device to track their position in comparison with satellite imagery and site boundary stored in the online database. Accuracy can typically be obtained to within a meter using the sub-meter GPS device discussed in the Global Positioning System (GPS) Coordinate Collection and Handling SOP (Appendix B).

To the extent feasible, solid media field samples and import samples will be collected and analyzed in accordance with the procedures set forth in this QAPP. This will ensure that results of the analytical data are representative and appropriate for comparison to the RALs set forth in the ROD.

For laboratory data, accuracy will be assessed by measuring recovery of laboratory control standards, specifically National Institute of Standards and Testing (NIST) for metals. Recovery will be calculated and bias evaluated.

Bias is the systematic or persistent distortion of a measurement process that causes error in one direction. Accuracy refers to how close a measurement is to the true value. Bias and accuracy will be evaluated by the analysis of matrix spike samples and laboratory control samples and can be mathematically expressed as the percent recovery of an analyte that has been used to fortify a field sample or clean laboratory matrix sample at a known concentration prior to analysis. The percent recovery (R) for a matrix spike sample is calculated as follows:

$$R = \frac{(\mathrm{SSR} - \mathrm{SR})}{\mathrm{SA}} * 100$$

Where:

SSR = Spiked sample result

SR = Sample result

SA = Spike added

The following calculation is used to determine R for a laboratory control sample or reference material:

$$R = \frac{RM}{RC} * 100$$

Where:

RM = Reference material result

RC = Known reference concentration

Results of matrix spike and laboratory control samples will be evaluated to the laboratory’s control limits. Control limits are defined as the mean recovery, plus or minus three standard deviations, of the 20 data points, with the warning limits set as the mean, plus or minus two standard deviations. The laboratory will review the QC samples and surrogate standard recoveries for each analysis to ensure that internal QC data lie within the limits of acceptability. The laboratory will investigate any suspect trends and take appropriate corrective actions.

Field blank samples and method blank samples will also be used to evaluate bias of the data. Results for field and method blanks can reflect systematic bias that results from contamination of samples during collection or analysis. Analytes detected in field or method blank samples will be evaluated as potential indicators of bias.

A.7.3 Representativeness

Representativeness concerns the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Where appropriate, sampling locations will be selected on both systematic and biased (judgmental) sampling bases in an attempt to spatially cover the study area.

A.7.4 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system. Completeness will be measured for each set of data received by dividing the number of valid measurements actually obtained by the number of valid measurements that were planned. Although 100 percent is the goal for completeness, 90 percent is the minimum acceptable level.

A.7.5 Comparability

Comparability is a qualitative QA criterion that expresses the confidence in the ability to compare one data set with another. Comparability among data sets is achieved through the use of similar sampling procedures and analytical methods. Sampling procedures will be performed as specified in the sampling and analysis plan (SAP). Analytical procedures will be conducted according to the methods discussed in this QAPP.

A.7.6 Sensitivity and Method Detection Limits

Sensitivity is the capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest. The method detection limit (MDL) is defined as the statistically calculated minimum amount that can be measured with 99 percent confidence that the reported value is greater than zero. MDLs are specified in the individual methods and are developed by the laboratory for each analyte of interest representing the aqueous and solid matrices within the capability of an analytical method.

The method reporting limit (MRL) or practical quantitation limit (PQL) is the lowest value to which the laboratory will report an unqualified quantitative result for an analyte. The PQL is always greater than the statistically determined MDL. The PQLs required for this project are such that data can be compared to the lowest possible applicable, relevant, and appropriate requirements (ARARs) suitable for the site.

A.8 Training Requirements/Certification

A.8.1 Field

Many of the railroad assets are located close to active rail lines. Therefore, all individuals involved in the asset inspection process must have appropriate training. Prior to starting field work, field team members working on, or adjacent to, BNSF tracks must complete the following, at a minimum:

Table A-2: Training Requirements

Training Requirement	Documentation Specifying Training Requirement Completion
Read and understand the site-specific health and safety plan (HASP)	HASP signature sheet
Attend an orientation session with the field Health and Safety (H&S) Manager	Orientation session attendance sheet
Complete OSHA 40-Hour Hazardous Waste Operations and Emergency Response (HAZWOPER) and relevant 8-hour refreshers	OSHA training certificates
Hold current 40-hour HAZWOPER medical clearance	Physician letter in the field personnel files
BNSF Contractor Safety Training (includes Roadway Worker Protection)	Training card
Union Pacific Contractor Orientation	Training card
BNSF/Union Pacific ERailSafe Certification	System badge
BRES Training (for those conducting inspections and evaluations of BRES sites)	Completion of BRES training course with EPA or their designee.

H&S-related training documentation will be stored in the onsite HASP. It is the responsibility of the field H&S Manager to keep H&S-related training documentation up-to-date and on file for each field team member.

Prior to beginning field sampling activities, a field planning meeting will be conducted to discuss and clarify the following:

- Objectives and scope of the fieldwork
- Equipment and training needs
- Field operating procedures, schedules of events, and individual assignments

- QA/QC requirements
- H&S requirements
- On-track safety procedures.

It is the responsibility of each field team member to review and understand applicable governing documents associated with this asset management plan, including this QAPP, associated SOPs (Appendix B), and the applicable HASP.

A.9 Documentation and Records

A.9.1 Field

Field documentation will be collected and stored online in the Railroads' asset database managed by the Technical Representative. Field teams will record information on forms and then entered into the database by the Database Coordinator, as described in the DMP (Kennedy Jenks 2023b). The Railroad's Technical Representative will retain field documentation, which will be maintained and archived. Field documentation is discussed by topic throughout Section B. Field data management, including adding data to the asset database, is discussed in detail in Sections B.10.3 and B.10.4.

A.9.2 Inspection Report Revisions

The Technical Representative will disseminate approved copies of inspection reports associated with the BRES and stormwater BMP inspections to each of the project personnel on the distribution list. These reports are described in Section B.2.5 of this QAPP. The Technical Representative will provide copies of revisions to the project personnel on the distribution list as needed.

A.9.3 QAPP Revision

The Technical Representative's PM will disseminate copies of the QAPP to each of the project personnel on the distribution list once it is approved. Any revisions to the QAPP will be numbered sequentially. It will be the responsibility of the Technical Representative to see to it that each of the project personnel on distribution list receives copies of any revisions.

In addition to the QAPP, documents and records produced for BPSOU may include, but are not limited to:

- Field notes and records
- Chain-of-custody forms
- Laboratory analytical reports
- Field and laboratory QC data
- Photographs

- Spatial data
- Records of communication such as telephone logs, memorandums, e-mails, or other written correspondence.

Section B: Measurement/Data Acquisition

B.1 Study Design

The primary goal of the BRES and stormwater BMP programs is to maintain the caps and surface drainage control improvements to protect the capped mining waste from erosion and to maintain drainage on railroad property, respectively, in order to manage ecological risk and human health risk in BPSOU related to arsenic and lead. Inspecting these features on a set cycle verifies the features are functioning per design and gives CAPs that are implemented time to take effect.

Detailed information on sampling procedures and methods are presented in Section B.2.

B.1.1 Mobilization and Access

The Technical Representative will identify and provide the materials and personnel necessary to complete mobilization and demobilization associated with evaluation and sampling field activities.

Prior to beginning field activities, an internal field planning meeting will be conducted by the PM, which will be attended by the field team members conducting the work, a member of the QA team, a member of the H&S staff, and the BNSF and Union Pacific PMs as necessary. The agenda, prepared by the PM, will be reviewed and approved by QA and H&S staff prior to the field planning meeting. The meeting will briefly address and clarify:

- Documents governing fieldwork that must be in the field
- Changes in the governing documents
- Objectives and scope of the fieldwork
- Equipment and training needs
- Field operating procedures, schedule of events, and individual assignments
- Required QC measures
- H&S requirements
- BNSF- and Union Pacific-specific H&S requirements and procedures.

During the field planning meeting, copies of the agenda and additional necessary documents, including the HASP, will be distributed. Additional meetings will be held as needed to communicate changes to the documents governing fieldwork or the scope of the assignment.

Field team members will perform the following activities before and during field activities, as applicable:

- Review and understand applicable governing documents
- Record appropriate levels of documentation regarding activities conducted
- Obtain the necessary sample containers and other supplies
- Obtain, check, and calibrate field sampling equipment
- Obtain and maintain personal protective equipment (PPE)
- Coordinate with BNSF roadmasters to obtain track protection.

B.1.2 Site Evaluations

Site evaluations of all BRES sites occur on a 4-year cycle and site evaluations of all stormwater BMP sites occur on an annual basis as discussed in Section A.5.2. Figure A-3 identifies the location of the five geographic railroad areas within BPSOU and Figures A-4 through A-8 identify the location of each individual railroad asset. This section summarizes activities associated with the BRES and stormwater BMP site evaluations.

B.1.2.1 Field Procedures

The BRES and stormwater BMP site evaluation procedures are provided in BRES guidance (CDM Smith 2006) and the Stormwater BMP O&M Plan (Kennedy Jenks 2023a), respectively. The general procedures for site evaluations are described in Section B.2 of this report.

B.1.2.2 Field Equipment

An inventory of project-procured equipment and supplies will be conducted by field personnel prior to field work. Additional required equipment or supplies will be procured. The following equipment is required for sampling activities conducted under this QAPP:

- BRES Evaluation Field Forms or Stormwater BMP Evaluation Field Forms (provided in Appendices C and D, respectively)
- Indelible ink pens
- iPad (or similar) hand-held tablet
- GPS unit
- Site maps, including asset location maps
- Digital camera with memory card (if tablet does not have camera).

B.1.2.3 Post Field Collection Data Management

Evaluation forms entered onto the tablet in the field will be quality checked by the database manager and uploaded to the railroad asset database. Likewise, photographs from site evaluations will be pinned to the geographic location from which they were taken and uploaded to the Railroads’ online asset management site. Details of this workflow are described in the DMP (Kennedy Jenks 2023b).

B.1.3 Solid Media Site Sampling

B.1.3.1 Field Procedures

Based on site evaluations, the Railroads’ Technical Representative will perform field reconnaissance to determine sample locations. Solid media samples will be collected in the investigation area and field parameter measurements will be conducted and recorded. The number of solid media samples collected will be determined by field personnel based on the area and quantity of sediment in question and on field results obtained from a number of inspections, tests, and analyses. These procedures include visual inspection, field analysis for pH, field X-Ray fluorescence (XRF) analyses, and laboratory analyses as necessary. The solid media sampling procedures are provided in Appendix B. The general procedure for sampling of solid media for site characterization and laboratory sample collection is:

- Solid media will be visually inspected by BRES-qualified personnel during site evaluations.

- A pH analysis will be performed. The analyses will 1) target areas suspected to have heavy metals present based on the visual inspection and 2) be performed in a manner to obtain a representative pH of the solid media in question to identify subsequent analyses to be performed and guide solid media management. Solid media with a pH of less than 5.5 will be managed as described in the Solid Media Management SOP.

- Testing for metals will include an XRF and/or laboratory analyses. In addition to field XRF analysis, a minimum of 5 percent of samples field screened using XRF will be submitted for confirmatory analysis to a laboratory. Samples selection for laboratory confirmation will consider XRF results relative to action levels. If XRF results are below and within 35 percent of action levels, confirmatory sample selection will prioritize these. Results of XRF and laboratory testing will be used to guide solid media management.

- Shovel or trowel sampler is to be cleaned and disposable equipment will be disposed of.

A flow chart of the general procedure for sampling of solid media is provided on Figure 1 of the Solid Media Management SOP in Appendix B of this QAPP.

B.1.3.2 Field Equipment

For the solid media site sampling, the following field equipment is needed:

- Portable table

- Plastic sheeting

- Digital camera
- GPS unit
- Sterilized shovel or trowel
- No. 10 sieve
- Electric portable oven (RoadPro 12-volt Portable Stove or similar)
- Oven thermometer
- Delta Classic XRF unit (or equivalent)
- Gallon, or larger sized plastic zip-top bags
- Plastic 5-gallon pails with lids or cooler
- De-mineralized water
- Plastic bristle brush
- Alconox® or similar comparable equipment decontamination cleaning agent
- Paper towels
- 6-mil poly bag
- Trash bag
- Indelible ink pens
- Sample identification (ID) labels
- Cooler or other rigid container
- Custody Seals.

B.1.4 Solid Media Import Sampling

B.1.4.1 Field Procedures and Equipment

The procedures associated with the import of solid media for site use are described in the Type 1 Materials Testing, Rock Cap Materials Testing, and Backfill Materials Testing SOPs provided in Appendix B of this QAPP. The roles and responsibilities associated with the import of solid media are described in Section B.8 of this QAPP.

B.2 Evaluation and Sampling Methods Requirements

Field preparation activities include review of SOPs, procurement of field equipment, laboratory communication and coordination, railroad communication for track protection, and a field planning meeting discussed in Section A.8.1.

B.2.1 Evaluation and Sampling Technical SOPs

The technical SOPs to be followed are provided in Appendix B and are listed below in Table B-1.

Table B-1: Technical Standard Operation Procedures List

SOP Number	Title	Author
SOP-BPSOU-01	Solid Media Management	Kennedy Jenks
SOP-BPSOU-02	Vegetated Caps Barren Areas Sampling and Evaluation	
SOP-BPSOU-03	Type 1 Materials Soil Testing Requirements	
SOP-BPSOU-04	Rock Cap Materials Testing	
SOP-BPSOU-05	Backfill Material Testing	
SOP-BPSOU-06	Sample Packaging, Shipping, and Custody	
SOP-BPSOU-07	Field Equipment Decontamination	
SOP-BPSOU-08	Sample Collection from Excavations and Hand Dug Pits	
SOP-BPSOU-09	Surface Soil Sampling	
SOP-BPSOU-10	Handling and Disposing of Investigation-Derived Waste	
SOP-BPSOU-11	Global Positioning System (GPS) Coordinate Collection and Handling	

B.2.2 BRES Evaluation Techniques

Qualified field personnel will perform BRES site evaluations in accordance with the evaluation techniques described in EPA’s 2006 BRES Manual (CDM Smith 2006) for the inspection and maintenance of vegetated and engineered rock caps within BPSOU. Field personnel will review the parameters listed on the BRES Evaluation Field Forms and will identify trigger items. Field personnel will be equipped with a tablet with ArcGIS Collector software or equivalent to record geo-referenced field data, as described in the GPS Coordinate Collection and Handling SOP in Appendix B of this report. BRES Evaluation Field Forms are provided in Appendix C of this report.

B.2.3 Stormwater Best Management Practices Evaluation Techniques

Qualified field personnel will perform stormwater feature evaluations in accordance with the evaluation techniques described in the *Revised Interim Operation and Maintenance Plan 2023* (Kennedy Jenks 2023a) for the inspection and maintenance of the Railroads’ storm sewer systems components BMPs. Inspections will be conducted using Stormwater BMP Evaluation Field Forms provided in Appendix D of this report. Field personnel will be equipped with a tablet with ArcGIS Collector software or equivalent to record geo-referenced field data, as described in the GPS Coordinate Collection and Handling SOP in Appendix B of this report.

B.2.4 Sample Collection Techniques

Field personnel will record information collected in the field logbook or using the applicable field devices with logging or data recording capabilities. The decision to collect additional “opportunistic” samples will be made in the field by the sampling crew personnel and/or EPA personnel during the time of sampling. The BPSOU confirmation soil samples will be shipped to a certified laboratory for analyses. General collection procedures are below. Specific procedures are provided in the Solid Media Management SOP in Appendix B of this QAPP.

- Visually inspect the site to identify the number of sections needed for composite sampling. Maximum recommended composite section should be 50 feet by 50 feet, or 2,500 square feet.

- Take photographs to create a record to document the condition of the specific areas identified. Note the areas of concern from which solid media may be removed and document any physical structures or features (e.g., structures, fences, trees, etc.) that may be affected.

- Collect samples from the area of excavated solid media, stockpiled in appropriate area. Collect up to five subsamples from each composite sample section. The first composite sample will consist of subsamples from the 0 to 2-inch depth interval, the second composite sample will consist of sub samples from the 2- to 6-inch depth interval, and the third composite sample will consist of sub samples from the 6- to 12-inch depth interval, as needed. Thoroughly homogenize each composite sample in the bag (or stainless-steel bowl) by kneading the soil and pass the soil samples though a No. 10 sieve. Preservation of soil sample is unnecessary for the designated metals analysis. Sample volumes will consist of approximately 4 ounces of material using clean sample collection equipment.

- Place samples in electric portable toaster oven (or similar) for 2 to 4 hours at a temperature of less than 150 °C. Use an oven thermometer to measure temperature. Once samples are dry, remove all large organic debris and non-representative material, such as twigs, leaves, roots, insects, asphalt, and rock.

- Place solid media sample into new zip-top bag of appropriate size (minimum, quart size), close bag with minimum headspace, and apply sample ID, date, and time. Equal amounts of soil from each designated subsample location will be collected for compositing.

- No. 10 sieves will be cleaned between each composite sample. Clean and new plastic sheeting will be used to create a sample compositing work area at each location.

B.2.5 Corrective Action

Based on the findings of the Railroads’ 4-year-cycle BRES site evaluations, the Railroads will compile an inspection and technical recommendations report, including the status of the sites inspected, which will be submitted to the EPA and DEQ for review. If a CAP is necessary for the BRES sites, a CAP addendum will be created following the EPA-approved inspection and technical recommendations report. Once this CAP addendum is approved by EPA, the CAP(s) will be implemented. A Corrective Action Report template is provided in Appendix E of this report.

Based on the findings of the Railroads' annual inspection of stormwater BMPs, the Railroads will compile inspection and maintenance information into an annual maintenance report for the system, which will be submitted to the EPA and DEQ for review. The annual report will identify the effectiveness of existing maintenance and inspection protocol; identify repairs, deviations, or changes from the specified O&M activities; include copies of inspection forms; and include recommended changes to the plan, if necessary.

Separate from the maintenance needs identified during the formal inspections of Railroad BRES sites and stormwater BMPs: if basic maintenance needs are observed between inspection cycles, EPA will be notified of the need to conduct maintenance, and the maintenance record information will be submitted with the monthly status report or as agreed by EPA and the Railroads.

B.3 Sample Handling and Custody Requirements

B.3.1 Sample Identification

Samples will be labeled with sample ID numbers supplied by the Project QA Manager. The labels will be affixed to the sample containers and the sample ID number will be written in indelible ink on the sample label and chain-of-custody forms as described below. Sample IDs will be assigned based on the sample location or feature (e.g., BRES-992292A), analysis type (if applicable) and sample number from that location (e.g. XRF-001, pH-001), sampling date and time [e.g., YYYYMMDD@HHMM (military time)], and sample depth in feet (e.g., 0-0.5). A common nomenclature will be used from one sampling event to another for each area.

B.3.2 Sample Custody

Chain-of-custody procedures will be followed from the initial sampling through the completion of the laboratory analyses.

B.3.2.1 Field Custody Procedures

Labels will be prepared and attached to each sample container. Sample codes will be used to establish the identity of each sample. Sample labels will be completed in indelible ink with the following information:

- Client
- Sample identification code
- Date
- Time
- Initials of collector

- Method of analysis
- Preservative.

A chain-of-custody form will be filled out upon sample collection and field sample chain-of-custody records will be maintained during the sampling. The chain-of-custody form will include sample information, as well as chain of possession. At a minimum, the following information will be written on the chain-of-custody form:

- Sample identification number
- Time and date of collection
- Field sampler’s name
- Sample matrix
- Type, quantity, and volume of sample containers
- Project number
- Preservatives added
- Required analyses
- Requested analytical turn-around-time
- Additional information the laboratory must know to perform the requested analysis, such as holding time, filtering requirements, etc.

Each day at the conclusion of sampling, individual samples will be custody sealed and securely packed inside plastic coolers with ice or ice substitute. The chain-of-custody form will be enclosed in plastic and affixed to the cooler, which will be sealed such that the seal must be broken to open the cooler.

If following receipt by the laboratory a request for change is made to the chain-of-custody form by the sampler, a copy of the chain-of-custody form will be revised, initialed, and forwarded to the laboratory and will supersede the original chain-of-custody form. A copy of the original chain-of-custody form and documented changes to the original will be included as part of the final analytical report. This record will be used to document sample custody transfer from the sampler to the laboratory and will become a permanent part of the project file.

B.3.2.2 Sample Packaging and Shipment

Samples will be packed and shipped in accordance with applicable and current U.S. Department of Transportation (DOT) regulations, field consultant guidelines, and International Air Transport Association (IATA) standards (as detailed in the most current edition of IATA Dangerous Goods Regulations for hazardous materials shipments).

B.3.2.3 Laboratory Custody Procedures

The Laboratory Sample Custodian will be responsible for samples received at the laboratory. The Laboratory Sample Custodian will be familiar with custody requirements and the potential hazards associated with environmental samples. In addition to receiving samples, the Laboratory Sample Custodian will also be responsible for documenting sample receipt, storage before and after sample analysis, and the proper disposal of samples. Upon sample receipt, the Laboratory Sample Custodian will accomplish the following tasks.

- The coolers and sample containers will be checked for integrity and to verify that custody seals are intact.

- The temperature of the samples and presence of leaking or broken containers upon receipt will be noted on the chain-of-custody/sample analysis request forms.

- The preservation of the samples will be checked and recorded (unless it is checked in the appropriate laboratory area, i.e., volatile aqueous samples).

- The chain-of-custody/sample analysis request forms will be signed and marked with the date and time of receipt, thereby assuming custody of the samples.

- Laboratory sample identification numbers will be assigned to each sample.

- The information on the chain-of-custody/sample analysis request forms will be compared to the sample labels to verify sample identity. Inconsistencies will be resolved with a field sampling representative before sample analysis proceeds.

- The samples will be placed in a secured, climate-controlled, storage area.

In the event of sample leakage or other evidence of damage to a sample, the PM will be contacted for a decision regarding sample disposition. Original samples will remain in a secured storage area at all times unless being used for analysis. Access to this area will be limited to designated laboratory personnel. Following analysis, samples will be retained in a secured area until notified otherwise by the PM.

B.4 Analytical Methods Requirements

B.4.1 Laboratory Quality Assurance Program

Laboratory activities will be performed by qualified personnel. Each staff member will have the combination of experience and education needed to demonstrate the required knowledge for his or her position. The laboratory QA Manager will conduct internal laboratory inspections to evaluate compliance with the project requirements and this document. The laboratory will be responsible for verifying that QC procedures are followed and that the results of QC analyses are within the specified acceptance criteria. The Project QA Manager will be notified of deviations from the QC requirements.

B.4.2 Equipment

In accordance with BPSOU Solid Media Management SOP provided in Appendix B of this QAPP, instruments for pH analysis of solid media will include nitrile gloves, stainless steel trowel or disposable towel, clean container (e.g., disposable cup), distilled water, and direct soil pH meter such as a HI 99121 Soil pH Meter by Hanna Instruments or equivalent. The pH paste method is described in Appendix F. Alternatively, the pH measurement may be performed using distilled water and a YSI EcoSense pH100 hand-held meter or equivalent. When using distilled water and a YSI, the pH for the solid media will be collected using the *Saturated Soil Paste Method* (U.S. Department of Agriculture 1954). For pH testing, clean and new plastic sheeting will be used to create a pH analysis work area at each location.

In accordance with BPSOU Solid Media Management SOP provided in Appendix B of this QAPP, equipment for XRF analysis of solid media will include nitrile gloves, stainless steel tape measure or ruler, stainless steel trowel or disposable towel, No. 10 sieve, electric portable toaster oven, oven thermometer, stainless steel bowl or cleaned foil pan, sample container, zip-top bag, plastic sheeting, and Delta Classic XRF unit (or equivalent).

B.4.3 Methods

Field personnel will conduct analysis for pH and XRF analyses of solid media samples in accordance with the BPSOU Solid Media Management SOP provided in Appendix B of this QAPP. The actual number of sample locations will be evaluated in the field based on environmental conditions of the site and after consultation with the Agencies. Rationale for laboratory sample submission will be based on the results obtained from the original XRF field analysis as well as 5 percent of all samples collected.

Selected samples will be submitted for laboratory analysis to confirm and expand on field XRF results. Confirmation samples will be analyzed for the analytes listed in Table A-1. Samples will be prepared for metals analysis in accordance with the published laboratory procedures. Sample turnaround time is a maximum of 2 weeks from the submittal date. The laboratory will analyze samples for metals in accordance with *EPA Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, also known as SW-846 Test Method 6010D: Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-AES), Revision 5, July 2018* (EPA 2018) or subsequent revision.

B.4.4 Turnaround Time

The laboratory's "standard" turnaround time will be requested for sample analyses performed under this QAPP. A laboratory's standard turnaround time varies and usually ranges from 10 to 15 business days. However, actual completion of the analyses and deliverable of the final analytical report depends on the analyses requested, the backlog at the laboratory, and whether re-analyses are required due to out of control QC criteria or the need for dilutions. Should a faster turnaround time be necessary, it will be discussed with the laboratory to determine whether the laboratory can meet the requested turnaround time.

B.4.5 Corrective Action

As stated in Section B.4.1, the laboratory QA Manager is responsible for notifying the Technical Representative’s Project QA Manager of deviations from the QC requirements and for implementing corrective action if the QC acceptance criteria are not met.

B.5 Quality Control Requirements

QC samples will be assessed for both field and laboratory operations to evaluate overall precision/bias and accuracy throughout the project. Field QC samples will include field duplicate and blank samples. The frequency of field QC samples is discussed below. Laboratory QC parameters, criteria, and frequency are specified in the analytical methods referenced in Section B4.2 above. Comparison of QC sample results against established criteria is performed during the data verification process described Section D.

B.5.1 Field Quality Control Samples

QC samples will be collected early on in the sampling event. Additional QA/QC samples will be collected if field conditions change and additional samples are deemed necessary.

B.5.1.1 Equipment Blank Samples

Equipment blank samples are collected to monitor the effectiveness of decontamination procedures and to identify potential cross contamination between sampling locations. Equipment blank samples will be collected when sampling equipment is being reused during sampling. One equipment blank sample will be collected each day of sampling if sampling equipment is being used. The equipment blank sample will be collected after decontamination and before use at the subsequent sampling location. An equipment blank sample is collected by rinsing decontaminated sampling equipment with distilled or deionized water and placing the collected water in an appropriate sample container with preservative as necessary. Equipment blank samples will be analyzed for the same parameters as the environmental samples collected using the equipment in question.

B.5.1.2 Field Duplicates

Field duplicate samples are designed to monitor overall sampling and analytical precision. In general, duplicate samples will be collected at a frequency of approximately one duplicate sample per 20 samples or one duplicate sample per batch of samples if less than 20 samples are collected. Note: A batch is herein defined as six samples or more. No duplicate samples will be collected if five or fewer samples are collected for a given sampling task.

Soil field duplicate samples will consist of collecting a sample, homogenizing the sample, and splitting the sample into two equal aliquots. If the sample is to be analyzed for volatile compounds, the sample will not be homogenized before collection of primary or duplicate sample. For duplicate water samples, sample containers will be alternately filled.

Field duplicate samples will be collected from locations including areas of known or suspected contamination. Duplicate samples will be treated as separate samples from the originals (assigned unique sample numbers), and not identified to the laboratory as duplicate samples. Field duplicate samples will be documented on the daily field report, in the field logbook, or other appropriate field form.

B.5.2 Laboratory Quality Control Samples

The general objectives of the internal laboratory QC program are to:

- Verify that procedures are documented, including changes in administrative or technical procedures.

- Verify that analytical procedures are validated and conducted according to method guidelines and laboratory SOPs.

- Monitor the performance of the laboratory using a systematic inspection program.

- Verify that data are properly reported and archived.

Laboratory QC consists of a laboratory and a matrix component. The laboratory component measures the performance of the laboratory analytical process during sample analyses, while the matrix component measures the effects of a specific medium on the method performance. The QC samples used to assess these two components are described below. Corrective actions for instrument calibrations or QC sample data that are out of compliance are typically described in the laboratory-specific QA/QC program.

The laboratory will conduct internal QC checks for analytical methods in accordance with the individual method requirements and the laboratory SOPs. The laboratory will notify the PM or QA Manager in writing before making corrective action changes to procedures described in this QAPP, or to the laboratory standard analytical methodology. The PM or Project QA Manager will need to approve these proposed corrective actions in writing prior to implementation.

The laboratory will, at a minimum, analyze internal QC samples at the frequency specified by the analytical method and the laboratory’s internal quality program. Method-specific QC procedures, frequency of QC sample analysis, acceptance criteria (control limits), and corrective actions identified in the laboratory SOPs provided by the laboratory will be in accordance with this QAPP. The following sections discuss holding times and the QC samples used by the laboratory to assess data quality.

B.5.2.1 Sample Holding Time

Sample holding time is the length of time that a sample or sample extract can be expected to remain representative of environmental conditions. Holding times for the proposed metals analyses are 180 days from the date of collection (EPA 2018). Samples will not be analyzed outside specified method holding times without approval of the PM. The laboratory is responsible for disposal of remaining samples after the holding time has elapsed. The laboratory must obtain approval from the PM before sample disposal.

B.5.2.2 Matrix Spikes and Matrix Spike Duplicates

MS/MSDs measure matrix-specific method performance and will be used to assess accuracy and precision. MS/MSD samples will be used to assess the influence of the sample media (media interference) on the analysis. Samples for MS/MSD analysis will be site specific and analyzed at a frequency of 5 percent of the total number of samples (no less than one in 20 samples). Samples submitted as MS/MSDs should be as representative as possible of site conditions.

Each MS/MSD sample will be spiked with the compounds specified by the analytical method prior to sample extraction or analysis in accordance with the laboratory SOPs. Composite matrices should be constructed from portions of samples from the sample lot, homogenized, labeled as a batch matrix, and analyzed as a batch sample for MS/MSD.

B.5.2.3 Method Blanks

Method blank samples will be used to monitor the laboratory preparation and analytical systems for interferences and contamination from glassware, reagents, sample manipulation, and the general laboratory environment. The method blank sample is an analyte-free matrix (reagent grade water or laboratory grade sand) to which compounds, as specified in the method, will be added in the same volumes or proportions as used in sample processing and will be taken throughout the entire sample preparation/extraction and analytical process. Method blank samples will be analyzed at the frequency specified by the analytical method, in the laboratory QA program, and the laboratory SOPs.

B.5.2.4 Laboratory Control Sample

LCSs will be used to assess accuracy. The LCS may either be prepared from the same source as the calibration standards or independently of the calibration standards. An independently prepared LCS may either be obtained as or prepared from a certified reference solution or prepared from a certified reagent solid or from an alternate lot reagent solid relative to the calibration standards source. For each analytical batch, at least one LCS should be prepared from the same source as the calibration standards. In this way, if the recoveries of both the LCS and the MS are outside the acceptance limits, the analyst will be able to evaluate whether the problem is due to a calibration error or a matrix interference.

B.6 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Field equipment will include sampling shovels, XRF units, and GPS units, which will be tested, inspected, and maintained according to the manufacturer's guidelines and recommendations. XRF instrument manuals are provided in Appendix G of this QAPP. When a piece of equipment is found to be operating incorrectly, the equipment will be labeled "out of order" and placed in a separate area from the rest of the sampling equipment. The person who identified the equipment as "out of order" will notify the field team leader overseeing the confirmation sampling activities. It is the responsibility of the field team leader to facilitate repair of the out-of-order equipment. This may include having appropriately trained field team members complete the repair or shipping the malfunctioning equipment to the manufacturer. Field team members will have access to basic tools and spare parts required to make field acceptable repairs. This will allow timely repair of "out of order" equipment.

B.7 Instrument Calibration and Frequency

The calibration procedures described in this QAPP are designed to ensure that field equipment and instrumentation are calibrated to operate within manufacturer specifications and that the required traceability, sensitivity, and precision of the equipment/instruments are maintained. All field and laboratory instruments and equipment used for measurement data will be operated and calibrated according to manufacturer's guidelines and recommendations.

Calibration records must include the following information (whenever available and appropriate for the specific instrument or equipment):

- Calibration date
- Test method
- Instrument
- Analysis date
- Each analyte's name
- Analyst's initials or signature
- Concentration and response
- Calibration curve or response factor.

Only personnel properly trained in these procedures should operate and calibrate the instruments. Calibration measurements and maintenance records are documented so data may be verified and validated during an audit. Calibration records will be saved to the project file.

B.7.1 Field Instruments

Field instruments that may be used during investigative activities include, though are not limited to, an XRF unit and a GPS unit. The field instruments will be calibrated in accordance with the manufacturer's instructions and recommendations. The field instruments will be calibrated at the frequency described in Table B-2 and following equipment maintenance, correction of malfunction, or change or update of the analyzer software. The performance and results of equipment calibrations, and calibration source information (manufacturer, lot number, date opened), as well as any errors or maintenance will be documented in the field log book.

Table B-2: Field Instruments – Preventive Maintenance

Instrument	Activity	Frequency
pH Meter	Calibration and calibration check – pre-sampling event	Once prior to sampling event
XRF Unit	Calibration and Calibration Check – pre-sampling event	Once prior to sampling event
	Battery check	Daily
	Calibration – beginning of day	

Instrument	Activity	Frequency
	Calibration check – beginning of the day	
	Possible mid-day calibration check	
	Calibration check – end of day	
GPS iPad setup	Calibration and calibration check – pre-sampling event	Once prior to sampling event
	Battery and back-up battery check	Daily
	Positioning check	Hourly

B.7.2 Laboratory Instruments

Laboratory instrument calibration is necessary to verify that the analytical system is operating correctly and functioning at the proper sensitivity to meet the required quantitation limits. Calibration establishes the dynamic range of an instrument, establishes response factors to be used for quantitation, and demonstrates instrument sensitivity. Criteria for calibration are specific to the instrument and the analytical method. Laboratory instruments will be calibrated in accordance with the analytical method and laboratory SOPs.

B.8 Inspection/Acceptance Requirements for Supplies

Specifications for imported materials are provided in the material import SOPs in Appendix B of this report.

B.8.1 Responsibilities of the Technical Representative

The Technical Representative will review materials proposed for use, sample and test proposed import fill source (including chemical testing for the presence of hazardous substances), observe site grading, observe placement and compaction of fill, and test soils during placement of fill.

B.8.2 Responsibilities of the Contractor

Prior to bringing backfill to the site, the Contractor shall define the backfill source and vendor and provide Technical Representative with a sample of the material proposed for use as backfill for analytical testing.

Upon receipt of favorable test results, the Railroads' Technical Representative will conditionally approve import material for use. The Technical Representative may collect and analyze additional samples from imported fill to confirm compliance with the initial laboratory results and these specifications. Material brought to the site and found to deviate from the initially approved test results will be removed at the Contractor's expense. The Contractor will not import soil until the Technical Representative gives approval. Changes in materials or source may require additional analytical testing at the option of the Technical Representative.

The Contractor will pay for all testing costs, pay any additional costs including the Technical Representative's costs resulting from additional inspection and retesting due to noncompliance, remove and replace import fill found to deviate from the initially approved test results, and cooperate with the Technical Representative to obtain samples for testing.

B.9 Data Acquisition Requirements

It is important that data collection and analysis are performed correctly in accordance with standard data collection and analysis procedures. Due to the ongoing O&M status of this project, data are typically generated following inspection of railroad assets. In some circumstances, it may also be necessary to upload new data into component databases following laboratory analysis and/or corrective maintenance.

Generally, data collected as a result of inspections and ongoing O&M will fall under the category of field data. This includes field measurements, photographs, field book notes, sampling logs, survey data, GPS data, and data from observation forms. As described in the DMP (Kennedy Jenks 2023b), the Data Collector is responsible for submitting the field data to the Database Coordinator in the appropriate format suitable for associated component databases. Data collected may be categorized as one of three types: spatial, non-spatial, or image data, defined as follows:

- **Spatial data** consists of features typically represented by a point, line, or polygon. Drainage structures, caps, and other features with boundaries capable of being represented by GPS coordinates would be examples of spatial data.

- **Non-spatial data** consists of documentation or tabular data, such as analytical data, field observations, BRES inspection and maintenance field forms, and reports.

- **Image data** includes such items as monitoring and maintenance photographs, aerial photographs, drawings, figures, or diagrams.

Sampling data for laboratory chemical analysis may be collected. The locations of samples are measured to produce a spatial data point. Laboratory chemical analytical data will typically be transmitted from subcontractor laboratories to the Data Collector and/or the Database Coordinator electronically via email distribution or file transfer protocol (FTP). This will facilitate the subsequent QA/QC and analysis of these data while avoiding transcription errors that may occur with computer data entry. Data validation and flags and labels will be added to electronic (and paper[5]) transmissions.

Further description of data collected in association with the Railroads' assets in BPSOU, including data management roles and responsibilities, data collection, and data storage and management is provided in the DMP (Kennedy Jenks 2023b). Records will be preserved for a period of six years after submittal to EPA.

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[5] The EPA and the Railroads' preference is for submittals and associated data transmissions to be provided electronically.

B.10 Data Management

Data management for the railroad assets within BPSOU are detailed in the DMP (Kennedy Jenks 2023b). A general summary of data management is provided in the following subsections.

B.10.1 Laboratory Reporting Requirements

The laboratory will provide final laboratory analytical reports that will include the following at a minimum:

- Cover page with report case narrative summarizing deviations or problems with the analyses and confirmation that project-specific requirements have been fulfilled
- Sample information [including unique sample identification, sample collection date and time, date of sample receipt, and date(s) of sample preparation and analysis]
- Copies of chain-of-custody documentation
- Analytical results reported with an appropriate number of significant figures
- Reporting limits reflecting dilutions, interferences, and corrections for dry weight, as applicable
- Method references
- Appropriate QC results and correlations to sample batches for traceability and documentation
- Data qualifiers with appropriate references and narrative on the quality of results.

The laboratory will provide a Level 3 report for each sample delivery group. Those sample delivery groups requiring a Stage 4 validation will be supplemented with a Level 4 laboratory report. The laboratory is required to retain the information to produce a Level 4 report for six months following the Level 3 report. Reports will be provided within a standard turnaround time unless otherwise required.

Each data package, as described above, will be accompanied by an EDD prepared by the laboratory. If data qualifiers are required, they will be added to the laboratory EDD and provided for uploading to the database. Additional laboratory QC data can be included in the EDD. The EDDs will be cross checked against corresponding data reports to confirm consistency in results reported in Level 3 or Level 4 report as appropriate. This cross check will take place as part of the data verification process.

B.10.2 Data Management Roles and Responsibilities

The Railroad Database System (Database System) will be managed by Railroad PMs providing direction for oversight of Database System O&M to their Technical Representative. The Technical Representative oversees the Database System operators, including, but not limited to, the Database Coordinator and Project QA Manager. Participants in this Database System include Data Collectors, Data Producers, a Database Coordinator, a QC Manager, Server Administrators, and Data Users.

B.10.3 Data Collection

Data collected according to the SOPs and project-specific plans/manuals are stored in a collection of component databases that make up the project Database System. These component databases are maintained by the Railroads and their Technical Representative. The Railroads GIS Map is a component database that stores spatial data and some image data. Data collected from the inspection and maintenance of railroad assets is stored in two component databases: the BRES Inspection and Maintenance Database and the Railroad Assets Database. The Railroads maintain a component database document repository that stores digital copies of EPA-approved documents for the Railroads' BRES and stormwater BMPs O&M programs. This component document repository is located on a web-based SharePoint site (the Railroads' SharePoint Online Website), which serves as the External Database System Portal.

The internal flow of data from collection to quality assurance review to database input to database output is generally described as follows:

- Data are collected under the BRES and stormwater BMPs O&M programs during inspections and maintenance/construction.

- Data are captured by Data Collectors on O&M program-specific forms and checklists (non-spatial data) and the Railroads' web-based GIS map (georeferenced spatial and image data).

- The BRES forms are managed, reviewed for quality assurance by the Project QA Manager or by a designee identified by the Project QA Manager, and stored within the BRES Inspection and Maintenance component database. Stormwater BMP field forms are stored on a private server and receive a quality review by a qualified technical project team member who crosschecks the accompanying checklists. The stormwater BMPs checklists then receive a QA review by the Database Coordinator and are embedded into the Railroads Asset Database.

- Once data have been through QA review, reports can be prepared, and status exhibits can be updated on the External Database System Portal (Railroads' SharePoint Online Website). When O&M-related reports are approved by EPA, they will also be uploaded to the External Database System Portal (location of the document repository).

B.10.4 Data Storage and Management

The Database System is the data storage reservoir in which component databases with different data storage functions exist for the railroad assets data. This system and its components are described in further detail in the DMP (Kennedy Jenks 2023b).

Section C: Assessment and Oversight

C.1 Assessment and Response Actions

Performance assessments are quantitative checks on the quality of a measurement system and are appropriate to analytical work. System assessments are qualitative reviews of different aspects of project work to check the use of appropriate QC measures and the general function of the QA system. Field system assessments will be performed under the direction of EPA RPM or designate, with support from the Technical Representative PM or designate. Field surveillances will be conducted at the onset of field sampling activities and if field processes are revised or other QA/QC procedures indicate potential deficiencies field personnel will document procedure revisions and work with the PM and QA team members to address deficiencies. It is not anticipated that a field audit will be conducted for the evaluation or sampling efforts described in this QAPP. Laboratory system assessments/audits will be coordinated by the EPA. Performance assessments for the laboratories may be accomplished by submitting blind reference material (i.e., performance evaluation samples). These assessment samples are samples with known concentrations that are submitted to the laboratories without identifying them as such to the laboratories.

Corrective response actions will be implemented on a case-by-case basis to maintain quality. Minor actions taken to immediately maintain quality will be documented in the applicable field document or laboratory logbook and a verbal report will be provided to the appropriate manager (e.g., the Technical Representative PM). For potential quality deficiencies that are not resolved with rapid corrective action, the individual identifying the potential quality deficiency will notify the PM and Project QA Manager, who will be jointly responsible for investigating the potential deficiency and following up on the resolution. The documentation of the resolution will be provided to the EPA RPM and the Railroads. EPA project management will be notified when quality problems arise that cannot be corrected quickly through routine procedures.

C.2 Reports

Monthly activity update reports will be prepared for months that activities occurred. Reports will be emailed to the Railroads for review, prior to submission to the EPA RPM and complete distribution list. These reports summarize the meetings between the Railroads and the EPA and DEQ, report submissions to the EPA and DEQ, and fieldwork conducted on behalf of the Railroads. Additionally, QA reports will be provided to EPA management when quality corrective actions are taken. Field staff will note potential quality deficiencies on field documents. Furthermore, the Technical Representative will inform the EPA RPM and the Railroads upon encountering quality deficiencies that cannot be immediately corrected.

Section D: Data Validation and Usability

D.1 Data Review, Validation, and Verification

The goal of the data validation process is to evaluate overall data quality and to assign data qualifiers, as appropriate, to alert data users to potential data quality issues. Criteria that will be evaluated include sample receipt, sample preparation, instrument calibrations, blank analysis (if applicable), recount/repreparation analysis (if applicable), and overall assessment of data.

Field and laboratory data generated during implementation of the long-term O&M of railroad assets will be reviewed, verified, and validated. Field data entered into databases will be verified. Errors identified during the verification of data will be corrected prior to release of the final data.

The laboratory is responsible for verifying analytical results prior to the submittal of the final laboratory data report. Initially, analytical data generated by the laboratory are verified by the laboratory. During the analysis process, the analyst and the laboratory QA Manager verify that the results have met various performance-based control limits (e.g., surrogate recoveries and continuing calibration). Non-conformance of various method QC requirements and control limits warrants the re-analysis and/or re-extraction of a sample.

Once the laboratory has released the final data report, the data will be reviewed by the Technical Representative's Project QA Manager. The Project QA Manager will review the data package to verify that all samples are accounted for. Finally, the data will be verified and validated based on the quality objectives specified in this QAPP and performance-based criteria specified in the analytical methods in accordance with applicable portions of EPA's *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA 2020). If data do not meet required criteria, they will be flagged with data qualifiers as specified under the action portion of each requirement of these functional guidelines.

- Data verification and validation will be conducted to assess the laboratory's performance in meeting the quality objectives identified in the QAPP (e.g., reporting limits and control limits) and performance-based criteria specified in the analytical methods. Data validation will be conducted by the Project QA Manager or another designee in accordance with applicable sections of the *Clark Fork River Superfund Site Investigation (CFRSSI) Data Management/Data Validation Plan* (ARCO, 1992a), *Clark Fork River Superfund Site Investigation (CFRSSI) Data Management/Data Validation Plan* Addendum (AERL, 2000), EPA's *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA 2020) and project data quality objectives.

If data do not meet the quality objectives and required criteria, they will be flagged with data qualifiers as specified under the action portion of each requirement of the functional guidelines (EPA 2020). Typical data qualifiers include, but are not limited to, "J," used to indicate an estimated value, "U," used to indicate not detected via validation above the method reporting limit, and "R," used to indicate a rejected value. Upon completion of the data validation, the findings will be summarized in the technical memorandum report.

D.2 Data Verification and Validation Methods

D.2.1 Data Verification

Data verification includes checking that results have been transferred correctly from the original hand-written, hard copy field notes, or field collection software, and analytical laboratory documentation to a database. The goal of data verification is to identify and correct data reporting errors. The Level A/B review (see checklist in Appendix H), as described in the CFRSSI Data Management/Data Validation (DV/DM) Plan (ARCO 1992a) and the CFRSSI DM/DV Plan Addendum (AERL 2000b), will be used in the verification process for field documentation related to samples collected for laboratory analysis.

The Level A criteria include:

- Sampling date.
- Sample team and/or leader.
- Physical description of sample location.
- Sample depth (soils).
- Sample collection technique.
- Field preservation technique.
- Sample shipping records.

The Level B criteria include:

- Field instrumentation methods and standardization completed.
- Sample containers preparations.
- Collection of field duplicates.
- Proper and decontaminated sampling equipment.
- Field custody documentation.
- Shipping custody documentation.
- Traceable sample designation number.
- Field notebook(s), custody records in secure repository.
- Complete field forms.

The data verification review identifies data reporting issues to be rectified to limit the impact on overall data quality. For analytical laboratories that utilize the project-specific electronic data deliverables (EDDs) for solid media data reporting, a 10 percent verification will be performed on the first data set by the validator with periodic verification of detections occurring after the initial verification. If issues are identified during the data verification, the frequency of these checks may be increased as appropriate. Further data verification may be performed by Technical Representative staff familiar with project-specific data reporting, and sampling requirements. If issues are identified, they will be discussed with the validator or Database Coordinator.

It is the responsibility of the project Database Coordinator to coordinate with the Project QA Manager to resolve project database corrections and address recommended field or laboratory procedural changes resulting from verification or validation. The names of the individuals who performed the data verification, and the dates of each review will be maintained in the Data Validation Summary Form.

D.2.2 Data Validation Methods

The data will be validated during the data validation process with guidance from the CFRSSI QAPP (ARCO 1992b), the CFRSSI DM/DV Plan (ARCO 1992a), the CFRSSI DM/DV Plan Addendum (AERL 2000b), the *National Functional Guidelines for Inorganic Superfund Methods Data Review* (EPA 2020b), laboratory-specific QC criteria, and/or method-specific criteria where applicable. The use of the Functional Guidelines versions listed above is important to maintain consistency between data validation and qualification of data currently being performed and future work to be performed under the RMAP program. It should be noted that the US EPA National Functional Guidelines, which were developed for the validation of data generated according to the Contract Laboratory Program (CLP), are not directly applicable to the type of analysis/protocols associated with the analysis for this project. EPA National Functional Guidelines qualifies data based on strict contractual CLP method requirements and acceptance criteria which may not be consistent with the requirements and acceptance criteria presented in SW-846 methods. Data validators will apply EPA guidelines as appropriate, assess the data relative to method QC protocols and DQOs in this QAPP, and use professional judgment according to the documents listed above.

Data qualifiers will follow those used in the EPA *National Functional Guidelines for Inorganic Superfund Methods Data Review* (EPA 2020b) and listed in the table below. Data validation for each laboratory data package will be documented on the data validation checklists based on the CFRSSI DM/DV Plan Addendum (AERL 2000b) guidance (Attachment K). The Data Validator will be responsible for reviewing field documentation associated with sample collection, conducting the verification and validation of laboratory-produced data, and completing a data validation report, which will be reviewed by the Project QA Manager.

Qualifier	Definition
U	The result is qualified as non-detect due to the detection of the analyte in an associated QC blank.
J	The result is an estimated quantity. The associated numerical value is the approximate concentration of the analyte in the sample.
J+	The result is an estimated quantity, but the result may be biased high.
J-	The result is an estimated quantity, but the result may be biased low.
UJ *	The analyte was analyzed for, but was not detected. The reported quantitation limit is approximate and may be inaccurate or imprecise.
R	The data are unusable. The sample results are rejected due to serious deficiencies in meeting QC criteria. The analyte may or may not be present in the sample.

* U may be omitted if a “<” sign is used preceding the result to indicate the result was not detected. This allows for rapid identification of qualification due to associated QC blanks.

D.2.2.1 Validation Stages

The content and scope of the Stage 2B and Stage 4 data validation will be performed with guidance from *Guidance for Labeling Externally Validated Laboratory Analytical Data for Superfund Use, OSWER No. 9200.1-85, EPA 540-R-08-005, 13* (EPA 2009). The major difference between Stage 2B and Stage 4 data validation is the detail level of the data evaluation. Stage 4 data validation is an in-depth process that consists of a comparison between raw data and summary forms to check for inconsistencies between reported data and raw data. Stage 2B data validation does not involve evaluating raw data or comparing reported data with raw data and assumes that all results and recoveries are correctly reported.

The first sample delivery group will undergo Stage 4 validation. The number of samples in each sample delivery group (SDG) may vary depending on the extent of sampling. Therefore, a minimum of 5 samples will undergo stage 4 validation. The data validator will perform Stage 4 data validation on the first 5 samples collected in the first SDG or subsequent SDG if fewer than 5 samples are collected in the first SDG. Stage 4 validation for these samples will verify the laboratory is analyzing the project samples according to the applicable analytical methods and QAPP procedures and is providing required data deliverables. The remaining data will be validated at a Stage 2B level. This approach will allow the data validator to identify and have the laboratory correct laboratory issues early in the data collection process. In the event significant problems or issues are identified during the initial Stage 4 data validation effort, it may be necessary to increase the amount of data subjected to Stage 4 validation to confirm identified errors and non-compliances have been appropriately corrected. In addition, the technical representative can also offer guidance or request Stage 4 data validation as the required level of validation based on project DQOs. Requests for Stage 4 data validation must be made within 2 months of receipt of the laboratory report.

Stage 2B and Stage 4 data validations and reports are generated by an initial reviewer on a per SDG basis from the Level 3 or Level 4 data package to confirm completeness and data usability of data packages. Level 3 data packages contain the same information as the Level 4 data packages with the exception that instrumental QC (i.e., instrument tunes and raw data) to support the sample and the QA/QC results are not provided. Each validation report is reviewed by a senior chemist for accuracy to confirm that the initial reviewer has rigorously evaluated the recoveries/results and applied the applicable qualifiers to the data. The following table summarizes the Stage 2b and Stage 4 quality control elements to be evaluated.

QUALITY CONTROL ELEMENTS	**STAGE 2B**	**STAGE 4**
HOLDING TIME AND SAMPLE MANAGEMENT/PRESERVATION REQUIREMENTS WERE MET	√	√
CHAIN-OF-CUSTODY FORM(S) WERE PROPERLY FILLED OUT AND SIGNED AND ANALYSES MATCH THE SAMPLE PLAN AND REPORTED RESULTS	√	√
S**OIL SAMPLES ARE REPORT ON A DRY-WEIGHT BASIS**	√	√
GAS CHROMATOGRAPHY COUPLING WITH MASS SPECTROMETRY (GC/MS) OR HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY WITH MASS SPECTROMETRY (HPLC/MS) INSTRUMENT TUNING	N/A	N/A
INDUCTIVELY COUPLED PLASMA-MASS SPECTROMETRY (ICP/MS) TUNING	√	√
INITIAL CALIBRATION (ICAL)	√	√
INITIAL CALIBRATION VERIFICATION (ICV)	√	√
CONTINUING CALIBRATION VERIFICATION (CCV)	√	√
INITIAL CALIBRATION BLANK AND CONTINUING CALIBRATION BLANK (ICB/CCB)	√	√
BLANKS - METHOD BLANK, FORTIFIED BLANK, AND FIELD COLLECTED BLANK (I.E. FIELD BLANK, TRIP BLANK, EQUIPMENT BLANK) CONTAMINATION **AND FREQUENCY**	√	√
SURROGATE SPIKES	N/A	N/A
MULTIPLE RESULTS FOR ONE SAMPLE	√	√
INDUCTIVELY COUPLED PLASMA (ICP) INTERFERENCE CHECK SAMPLE	√	√
MATRIX SPIKE (MS), MATRIX SPIKE DUPLICATE (MSD), LABORATORY DUPLICATE, OR POST-DIGESTION SPIKE (PS) RECOVERY AND FREQUENCY	√	√
LABORATORY CONTROL SAMPLE (LCS), LABORATORY CONTROL SAMPLE DUPLICATE (LCSD), AND/OR STANDARD REFERENCE MATERIAL (SRM) RECOVERY AND FREQUENCY	√	√
SERIAL DILUTION	√	√
INTERNAL STANDARDS	√	√
FIELD DUPLICATE RPD	√	√
REPORTING LIMIT CHECK SAMPLE ANALYSIS (CRA)	√	√
PROJECT REPORTING LIMITS (RL)	√	√
TARGET ANALYTE/COMPOUND IDENTIFICATION	N/A	N/A
TARGET ANALYTE/COMPOUND QUANTITATION	--	√
SYSTEM PERFORMANCE	--	√
OVERALL DATA USABILITY ASSESSMENT	√	√

N/A – Not applicable

"√" – Indicates the QC parameter is to be reviewed

-- – Indicates the QC parameter is not reviewed in the validation process

D.3 Reconciliation with Data Quality Objectives

D.3.1 Data Evaluation and Reduction

The analytical data generated through the analytical laboratories for this project will be evaluated for compliance with parameter criteria as described in the DQOs in Section A.7 and Appendix A of this report. This includes a review of the following items:

- Holding times and preservation
- Laboratory method (preparation) blanks
- System monitoring compounds (surrogates)
- MS/MSDs
- LCSs
- Field duplicates
- Equipment and trip blank samples (if collected).

Data determined to be not usable will be marked as rejected with the qualifier 'R' and noted in the Acceptability/Use of Data section of the Data Validation Summary Form.

Samples are not expected to be analyzed by more than one method for the same analyte or analyzed multiple times by the same method for a given sample; however, should this occur, a project-specific evaluation will be performed to select results to be kept and used. Results not selected will be marked rejected. Non-detect results with PQLs higher than the Solid Media Action Levels will be evaluated to identify the reason for elevated PQLs and documented in the Data Validation Summary Form. Usable data collected under this QAPP will not be further reduced.

Defined acceptance criteria and quantitative or qualitative goals (e.g., control limits) for precision, accuracy, representativeness, comparability, completeness, and sensitivity will be used when conducting a data quality assessment. If data satisfy the project DQOs, usability of the data will follow the enforcement/screening/unusable data categories as described in the CFRSSI DV/DM (ARCO 1992a):

Quality Designation	Status Qualifier	Data Use	Assignment Criteria
Enforcement	E	Data may be used for all purposes under the Superfund program including the following: site characterization, health and safety, Environmental Evaluation/Cost Analysis, remedial investigation/feasibility study, alternatives evaluation, confirmational purpose, risk assessment, and engineering design.	No qualifiers assigned via validation and meets Level A and B criteria.
Screening	S	Data may potentially be used depending upon their quality, for site characterization, determining the presence or absence of contaminants, developing or refining sampling and analysis techniques, determining relative concentrations, scoping and planning for future studies, engineering studies and engineering design, and monitoring during implementation of the response action.	J or UJ qualifiers assigned via validation and/or meets only Level A criteria.
Rejected or Unusable	R	Data are not useable for Superfund-related activities.	R qualified via validation and/or does not meet Level A or B requirements.

Results of the QA review and/or validation will be included in subsequent reports, which will provide a basis for meaningful interpretation of the data quality and evaluate the need for corrective actions. Corrective actions for field and laboratory issues will be submitted on the Corrective Action Report/ Corrective Action Plan form in Appendix H. Furthermore, data validation information including usability designations and qualifiers will be captured electronically.

If, as a result of the DQA process, it is determined that data do not satisfy all DQOs, then corrective action(s) should be recommended and documented in the data reporting. Corrective actions include, but are not limited to, revision of the DQOs based on the results of the investigation, or collection of more information or data. It may be determined that corrective actions are not required, or the decision process may continue with the existing data, with recognition of the data limitations.

D.3.2 Data Reporting

Sample data will be maintained electronically by the Technical Representative on behalf of the Railroads and reported in either task specific summary or completion reports or as appropriate in technical memorandums or monthly status reports.

Section E: References

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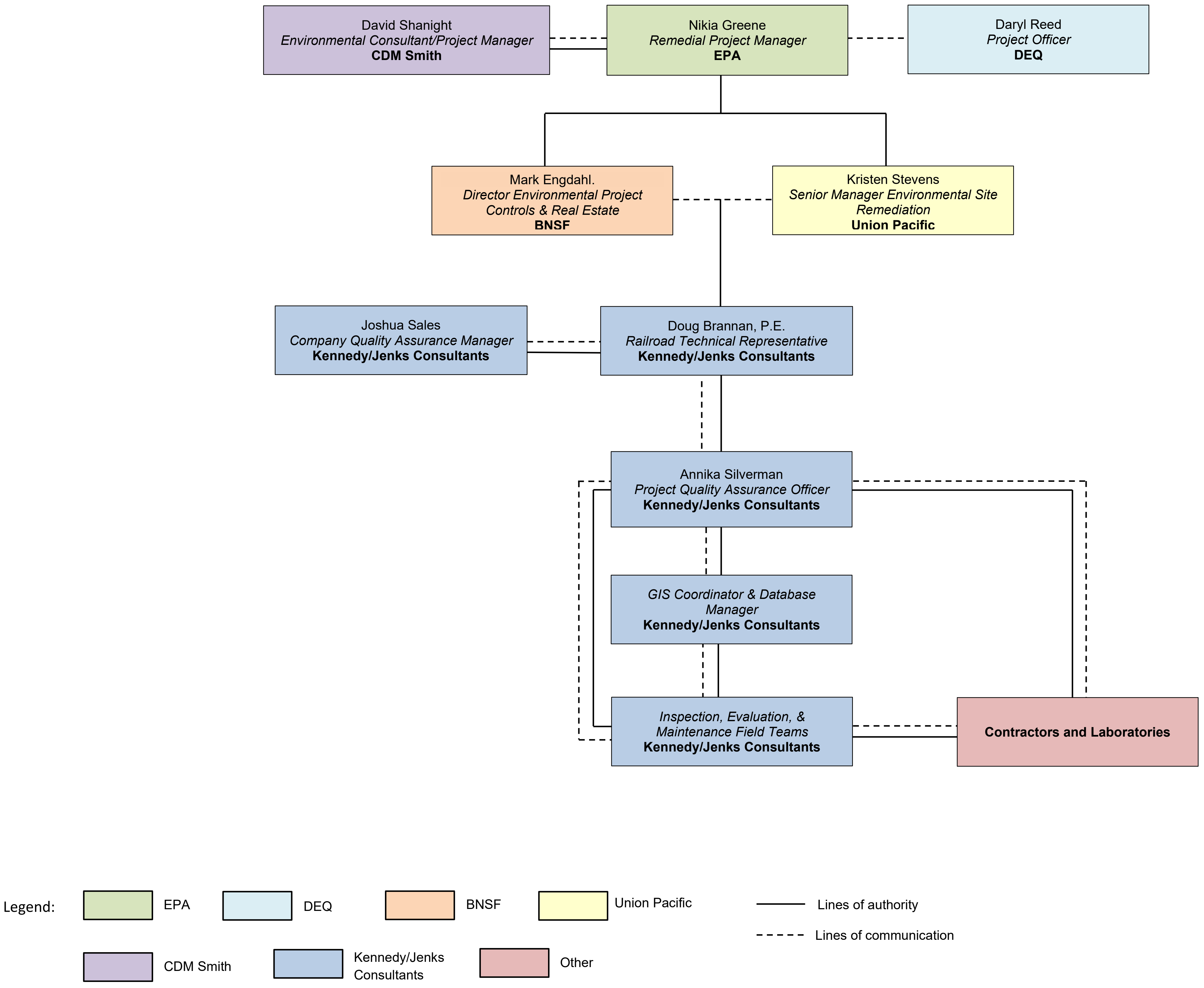
Figures

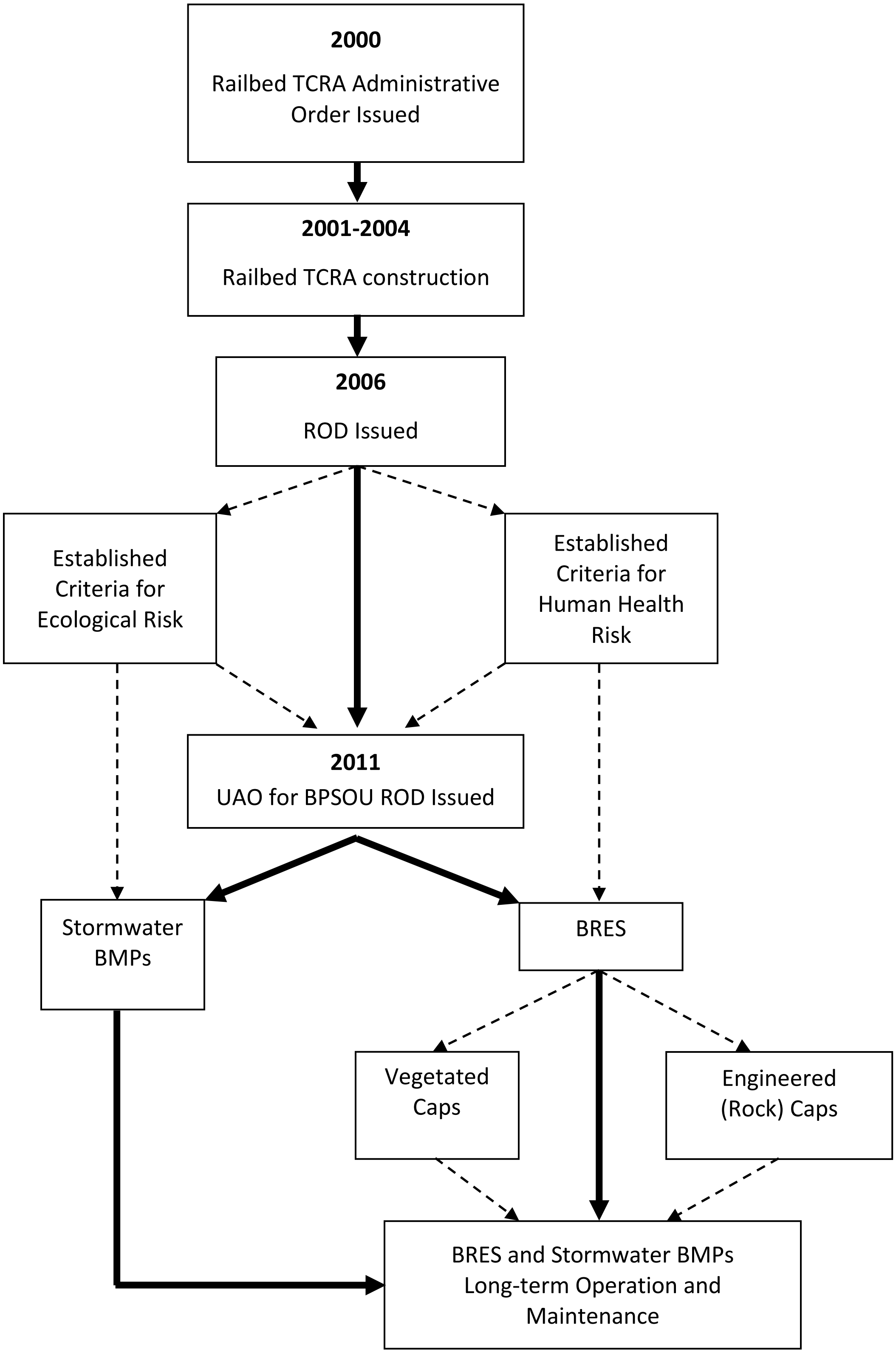


Kennedy Jenks

Butte Priority Soils Operable Unit
Butte, Montana

Organizational Chart for
Long-term Operation & Maintenance of Railroad Assets
Quality Assurance Project Plan

Figure A-1



Notes:
UAO= Unilateral Agreed Order
TCRA= Time Critical Removal Actions
ROD= Record of Decision
BPSOU= Butte Priority Soils Operable Unit
BRES= Butte Reclamation Evaluation System
BMPs= Best Management Practices

Primary Flow

Secondary Flow

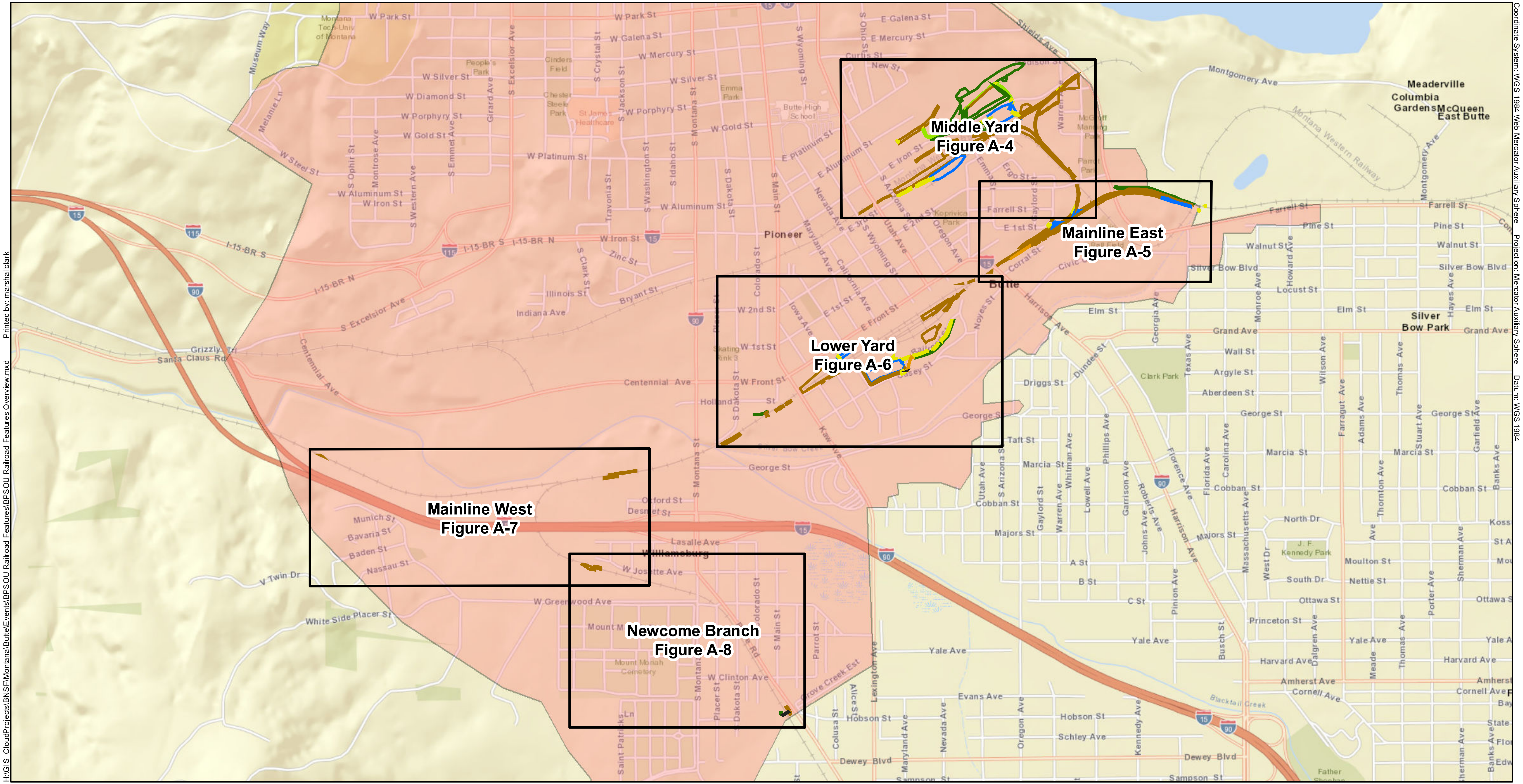
Kennedy Jenks

Butte Priority Soils Operable Unit
Butte, Montana

Regulatory Timeline – 2000 to Present

Figure A-2

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, © OpenStreetMap contributors, and the GIS User Community



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Coordinate System: WGS 1984 Web Mercator Auxiliary Sphere Projection: Mercator Auxiliary Sphere Datum: WGS 1984

Legend

🟥	Butte Priority Soils Operable Unit (BPSOU)
☐	Detail Figure Locations

N

0 0.25 0.5

Miles

Kennedy Jenks

Butte Priority Soils Operable Unit
Butte, Montana

Figure Location Overview Map

Figure A-3

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl   Projection: Lambert Conformal Conic   Datum: North American 1983 HARN

Legend

- — Railroad Drainage Pipes/Culverts
- ■ Concrete Apron
- ● Railroad Drainage Structure
- ☐ Riprap Ditch, Apron, or Berm
- ☐ Grass Cap or Berm
- ☐ Grass Ditch
- ☐ Rock Cap, Ditch, or Berm
- ☐ Sediment Basin

Notes:

1. All locations are approximate.

N

0 250 500

Scale: Feet

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Butte Priority Soils Operable Unit
Butte, Montana

Middle Yard
Railroad Assets

Figure A-4

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl
Projection: Lambert Conformal Conic
Datum: North American 1983 HARN

Legend

- — Flow Path
- ● Railroad Drainage Structure
- ☐ Barren Berm or Ditch
- ☐ Riprap Ditch, Apron, or Berm
- ☐ Grass Cap or Berm
- ☐ Rock Cap, Ditch, or Berm
- ☐ Sediment Basin

Notes:

1. All locations are approximate.

N

0 180 360

Scale: Feet

Kennedy Jenks

Butte Priority Soils Operable Unit
Butte, Montana

Mainline East
Railroad Assets

Figure A-5

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl Projection: Lambert Conformal Conic Datum: North American 1983 HARN

Legend

- ― Railroad Drainage Pipes/Culverts
- ● Railroad Drainage Structure
- ☐ Barren Berm or Ditch
- ☐ Riprap Ditch, Apron, or Berm
- ☐ Grass Cap or Berm
- ☐ Rock Cap, Ditch, or Berm
- ☐ Sediment Basin
- ☐ Culvert

Notes:

1. All locations are approximate.

N

0 265 530

Scale: Feet

Kennedy Jenks

Butte Priority Soils Operable Unit
Butte, Montana

**Lower Yard
Railroad Assets**

Figure A-6

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Coordinate System: NAD 1983 HARN StatePlane Montana FIPS 2500 Feet Intl   Projection: Lambert Conformal Conic   Datum: North American 1983 HARN

Legend

▭ Rock Cap, Ditch, or Berm

Notes:

1. All locations are approximate.

N

0 265 530

Scale: Feet

Kennedy Jenks

Butte Priority Soils Operable Unit
Butte, Montana

Mainline West
Railroad Assets

Figure A-7

Service Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

\\kjc.local\kjc-root\GIS\GIS CloudProjects\BNSF\Montana\Butte\Events\20221116 DataManagementPlan\FigA 8 NewcomeBranch.mxd Date: 9/7/2023 Printed by: JenniferJoern

Legend

🟫 Rock cap, Ditch, or Berm

⬛ Culvert

🟩 Grass Cap or Berm

Notes:

1. All locations are approximate.

N

0 150 300

Feet

Kennedy Jenks

Butte Priority Soils Operable Unit
Butte, Montana

**Newcome Branch
Railroad Assets**

Figure A-8

Appendix A

Detailed Data Quality Objectives

APPENDIX A

Detailed Data Quality Objectives

The data quality objective (DQO) process, based on scientific methods, is a series of planning steps that are designed to confirm that the type, quantity, and quality of environmental data used in decision-making are appropriate for the intended purpose. The DQOs presented in this appendix were developed in accordance with U.S. Environmental Protection Agency (EPA) guidance (EPA 2006b).

The DQO process specifies project decisions, the data quality required to support those decisions, specific data types needed, data collection requirements, and analytical techniques necessary to generate the specified data quality. The process also verifies that the resources required to generate the data are justified. The DQO process consists of seven steps; output from each step influences the choices that will be made later in the process. These steps include:

1. State the problem
2. Identify the goals of the study
3. Identify information inputs
4. Define the study boundaries
5. Develop the analytic approach
6. Specify performance or acceptance criteria
7. Develop the plan for obtaining data.

A.1 Step 1 – State the Problem

The purpose of this step is to describe the problem to be studied so the focus of the evaluation will be unambiguous.

As presented in Section A.5 of this QAPP, Butte Priority Soils Operable Unit (BPSOU) is one of the remedial operable units identified by the EPA within the Butte Area portion of the Silver Bow Creek/Butte Area National Priorities List (NPL) site within and near Butte, Montana. The Railroads completed BPSOU remedial actions in the 2000s termed Railbed Time Critical Removal Actions (RBTCRA). Remedies (or railroad assets) constructed during the RBTCRA included vegetated or engineered (rock) caps (now termed BRES caps) over mining-related materials with metals concentrations above applicable clean up goals, and surface drainage control improvements [now termed Stormwater Best Management Practices (BMPs)] to protect the BRES caps from erosion and to maintain drainage on railroad property.

In 2006, the BPSOU Record of Decision (ROD) was issued calling for long-term management of ecological risk and human health risk in BPSOU related to arsenic and lead (EPA 2006a). In 2011, EPA issued a Unilateral Administrative Order (UAO) for performance of the remedial actions pursuant to the 2006 BPSOU ROD. With respect to the Railroads as "Group 2 Respondents," the 2011 UAO resulted in construction of additional railroad stormwater BMPs, implementation of inspection programs for maintaining caps (i.e., BRES) and Stormwater BMPs.

Therefore, the problem to be studied is the operating conditions of railroad assets which were designed to protect capped mining-related materials and control erosion/sediment transport.

As presented in Section A.5.2.3 of the main text body of this QAPP, *the Primary Objectives of Project QAPP include confirmation of metals concentrations in cover soil, finer grained quarry source backfill material, and accumulated solid media in Stormwater BMPs*

A.2 Step 2 – Identify the Goals of the Study

This step identifies what questions the investigation (collectively the inspections and evaluations for BRES Program and Stormwater BMPs Program) will attempt to resolve and what decisions [corrective action plans (CAPs)/maintenance plans] may result. The principal study questions and possible alternative actions are as follows:

- Vegetated BRES Caps and Stormwater BMPs Ditches:
    - Are barren areas (or gullies) present, and does the nature and extent of the barren areas warrant site-specific cover soil testing to determine the cause of the barrenness, and/or a reclamation prescription to revegetate?
- Engineered (rock) BRES Caps and Stormwater BMPs Pads/Aprons:
    - Has rock become displaced, and does the nature and extent of displacement warrant site-specific maintenance and potential design modifications?
- Stormwater BMPs Sediment Basin and Conveyance Infrastructure:
    - Has sediment accumulated to such an extent it could reduce BMP's operational capacity such that sediment removal and possible site-specific upstream source controls or BMP design modifications are recommended?
- Analytical goals of the QAPP include confirming *concentrations of metals in imported backfill, and in accumulated solid media are less than applicable RALs from the 2006 BPSOU ROD.* The RALs for lead and arsenic in solid media are summarized in Table A-1. In addition, for in situ or replacement cover soils intended for use as growth media for vegetated BRES caps, analytical goals of the QAPP include compliance with the Butte Hill Revegetation Standards (BHRS) presented in Appendix B Section 6.3.

Table A-1: Solid Media Action Levels

Constituent	Solid Media	Action Levels[(a)]	Land Use
Lead	Soil	1,200 mg/kg[(b)]	Residential
	Soil	2,300 mg/kg	Non-Residential
Arsenic	Soil	250 mg/kg	Residential
	Soil	500 mg/kg	Commercial
	Soil	1,000 mg/kg	Recreational

Notes:

(a) Action Levels from ROD Solid Media, Table D-1 (EPA 2006a).

(b) mg/kg = milligrams per kilogram.

A.3 Step 3 – Identify Information Inputs

The purpose of this step is to identify the information and measurements that need to be obtained to resolve the decision statements. The information needed to resolve the principal study questions are summarized in Table A-1.

Table A-2: Summary of Inputs to Resolve Study Questions and Use of Information Acquired from Inputs

Principal Study Questions	Input to Resolve Question	Tools Used for Input	Use of Input to Resolve Question
Are BRES Caps performing per design?	BRES Caps and inspections and evaluations	Measuring wheel, GIS iPad setup, camera, visual observations, BRES guidance[(a)], BRES inspection forms	Scheduled inspections and evaluations will be performed to assess operating conditions of railroad BRES sites. Results of inspections and evaluations will guide whether CAPs are necessary to protect capped mining-related materials.
Are Stormwater BMPs performing per design?	Stormwater BMPs inspections and evaluations	Measuring tape/ruler, GIS iPad setup, camera, visual observations, Stormwater BMPs inspection form	Scheduled inspections and evaluations will be performed to assess operating conditions of railroad Stormwater BMPs. Results of inspections and evaluations will guide whether maintenance plans are necessary to prevent erosion/sediment transport.
Do imported cover soil, finer grained quarry source material (e.g., backfill), or accumulated solid media contain metals concentrations above the RALs?	XRF and analytical laboratory data	Delta Classic XRF unit (or similar), laboratory ICP-OES	Field and/or laboratory analytical data will be used to confirm. Results of field and laboratory analytical data will guide whether solid media can be imported (for cover soil and quarry source material) and the appropriate placement or disposal of accumulated solid media.
Does cover soil planned for use as growth media at vegetated BRES caps meet BHRS requirements?	Analytical laboratory and soils testing laboratory data	Laboratory results	Laboratory results will be used to confirm compliance with BHRS requirements, which is necessary to allow use of in situ or imported cover soil for use as growth media.

Notes:

BRES = Butte Reclamation Evaluation System; BMP = best management practice
RAL = Remedial Action Limit
XRF = X-Ray fluorescence
ICP-OES = Inductively Coupled Plasma-Optical Emission Spectrometry
(a) CDM 2006.

A.4 Step 4 – Define the Boundaries of the Study

This step specifies the spatial and temporal boundaries of the problem.

A.4.1 Spatial Bounds

Spatial bounds include railroad assets located within five distinct geographic Railroad areas within BPSOU shown on Figures A-4 through A-8 of the QAPP.

Solid media sample collection to evaluate surface soils will typically be performed between ground surface and 1 feet below ground surface but may extend deeper depending on conditions at the sampling location. Sampling performed under a work plan or to evaluate backfill borrow sources will be performed at targeted sample depths described in the work plan or necessary for the proposed work.

A.4.2 Temporal Bounds

The BRES Program and Stormwater BMPs Program schedules are presented in Section A.6.2 of the QAPP; potential resource and time constraints are also presented in Section A.6.2 of the QAPP. In summary, BRES Program inspections/evaluations ideally occur in spring during ideal conditions for plant identification, and Stormwater BMPs Program inspections/evaluations ideally occur in summer during drier conditions when minimal standing water is present.

A.5 Step 5 – Develop the Analytic Approach

The purpose of this step is to describe the method the project team will use to assess whether the data collected indicate acceptance and the resulting decision applied when acceptance is not obtained. The principal study question, inputs to resolve study questions, action levels, and decision rules are summarized in Table A-2.

Table A-3: Decision Rules

Principal Study Question	Input to Resolve Question	Tools Used for Input	Action Level	Decision Rule
Are BRES caps performing per design?	BRES caps inspections and evaluations	Measuring wheel, GIS iPad setup, camera, visual observations, BRES guidance[(a)], BRES inspection forms	CAP necessary per BRES guidance[(a)]	If CAP necessary, implement agency-approved CAP. If no CAP necessary, take no action.
Are Stormwater BMPs performing per design?	Stormwater BMPs inspections and evaluations	Measuring tape/ruler, GIS iPad setup, camera, visual observations, Stormwater BMPs inspection form	Maintenance necessary per Stormwater BMPs Operations and Maintenance (O&M) Plan[(b)]	If maintenance necessary, implement agency-approved maintenance. If no maintenance necessary, take no action.
Do imported cover soil, finer grained quarry source material (e.g., backfill), or accumulated solid media contain metals concentrations above the RALs?	XRF and analytical laboratory data	Delta Classic XRF unit (or similar), laboratory ICP-OES	See table A-1.	If concentrations are below RALs, import solid media (for cover soil and quarry source material); appropriately place accumulated solid media. If concentrations exceed RALs, do not import solid media (for cover soil and quarry source material); appropriately dispose of accumulated solid media.

Principal Study Question	Input to Resolve Question	Tools Used for Input	Action Level	Decision Rule
Does cover soil planned for use as growth media at vegetated BRES caps meet BHRS requirements?	Analytical laboratory and soils testing laboratory data	Laboratory results	See Appendix B Section 6.3 for BHRS action levels.	If in situ or imported cover soil for use as growth media meet the BHRS requirements, import solid media. If not do not import or use in situ media.

Notes:

BRES = Butte Reclamation Evaluation System; BMP = best management practice
RAL = Remedial Action Limit
XRF = X-Ray fluorescence
ICP-OES = Inductively Coupled Plasma-Optical Emission Spectrometry
(a) CDM 2006.
(b) Kennedy/Jenks Consultants 2023.

A.6 Step 6 – Specify Performance or Acceptance Criteria

The tolerable limits on decision errors, used to establish performance goals for the data collection design, are specified in this step.

Specific to the O&M of this project, one main type of decision error is possible:

Decision errors due to an inappropriate site condition response, including no action, are possible because site inspections and evaluations are conducted by personnel who can be subjective in scoring site performance criteria. This type of error is minimized by: 1) training field personnel prior to conducting evaluations, 2) having more than one person conduct site inspections together and compare findings, 3) having field lead convey daily findings to appropriate Project Quality Assurance (QA) Manager, and 4) performing QA practices to avoid incorrect entry into the databases.

A.7 Step 7 – Develop the Plan for Obtaining Data

This step identifies a resource-effective data collection design to generate data that satisfies the DQOs.

Site inspections and solid media sampling detailed in Sections B.1.2 through B.1.4 of this QAPP are designed to ensure data will be of sufficient quality and quantity to determine whether sites are performing per design and that solid media contaminant concentrations are below action levels, respectively.

Data gathering events from all sites will include the following tasks, as applicable, and will follow the specific measurement performance criteria associated with each activity's guiding document. This will ensure data is gathered in accordance with the project's DQOs.

- Complete an inspection and evaluation for all BRES sites in accordance with the inspection schedule detailed in Section A.6.2 of this QAPP.

- Complete an inspection and evaluation for all Stormwater BMPs in accordance with the Stormwater BMPs O&M Plan (Kennedy/Jenks Consultants 2022) and detailed in Section A.6.2 of this QAPP.

- Conduct soil sampling activities as necessary.

- Capture pertinent data with field forms, logbook, GIS iPad setup, and photographs.
- Develop draft and final inspection reports and complete CAPs and maintenance as necessary.

References

CDM Smith. 2006. Butte Reclamation Evaluation System (BRES): Butte Priority Soils Operable Unit: Silver Bow Creek/Butte Area NPL Site.

Kennedy/Jenks Consultants. 2022. Revised Interim Operation and Maintenance Plan 2022, Railroad Stormwater Best Management Practices within the Butte Priority Soils Operable Unit. July.

U.S. Environmental Protection Agency. 2006a. Record of Decision, Butte Priority Soils Operable Unit, Silver Bow Creek/Butte Area NPL Site. September.

_____. 2006b. EPA’s Guidance on Systematic Planning using the Data Quality Objectives Process, Publication No. EPA/240/B-06/001.

Appendix B

Standard Operating Procedures

APPENDIX B
Butte Priority Soils Operable Unit
SOP-BPSOU-01: Solid Media Management
Revision 1

1.0 Objective

This solid media management standard operating procedure (SOP) has been prepared on behalf of BNSF Railway Company (BNSF) and Union Pacific Railroad Company (Union Pacific), collectively termed the Railroads, for application during operation and maintenance (O&M) activities at the Railroads' assets[1] located within Butte Priority Soil Operable Unit (BPSOU). This SOP is regarding management of solid media potentially impacted with lead and/or arsenic concentrations at or above applicable solid media action levels from the BPSOU Record of Decision (ROD) [U.S. Environmental Protection Agency (EPA) 2006]; the applicable action levels for the Railroads' properties/rights-of-way (ROW) are 2,300 parts per million (ppm) for lead and 500 ppm for arsenic, presented in Table A-1 of the parent Quality Assurance Project Plan (QAPP) of this SOP.

Solid media management decision making will rely on results of inspections, field tests, and/or analyses. This SOP includes descriptions and guidance for the inspections, tests, and analyses. Figure 1 provides a decision tree flow chart for solid media management.

2.0 Definitions

Solid Media - (1) accumulated sediment within stormwater infrastructure, (2) soil exposed due to natural erosive processes (stormwater erosion, etc.), or (3) soil exposed due to non-natural processes (excavations, construction, regrading, etc.).

Visual Solid Media Inspection – Visual assessment of solid media conducted to evaluate presence of the distinctly red, yellow, tan, and/or gray colors sometimes indicative of lead and arsenic impacts within BPSOU.

pH Test – A solid media field screening test used to evaluate the potential presence of lead and arsenic based on pH chemistry inference that low pH values have been found to correlate with the presence of lead and arsenic in BPSOU. The method for testing pH for solid media in this SOP is the *Saturated Soil Paste Method*[2] (U.S. Department of Agriculture 1954).

X-ray fluorescence (XRF) – A portable field instrument used to screen solid media for heavy metals (including lead and arsenic) quickly and effectively by using short-wavelength x-rays to ionize atoms and measure energy released (as a photon) as electrons "fall" to inner orbitals to stabilize the electronic structure of the atom. The energy released as radiation has elemental characteristics used to identify the presence and concentrations of metals atoms.

Surface Soil – Soil located from ground surface to a maximum depth of 24 inches below ground surface (bgs).

No. 10 sieve – a mesh sieve with 2.00-millimeter nominal sieve opening.

---

[1] Butte Reclamation Evaluation System (BRES) sites (primarily consisting of caps) and stormwater best management practices (BMPs) located within the Railroads' property or right-of-way (ROW).

[2] This pH paste field testing method was approved for use by EPA's representative for visible tailings removal work during fall 2014/spring 2015 for work related to the Anaconda Smelter Superfund Site. EPA's representative, Mr. Ken Brockman, approved the method, and the approval email is provided in Appendix F.

3.0 Equipment for Solid Media Testing

The following equipment will be used during implementation of solid media inspection, testing, and analysis:

- Digital Camera – Used to provide photographic documentation of solid media encountered (at the origin) and tested, and to support visual solid media inspection.
- Global Positioning System (GPS) – Used to record the location and extent of encountered solid media (possibly point, polyline, or polygon feature, depending on disposition of solid media).
- Stainless Steel Tape Measure or Ruler – Used to mark the appropriate solid media interval.
- Stainless Steel Trowel or Disposable Trowel – Used to collect solid media samples for testing and placing into the appropriate receptacle for testing or analysis.
- No. 10 sieve – used for sieving solid media prior to testing.
- Electric portable toaster oven
- Oven thermometer
- Delta Classic XRF unit (or equivalent)
- Stainless Steel Bowl or Foil Pan – Appropriate receptacle for transferring solid media to appropriate container.
- Plastic Zip-Top Bags – Used when generating a composite sample to contain and homogenize solid media material following collection.
- Plastic sheeting – Used for covering pH analysis or XRF analysis work area. Sheeting will be replaced for each location.
- Cooler – Solid media samples collected for laboratory analysis will be stored at 4°C or less with ice and transported in a closed pail or cooler until relinquished.
- Personal Protective Equipment (PPE) – For personal protection and to prevent cross-contamination of samples (e.g., disposable, nitrile).
- De-ionized water (DI)– Used in field sprayers to suppress dust at solid media sample locations and to clean and decontaminate sampling equipment.
- Plastic Bristle Brush – Used to clean and decontaminate sampling equipment.
- Alconox or equivalent - Used to clean and decontaminate sampling equipment.

- Paper Towels – Used to dry decontaminated sampling equipment.
- 6-mil Poly Bag – Used to temporarily contain and store investigation-derived waste (IDW).
- Trash Bag – Used to store and dispose of general trash.
- Indelible Ink Pen (blue or black ink only).
- Field Logbook – Used to record field activities and observations.
- Sample Identification (ID) Labels – Pre-printed self-adhesive stickers used to label sample containers for laboratory analysis. Soil sample bags for XRF may be labeled using pen or marker.
- Custody Seals – Self-adhesive seals applied to an individual sample or sample container to demonstrate sample integrity has not been compromised during sample transfer to analytical laboratory.

4.0 Solid Media Evaluation

As mentioned in Section 1.0, Figure 1 provides a decision tree flow chart for solid media management. The following subsections provide procedural guidance on how to perform visual inspections, field-based pH paste method testing, field-based XRF analysis, and laboratory analysis.

The disposition of solid media encountered, how it is collected, and temporarily stockpile can vary. For example, it may be most safe and practical to collect small volumes of sediment from various accumulation points, stockpile the sediment, and then initiate the solid media management evaluation outlined on Figure 1.

4.1 Visual Inspections

The first step of evaluating solid media is to have qualified personnel conduct a visual inspection in accordance with *BRES – Butte Priority Soils Operable Unit – Silver Bow Creek/Butte Area NPL Site* (CDM 2006). The visual inspection will include (1) delineation of produced or encountered solid media with a GPS unit, (2) a written description detailing the nature of the solid media (see Solid Media definition), (3) photo documentation, and (4) a Unified Soil Classification System (USCS) (ASTM D2487-00) description of the solid media including detail pertaining to presence of tailings, slag, or waste rock. Soil handling requires the use of nitrile gloves. The visual properties of slag, tailings, and waste rock in BPSOU have been observed to be as follows:

- Slag: Non-metallic. Glass-like. Can have irregular texture (nodule-like appearance). Coarse material.

- Tailings: Fine-grained material that supports little or no vegetation. Often identified by red, yellow, tan, or grey colored materials with silty sand to a silt texture. The texture and color usually change abruptly at the interface with non-tailing materials.

- Waste Rock: Commonly a clayey to rocky material, often with sulfide mineral content.

As indicated on Figure 1, following the visual inspection, additional testing of the solid media is conducted.

4.2 Analysis for pH

If the visual inspection indicated the potential presence of heavy metals, a pH analysis will be performed. In addition, field pH analysis will be performed at a minimum of 5 percent of areas inspected visually. The pH measurement may be performed using a direct soil pH meter, such as a HI 99121 Soil pH Meter by Hanna Instruments or equivalent. Alternatively, the pH measurement may be performed using distilled water and a YSI EcoSense pH100 hand-held meter or equivalent. When using distilled water and a YSI, the pH for the solid media will be collected using the *Saturated Soil Paste Method* (U.S. Department of Agriculture 1954). This method consists of the following steps:

- Collect discrete or representative composite solid media sample using clean, stainless steel sample collection equipment.

- Place solid media sample into clean container (e.g., disposable cup).

- Prepare a paste by adding distilled water to solid media sample (fine to medium grain material) and mix into a paste-like texture by stirring with a sterilized instrument within container.

- Verify solid media is saturated. It is saturated when it (1) glistens and reflects light and (2) slides freely and cleanly off the mixing instrument (less so in soils with high clay content).

- After mixing is complete, the sample should set for at least an hour to allow for equilibrium conditions between soil and water.

- During equilibration, free water should not pond on top of the sample, nor should the sample stiffen. If ponding or stiffening occurs, remix the sample with more distilled water.

- Insert the electrodes of the EcoSense pH100 sensor (or equivalent) into the sample, slowly raising and lowering the tip of the sensor through the sample repeatedly until a reproducible pH reading is obtained. Document the pH in the field logbook. Low pH indicates the material has acidic properties characteristic of some mining relate materials, which may include lead and arsenic concentrations.

Sample locations for pH testing should be guided by the results of the visual inspection (e.g., locations suspected to have lead and arsenic should be sampled for pH testing). The number of soil samples to be tested for pH will vary depending on the aerial extent or volume of solid media and will be determined by field personnel.

Solid media with a pH less than 5.5 standard units will be capped regardless of lead and arsenic concentration. XRF and laboratory analysis of low pH materials will be performed to document material conditions.

4.3 XRF Analysis

XRF instruments are capable of detecting lead and arsenic in solid media at concentrations as low as 20 and 40 ppm (EPA 2007), respectively if appropriate sample preparation is followed. The XRF detection limits are below the lowest applicable BPSOU ROD action levels of 2,300 ppm for lead and 500 ppm for arsenic (EPA 2006) (see Table A-1 of the parent QAPP of this SOP). Due to this level of achievable accuracy, field XRF testing or laboratory methods may be used to analyze solid media encountered at the Railroads' assets that is suspected of lead or arsenic impacts.

XRF analysis can measure the concentration of certain elements by a means of ionization and subsequent measurement of energy radiation. XRF field screening will be conducted in general accordance with EPA Method 6200 (EPA 2007) and the manufacturer's instrument manual for the XRF model used (Delta Classic or equivalent). The manual for Delta Classic XRF unit as provided in Appendix G of the parent QAPP of this SOP. XRF analysis will be performed in the field on a clean portable table covered with new disposable plastic sheeting at each location. General procedures for XRF sample analysis are as follows:

- Required tools for sample collection: Nitrile gloves, stainless steel tape measure or ruler, stainless steel trowel or disposable towel, stainless steel bowl or cleaned foil pan, stainless steel No. 10 sieve, sample container, and zip-top bag.

- Dig a 6- to 12-inch square pit to a depth of approximately 12 inches. Measure the sample intervals to be 0-2 inches, 2- to 6-inches, and6- to 12-inches with a tape measure or a ruler and mark the appropriate interval.

- Collect approximately 500 to 800 grams of discrete or representative composite solid media sample using clean sample collection equipment. During solid media sample collection, care will be taken to avoid collection of vegetative (e.g., plant) debris and aggregate in the sample collection container.

- Prepare soil-like solid media samples using a No. 10 sieve in preparation for XRF analysis.

- Place solid media passing the No. 10 sieve into new zip-top bag of appropriate size (min. quart size), close bag with minimum headspace, and apply sample ID, date, and time [e.g., XRF001_YYYYMMDD @ 1300 (military time)].

- Placing the labeled side of the sample bag down, pat the sample flat, set the XRF laser over the center of the bag, and screen solid media sample directly through the zip-top bag. The XRF unit will specify analysis time (typically 1 to 2 minutes) to measure total lead and arsenic concentrations (units dependent on unit). Review and carefully follow the manufacturer’s health and safety procedures related to the instrument, as well as operational procedures for best results and instrument maintenance. One XRF reading per soil sample is insufficient to make a statistically valid measurement. A minimum of 4 XRF readings taken in different locations of the sample are needed (Crumbling). Therefore, at least 2 readings from each side of the soil sample bag will be taken. This process should provide a statistically representative result for the sample. The readings will be entered into a Data Spreadsheet to calculate the 1-sided t and 1-sided Chebyshev 95% UCLs. The appropriate UCL and individual XRF results will then be compared to the decision point to inform risk management decisions.

- Record results in the field logbook. The results are also stored electronically in the XRF unit memory for later download to a portable computer (as-needed).

- Retain all labeled samples for subsequent confirmatory analysis described below.

For quality assurance purposes, prior to XRF analysis of solid media samples, the standard reference material (SRM) provided by the XRF manufacturer with the XRF unit will be utilized to calibrate the instrument.In addition, and in accordance with EPA Method 6200, a minimum of 5 percent of samples field screened will be submitted to an analytical laboratory for confirmatory analysis using laboratory method SW-846 Test Method 6010D.The confirmatory samples will be selected from the lower, middle, and upper range of concentrations measured by the XRF. Samples selection for laboratory confirmation will consider XRF results relative to action levels. If XRF results are below and within 35 percent of action levels, confirmatory sample selection will prioritize these. A regression analysis will also be completed to evaluate the strength of correlation of the XRF results to laboratory confirmatory results and determine the adequacy of the measurements to meet definitive level data criteria. According to EPA Method 6200, the correlation coefficient (r) for the results should be 0.7 or greater for the XRF data to be considered screening level data. If the r value is 0.9 or greater and inferential statistics indicate the XRF data and the confirmatory data are statistically equivalent at a 99 percent confidence level, the data will be considered to have definitive level data criteria. Appropriate matched pair tests or other correlation tests will be used to determine statistical equivalence.

For a given area or volume of solid media to be managed, typically three solid media samples will be collected for XRF analysis. In general, the amount of soil samples to be analyzed for XRF will increase as solid media area or volume increases. Sample locations should be guided by the results of the visual inspection and pH testing (e.g., locations suspected to have heavy metals should be sampled for XRF analyses). Descriptive statistics such as number of subsamples, average, and maximum will be computed using soil sample XRF results for the review of lead and arsenic concentrations in each defined area or volume of the solid media being analyzed.

4.4 Laboratory Analyses

Samples within 35% of an action level and selected samples for use in statistical analysis will be submitted for analysis to confirm and expand on field XRF results. Solid media samples may be collected independent of the XRF (as an alternative; may be more suitable with small quantity of solid media) or as confirmatory split samples from the XRF analysis approach (see Section 4.3).

Samples will be analyzed in accordance with published laboratory method SW-846 Test Method 6010D: Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES), Revision 5, July 2018 (EPA 2018).

Solid media samples for laboratory analysis (independent of XRF analysis or split samples from XRF analysis) will be packaged for shipment to a certified analytical laboratory under standard chain-of-custody procedures. Sample packaging and handling procedures are provided in Appendix B, *SOP-SPSOU-06: Sample Packaging and Shipping.* Selected surface and subsurface soil samples will be analyzed for the following compounds:

- Lead using EPA Method 6010D (EPA 2018)
- Arsenic using EPA Method 6010D (EPA 2018).

Results of the laboratory analyses will be used (1) to determine whether lead and arsenic concentrations are below current ROD screening levels and, as mentioned above, (2) if applicable, to confirm results of XRF analyses.

5.0 Stockpiling / Transporting Solid Media

Earthwork to stockpile and transport solid media will be performed utilizing the accepted practices outlined by the Butte Silver Bow County in *Excavation and Dirt-moving Protocols* (Butte Silver Bow County 2013). This includes, but is not limited to, the following procedures:

- Cover stockpiled solid media with a tarp or other plastic sheeting to prevent dust generation and erosion
- Control visible dust during excavation and subsequent movement by spraying solid media with water
- Stockpile solid media away from storm drains, water courses, or wetlands
- Construct a berm, or other prohibitive surface flow feature, around the stockpiled solid media to prevent runoff from leaving the area.

6.0 Reporting and Corrective Action Plan Implementation

Following characterization of the solid media in question, results will be reported to the EPA along with a recommendation for a corrective action plan (if needed). One of four final decisions will be made on how to manage solid media following testing: 1) if there is no indication of impacts, the solid media may be disposed of or reused as desired by the Railroads; 2) if impacts are documented during testing, the solid media may be disposed at the current repository located at Middle Yard; 3) an existing cap will be removed and solid media will be placed above or adjacent to the existing target material and the cap will be replaced in accordance with Section 7.5 below and Figure 2; or 4) if impacts are documented during testing of the solid media, an EPA-approved implementation of a corrective action plan may be pursued (refer to Figure 1).

7.0 Associated Procedures

7.1 Field Documentation

Field documentation for samples collected using this procedure will be conducted in accordance with Section A.9.1 of the QAPP or as otherwise specified in the governing document referencing this procedure.

7.2 Field Equipment Decontamination

All reusable sampling equipment must be decontaminated between samples in accordance with *SOP-BPSOU-07: Field Equipment Decontamination* (Appendix B) unless otherwise specified in the governing document referencing this procedure.

7.3 Investigation-Derived Waste (IDW)

IDW will be managed as described in *SOP-BPSOU-10: Handling and Disposing of Investigation-Derived Waste* (Appendix B) and any other applicable governing documents. In general, replace the soil void with excess sample volume. The solid media should be placed back into the hole and tamped down lightly. If sandy areas are sampled, refilling the solid media void is not necessary. Rinse water, the roots of vegetation removed during sampling, and excess solid media volume may be returned to the sampled area.

Spent wipes, gloves, and PPE must be disposed of or stored properly as IDW in accordance with *SOP-BPSOU-10: Handling and Disposing of Investigation-Derived Waste* (Appendix B) unless otherwise specified in the governing document referencing this procedure.

7.4 Sample Custody, Packaging, and Shipping

Sample custody requirements for samples collected using this procedure will follow the current version of *SOP-BPSOU-06: Sample Packaging, Shipping, and Custody* (Appendix B), unless otherwise specified in the governing document referencing this procedure.

As may be applicable, sample packaging and shipping will follow the procedures outlined in *SOP-BPSOU-06: Sample Packaging, Shipping, and Custody* (Appendix B), unless otherwise specified in the governing document referencing this procedure.

7.5 Capping Newly Generated Solid Media

Sediment and other materials removed from the stormwater systems or produced while grading areas of cap repair with pH less than 5.5 standard units or that contain concentrations of arsenic and lead above the applicable ROD limits will be integrated with existing capped materials or disposed offsite. Existing cap materials will be removed to expose target soil. New solids will be placed and graded above or adjacent to existing materials. If the pH of the solid media is less than 5.5 standard units, a 2-inch layer of limestone will be placed above the material. Cap materials, including geotextile fabric and rock or vegetated soil will be replaced as shown on Figure 2 in accordance with the attached specifications:

02060	Furnishing and Installing Aggregate Material
02150	Clearing and Grubbing
02203	Site Grading and Excavation
02277	Geotextiles

8.0 Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) for activities described in this procedure will be attained through a variety of processes, including, at a minimum, the items discussed below. Additional QA/QC requirements, such as audits or field assessments, will be addressed in the governing document referencing this procedure.

8.1 Training

Training will be provided to staff to establish consistency in collecting solid media samples in support of the BPSOU. Consistency will be achieved to the extent possible through proper training, using designated field staff, and providing oversight. Deficiencies or inconsistencies in implementing this procedure will require re-training of field team members.

Field team members will have the following training:

- BNSF Contractor Safety Orientation
- Roadway Worker Protection
- Union Pacific Contractor Safety Orientation
- E-Railsafe Certification
- BRES Training.

8.2 Field Quality Control Samples

Solid media field duplicate samples will be collected at the rate specified in the parent QAPP of this SOP. Field duplicate samples will be collected as co-located solid media samples. For tracking purposes, the parent/duplicate sample relationship will be recorded in accordance with sample documentation requirements stated in the governing document referencing this procedure. These samples will be used to determine the variability of sample results but will not be used to determine variability in sampling technique.

9.0 References

Butte Silver Bow County, Planning Department. 2013. Excavation and Dirt-moving Protocols. May 2013.

CDM Smith. 2006. BRES - Butte Priority Soils Operable Unit – Silver Bow Creek/Butte Area NPL Site.

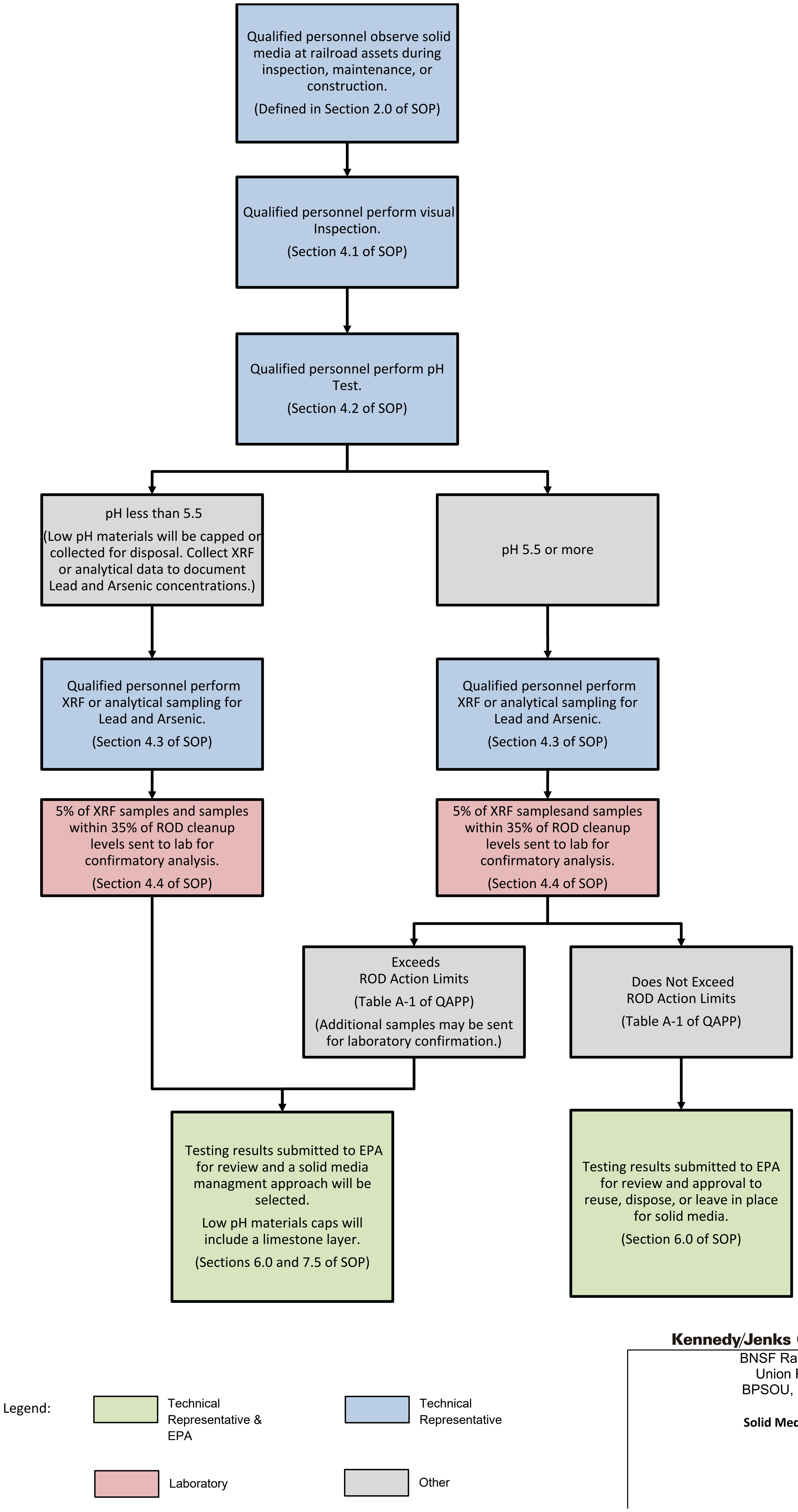
Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System. ASTM D2487-00.

U.S. Department of Agriculture. 1954. Diagnosis and Improvement of Saline and Alkali Soils – Handbook No. 60. February 1954.

U.S. Environmental Protection Agency. 2006. Record of Decision Butte Priority Soils Operable Unit Silver Bow Creek / Butte Area NPL Site. September 2006.

U.S. Environmental Protection Agency. 2007. Method 6200: Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment, part of Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. February 2007.

U.S. Environmental Protection Agency. 2018. Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, also known as SW-846: Test Method 6010D: Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Revision 5, July 2018. Available at U.S. Environmental Protection Agency



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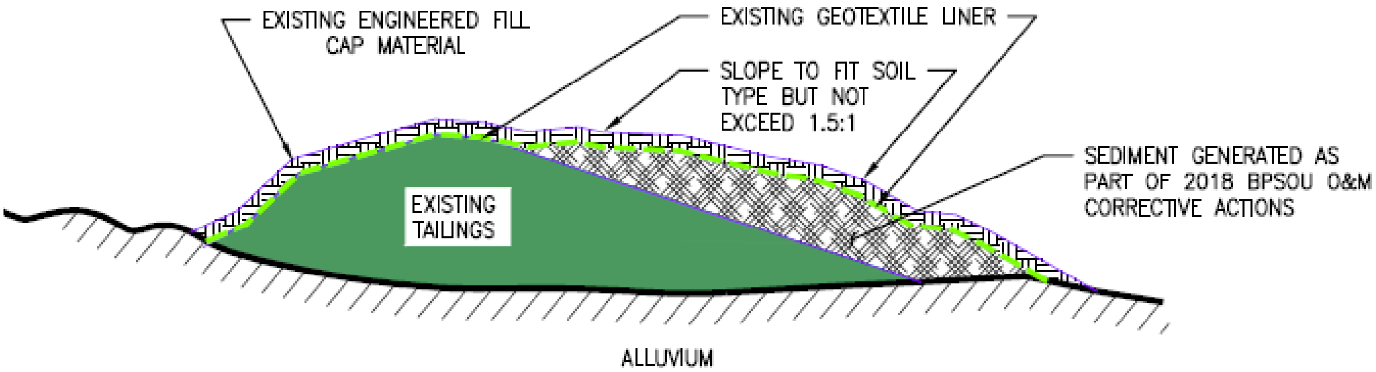
BNSF Railway Company
Union Pacific Railroad
BPSOU, Butte, Montana

Solid Media Management
Flow Chart

2299019.00
October 2023
Figure 1



ENGINEERED CAP

SCALE: NONE

NOTES:

1. ENGINEERED CAP WILL BE REHABILITATED IF DISTURBED. NEW GEOTEXTILE WILL BE PLACED ON DISTURBED AREA AND OVERLAP EXISTING GEOTEXTILE A MINIMUM OF ONE FOOT AROUND PERIMETER, WITH FAVORABLE REVIEW BY THE ENGINEER.
2. ENGINEERED CAP WILL CONSISTS OF GEOTEXTILE LINER, 6-INCHES OF TYPE 3 ROCK, COVERED BY 6-INCHES OF TOPSOIL. SEED DISTURBED AREA WITH NATIVE GRASS MIX, APPROVED BY THE ENGINEER.

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Solid Media Management
Engineered Cap Detail

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October 2023
Figure 2

SECTION 02060

FURNISHING AND INSTALLING AGGREGATE MATERIAL

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. Summary
- B. Submittals
- C. References
- D. Materials
- E. Quality control
- F. Source of materials
- G. Borrow source grading/reclamation
- H. Preparation for placement
- I. Placement
- J. Compaction
- K. Site restoration
- L. Field quality control

1.02 SUMMARY

A. Section Includes: Requirements for providing fill materials, borrow areas/sources of fill materials, and fill placement requirements for the following:
  1. Structural Fill
  2. Beneficial Fill
  3. Quarry Spalls
  4. Rock Cover (Type 3 Rock)
  5. Graded Rock Cover (Type 3A)
  6. Rip Rap (Type 2 Rock)

1.03 SUBMITTALS

A. Submit data sheets and test results from compliance testing of materials to the Engineer for review and approval.

1.04 REFERENCES

A. Sampling and Preparation:
  1. ASTM D75 - Standard Practice for Sampling Aggregates.
  2. ASTM D420 - Recommended Practice for Investigating and Sampling Soil and Rock.

B. Classification:
  1. ASTM D422 - Standard Method for Particle-Size Analysis of Soils.

2. ASTM D2488 – Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).
3. ASTM D4318 – Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

C. Density:

1. ASTM D698 or AASHTO T99 – Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures, Using 5.5 lb. (2.49 Kg) Hammer and a 12-inch (304.8 mm) Drop.

PART 2 - PRODUCTS

2.01 MATERIALS

Sources of materials acceptable for use on this project are as follows:

A. Structural Fill: The following granular materials may be utilized for structural fill: 3-inch minus washed crushed gravel, standard 3-inch minus road mix or sandy gravel meeting the following gradation:

Structural Fill Gradation Option

Sieve Size	Percent Passing by Dry Weight
3-inch	100
No. 4	30-70
No. 200	0-12
Liquid Limit less than 25% and Plasticity less than 6	

1. Structural fill is available from a number of local sources, subject to approval by the Engineer.

B. Beneficial Fill: Consists of cover soil previously approved for use by EPA currently stockpiled at BNSF’s Lower Yard (as shown on Drawings). Material is suitable for use for construction of the stormwater control berm shown on Drawings.

C. Quarry Spalls: Consists of gravel with 100 percent passing the 3-inch screen and a maximum of 10 percent passing the 3/8-inch sieve for construction of a stabilized construction entrance.

D. Rock Cover (Type 3): 0.5 – 3.0-inch material functioning as railroad ballast material that meets the following gradation or as approved by the Engineer.

Sieve Size	Percent Passing
2.5”	100
2”	95-100
1.5”	35-70
1”	0-15
0.5”	0-5

1. Type 3 rock previously approved for use by the EPA is available near Butte, Montana, from: Conda Mine located near Pipestone interchange on Interstate 90.

E. Graded Rock Cover (Type 3A): 3-inch minus pit run material.

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F. Rip Rap: Furnish stone that is hard, durable, angular in shape, resistant to weathering and to water action, free from overburden, spoil, shale, structural defects, organic material, and shall meet the appropriate gradation for random rip rap. Source and gradation shall be submitted to the Engineer for approval 7 days prior to placement. Rip Rap shall conform to State of Montana, Department of Transportation (MDT) Specification Section 701.06.2, Class I gradation (https://www.mdt.mt.gov/other/webdata/external/const/specifications/2014/2014_stand_specs.pdf).

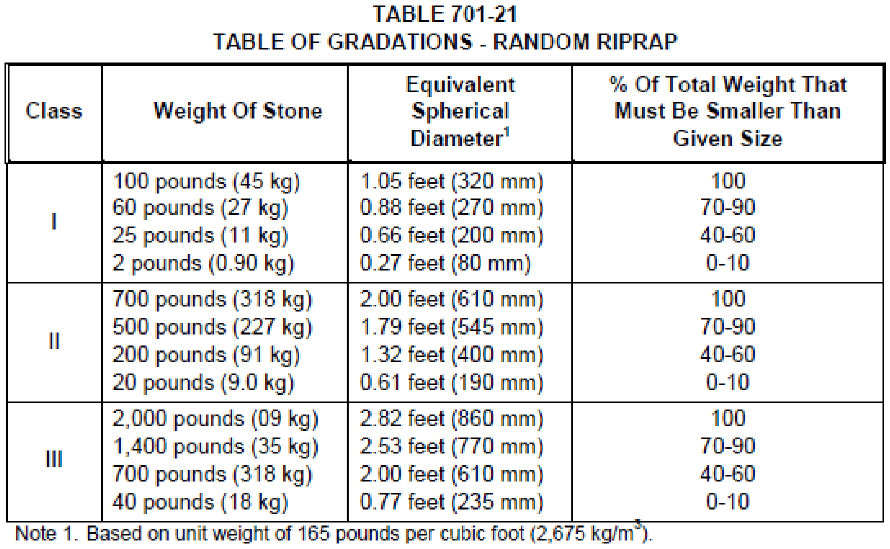

TABLE 701-21
TABLE OF GRADATIONS - RANDOM RIPRAP

Class	Weight Of Stone	Equivalent Spherical Diameter[1]	% Of Total Weight That Must Be Smaller Than Given Size
I	100 pounds (45 kg)	1.05 feet (320 mm)	100
	60 pounds (27 kg)	0.88 feet (270 mm)	70-90
	25 pounds (11 kg)	0.66 feet (200 mm)	40-60
	2 pounds (0.90 kg)	0.27 feet (80 mm)	0-10
II	700 pounds (318 kg)	2.00 feet (610 mm)	100
	500 pounds (227 kg)	1.79 feet (545 mm)	70-90
	200 pounds (91 kg)	1.32 feet (400 mm)	40-60
	20 pounds (9.0 kg)	0.61 feet (190 mm)	0-10
III	2,000 pounds (09 kg)	2.82 feet (860 mm)	100
	1,400 pounds (35 kg)	2.53 feet (770 mm)	70-90
	700 pounds (318 kg)	2.00 feet (610 mm)	40-60
	40 pounds (18 kg)	0.77 feet (235 mm)	0-10

Note 1. Based on unit weight of 165 pounds per cubic foot (2,675 kg/m^3).

1. Rip rap previously approved for use by the EPA was available near Butte, Montana, from: Conda Mine located near Pipestone interchange on Interstate 90.
2. A screen would need to be set up at the Conda (or Bernice) sources to screen rip rap from the waste rock piles.
3. Alternative sources of rip rap will require prior approval by the Engineer.

2.02 ADDITIONAL REQUIREMENTS

A. In addition to gradation testing, structural fill source shall be sampled for RCRA 8 metals and results shall be submitted to Engineer prior to approval for import.

B. All Rip Rap shall conform to:

1. Specific Gravity Requirements – Specific Gravity is a measure of the rock density (ASTM C127). The rock surface shall have a bulk specific gravity (saturated, surface dry) of 2.5 or greater.
2. Absorption Requirements – Absorption is a measure of rock porosity (ASTM C127). The rock shall have an absorption value of 2 percent or lower.
3. Los Angeles Abrasion Requirements – The Los Angeles Abrasion test is an indicator of hardness and structural soundness (ASTM C535). The rock shall have a test value of 35 percent or less for 500 revolutions.
4. Sodium Sulfate Soundness Requirements – Sodium Sulfate Soundness test is an indicator of durability against disintegration (AASHTO T104-94). The rock shall have a test value of 12 percent loss or less for five cycles.

2.03 QUALITY CONTROL

A. Contractor is responsible to pay for and provide Compliance Quality Control Testing as identified below. The Owners' will pay for and provide for the services of a laboratory to provide Quality Assurance Testing during construction. The Quality Assurance testing will be random checks during construction for the benefit of the Owners' and should not be relied upon by the Contractor to ensure compliance with the Specifications. Contractor to rely on their Quality Control Plan to ensure compliance.

B. Tests and analyses of aggregate materials will be performed in accordance with applicable ASTM test methods, as listed under Part 1.04. The gradation testing method shall be ASTM D422.

C. If any tests indicate materials do not meet specified requirements, change material and retest at no cost to the Owners.

D. Use a certified laboratory to determine material gradation as described in these Specifications. All fill materials shall at a minimum be sampled for these analyses, unless otherwise stated herein by and at the expense of the Contractor.

PART 3 - EXECUTION

3.01 SOURCE OF MATERIALS

A. Contractor shall obtain aggregate materials from a licensed source, as approved by the Engineer.

3.02 PREPARATION FOR PLACEMENT

A. Identify required lines, levels, and contours.

B. Stake and flag locations of utilities.

C. Locate, identify, and protect utilities that remain from damage. Notify utility companies for utilities which may be affected by the work, or which cross the work area.

D. Protect benchmarks and existing structures from excavating equipment and vehicular traffic.

E. Conduct site grading and excavation (where applicable) per Section 02203 Site Grading and Excavation.

F. Compact subgrade or existing underlying fill to meet density requirements, where necessary due to over-excavation.

G. Cut out soft areas of subgrade or existing underlying fill that cannot be compacted as specified in paragraph E, above. Backfill with material type specified for subsequent fill, and compact to minimum density requirements for subsequent material as specified in Part 3.05.

3.03 PLACEMENT

A. Do not place the aggregate base before the subgrade is approved by the Engineer.

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B. Spread the aggregate base material on the prepared subgrade by means of suitable spreading devices.

C. Segregation of large or fine particles of aggregate shall be avoided, and the material as spread shall be free from pockets of large and fine material.

D. Maintain positive surface drainage to avoid ponding of water on fill.

E. All surfaces upon or against which fill will be placed, including previously placed and compacted layers shall be clean of all objectionable materials, shall be moist but free of standing or ponded water.

F. Fill material requiring compaction shall not be frozen when placed. Material shall not be placed on ice or frozen material.

G. Install geotextile fabric (where specified) in accordance with Section 02277 Geotextiles.

H. Rip rap material shall not be placed until the surface has been prepared and approved. If specified, rip rap shall be placed on a prepared foundation of geotextile fabric (Section 02277) as shown on the Drawings. The material shall conform to the cross sections and profiles shown on the Drawings.

I. Rip rap material shall not be placed until the surface has been prepared in accordance with Part 3.05 Subgrade Preparation and approved. If specified, rip rap shall be placed on a prepared foundation of geotextile fabric (Section 02277) as shown on the Drawings. The material shall conform to the cross sections and profiles shown on the Drawings. The stone shall be carefully handled and dumped to avoid material segregation. The rock shall be manipulated by hand or machine methods sufficiently to secure a regular surface and mass stability. Where the thickness of the rip rap is not shown on the Drawings, it shall be a least 6 inches measured perpendicular to the slope. Unless otherwise shown, rip rap shall extend from 2 feet below the toe of the slope to the elevation shown on the Drawings.

J. When rip rap is specified for placement around pipe openings or concrete structures, special care shall be taken in placing and handling. Manipulation of individual rocks during placement of rip rap shall be required as determined by the Engineer. Damage to pipe or structures shall be repaired or replaced at no expense to the Owners.

K. Grouted Rip Rap: Place the material on geotextile fabric grouting in-place as specified in Part 3.04 Grouted Rip Rap. Conform to requirements shown on the Drawings.

L. Graded Type 3A rock material shall be placed in 6-inch loose lifts.

3.04 GROUTED RIP RAP

A. Grout mixture shall be 4,000 psi conventional concrete with a maximum aggregate size of ¾ inch. Grout should be mixed in a manner to produce a mixture having a consistency which will permit gravity flow into the riprap voids and should be used within 45 minutes after mixing.

B. Prior to grouting, rip rap shall be free of mud and fines to assure bonding between grout and stone. Rip rap should be wetted and kept moist prior to grouting.

C. Grout should be distributed over the rip rap by use of brooms or spades and worked into the space between stones from top to bottom with suitable brooms, spades, trowels, bars, or vibrating equipment. Contractor shall ensure that grout penetrates the total thickness of the rip rap.

D. After the grout has stiffened, a stiff stable broom shall be used on the entire surface to eliminate runs and to fill voids caused by sloughing. Grout should be removed from the top surfaces of the upper stones and from pockets and depressions in the surface of the riprap. Leave the top surface of the rip rap exposed.

E. The completed finished surface shall be prevented from drying for a minimum curing period of 7 days following placement. All grout should be cured and protected from premature drying, extremes in temperature, rapid temperature change, freezing, mechanical damage, flowing water, and exposure to rain. Preservation of moisture for grout surfaces can be accomplished by sprinkling, ponding, absorptive mats or sand kept continuously wet, impervious sheet material, or a membrane-forming curing compound. No workman or loads should be permitted on the grouted surface until proper strength has been developed.

3.05 SUBGRADE PREPARATION

A. Prior to rip rap and Type 3 rock placement, remove large or sharp-edged rocks, stones, sticks, roots, other sharp objects, or debris of any kind from the slope and bottom surfaces.

B. Smooth the subgrade to obtain a smooth and planar surface having no protrusions exceeding 1/4 inch above the immediately adjacent surface. Smoothing shall be accomplished by using a smooth steel double-drum roller or similar approved piece of equipment. A minimum of two passes of the compaction equipment shall be used, with additional passes as required to achieve a firm, unyielding surface with the required smoothness. Winching the roller up and down the slopes may be necessary. Smooth any depressions left by edges of the compaction equipment.

C. Protect the prepared subgrade surface. Standing water or excessive moisture shall not be allowed.

3.06 COMPACTION

A. Subgrade soils: Contactor shall compact to 90% maximum density.

B. Backfill: Contractor shall add water or aerate material as required to bring the material within 4% of optimum moisture content and 95% of the maximum dry density as determined by ASTM D698. The Contractor shall perform the necessary field test(s) to determine the in situ moisture content. The Contractor shall be responsible for determining moisture/density relationships of compacted backfill materials by supplying results of ASTM D698 to the Engineer.

C. Type 3 Rock: Contractor shall compact to 95% of ASTM D698.

3.07 POST-PLACEMENT GRADING

A. Grade all areas, including excavated, filled, and transition areas, to obtain the finished surface shown on Drawings to conform to Section 02203 – Site Grading and Excavation. Finished surface shall be reasonably smooth, and free from irregular surface changes. Finished surfaces shall have positive drainage to minimize ponding of water.

3.08 SURFACE RESTORATION

A. Where surface restoration is not specified, the Contractor shall restore the work area to pre-construction conditions at no additional cost to the Owners.

3.09 FIELD QUALITY CONTROL

A. At the Engineer and Owners' discretion, additional samples of fill materials may be taken to verify the sieve analyses data provided by the Contractor.

B. The Contractor and Engineer shall review and agree on layout locations for repair areas prior to beginning work. The Contractor and Engineer will review import and export quantities daily and agree upon payment quantities. Final compliance will be verified by the Owners' representative. Contours and elevations not meeting the requirements of these Specifications shall be corrected at the Contractor's expense.

END OF SECTION

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SECTION 02150

CLEARING AND GRUBBING

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes: Requirements for clearing, grubbing, and otherwise removing vegetation and debris within areas to be graded or where embankment and structures are to be constructed. This work shall also include the preservation from injury of vegetation and objects designated in the field by the Owners or the Representative (Engineer) to remain within the grading areas. Minimal clearing and grubbing is anticipated due to the lack of vegetation on the railroad embankments.

B. The work shall be classified as follows:
   1. Clearing: Clearing shall consist of the felling of trees and disposal of stumps, brush, windfalls, logs, limbs, sticks, piles of sawdust, rubbish, debris, vegetation, and other objectionable matter existing within the clearing limits. Clearing will also occur in areas that interfere with excavation, backfill, or other construction activities.
   2. Grubbing: Grubbing shall consist of the removal from the ground and the disposal of roots, stumps, stubs, together with duff, matted roots, and debris from the grubbing limits. Grubbing shall include stockpiling the existing topsoil for reuse as described below.

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

3.01 GENERAL

A. Clearing and grubbing shall be done at such times and in such manner that the surrounding vegetation, adjacent property, and anything designated to remain in the project work area shall not be damaged. Dragging, piling, and other work that may be injurious to vegetation shall be confined to areas that carry no vegetation or that will be covered by embankments or disturbed by excavations. The Owners' Representative (Engineer) will designate and mark trees, shrubs, plants, or other objects that are to remain. The Contractor shall preserve all objects so designated. The Contractor shall avoid injury to trees, shrubbery, vines, plants, grasses, and other vegetation growing on areas outside of the slope limits of excavation and embankment or areas to be graded.

3.02 CLEARING

A. Trees, stumps, brush, shrubs, and other vegetation shall be cut off within six inches of the ground. Where feasible, trees shall be felled toward the center of the area to be cleared so they will not injure other trees or objects designated to remain. The Contractor shall remove dead vegetation, logs, stumps, limbs, sticks, piles of sawdust, rubbish, or debris, and other undesirable matter.

3.03 GRUBBING

A. Grubbing shall be confined to the area over which excavation is to be actively prosecuted within approximately 5 days following grubbing operations and/or before heavy rainfall. Depressions outside of the excavation/embankment area resulting from grubbing operations shall be made free-draining by backfilling with suitable material or grading to drain. Where scour is likely to occur, temporary erosion control settling basins shall be constructed prior to any scour occurring. The top 6 inches or deeper thicknesses of topsoil shall be selectively handled and stockpiled for reuse in areas to be revegetated. All stumps, roots, logs, or other timber more than 3 inches in diameter and all brush, matted roots, and other debris within the grubbing limits shall be pulled or otherwise removed to a depth of not less than 12 inches below the original ground surface.

3.04 METHODS OF DISPOSAL

A. All brush, stumps, trees, vegetation, and all other debris resulting from clearing and grubbing operations shall be disposed of at a landfill or other disposal area approved by the Butte/Silver Bow County, EPA, and the Owners. Topsoil and organic soils shall be salvaged and stockpiled for reuse as described above.

END OF SECTION

SECTION 02203

SITE GRADING AND EXCAVATION

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes: Requirements for site grading, earthwork, embankments, and restoration required for the completion of the repairs. This work shall include site grading, materials removal and disposal, final grading, excavation, importation of borrow material, dressing and cleanup of the site as required by the Drawings and Specifications.

1.02 CLASSIFICATION OF EXCAVATION

A. All excavation shall be unclassified and shall consist of all materials encountered.

1.03 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of these Specifications to the extent referenced. The publications are referred to in the text by the basic designation only.

B. ASTM International (ASTM).

1.	ASTM D-442	Particle Size Analysis of Soils.
2.	ASTM D-698	Moisture-Density Relations of Soil Using a 5.5-lb Hammer and a 12-inch Drop.

PART 2 - PRODUCTS

2.01 WASTE MATERIAL

A. The intent for earthwork is to grade slopes and contours as shown on the Drawings using on-site soils. This may result in excess material. Excess material may be incorporated on the site by grading smooth in work areas as approved by local BNSF forces and Engineer.

B. Excess excavated material that is unable to be reused shall be stockpiled in conformance with Section 02235 – Stockpile Preparation and Management.

PART 3 - EXECUTION

3.01 SITE PREPARATION

A. CLEARING AND GRUBBING: Clearing and grubbing of the site in both areas of excavation and embankment shall be done in accordance with Section 02150 - Clearing and Grubbing. Topsoil shall be stripped and stockpiled for later usage if required in conformance with Section 02235 – Stockpile Preparation and Management.

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3.02 SITE GRADING

A. Fill placement and compaction shall conform to Section 02060 – Furnishing and Installing Aggregate Material.

3.03 EXCAVATION

A. GENERAL: The Owners and their Representative (Engineer) reserve the right to make minor adjustments or revisions in lines or grades, if determined to be necessary as the work progresses to obtain satisfactory construction.

B. CLASSIFICATION: All excavation shall be considered unclassified. All material encountered of whatever nature shall be removed and disposed of as specified in this Section. The presence of rock or frozen material shall not constitute a claim by the Contractor for extra work.

C. STOCKPILING: The material shall be stockpiled in approved areas for sampling and disposal in conformance with Section 02235 – Stockpile Preparation and Management.

3.04 WEATHER CONDITIONS

A. Earthwork operations shall be suspended at any time when satisfactory results cannot be obtained on account of rain, freezing weather, or other unsatisfactory field conditions.

3.05 DRAINAGE

A. During earthwork operations, the grade shall be maintained in such a condition that it will be well drained at all times. If necessary, temporary drains or diversion ditches shall be installed to intercept or divert surface water that could affect the work or leave the site.

3.06 FINISH GRADING

A. Except where shown otherwise in the Drawings, restore the finish grade to the original contours and to the original drainage patterns. Grade surfaces to drain away from structures. The finished surfaces shall be smooth and compacted.

3.07 CLEANUP

A. Excess material will not be permitted to be accumulated and shall be removed concurrently with the finishing operation. Care will be taken to prevent the entrance of the material into drainage structures, other waterway, or storm sewers during the construction period.

END OF SECTION

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SECTION 02277

GEOTEXTILES

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes: Requirements for providing geotextile as shown on the Drawings under rock cover, Type 3.

1.02 CERTIFICATIONS

A. Provide written certification from the manufacturer that the non-woven geotextile meets all of the standards and tests specified herein.

1.03 SAMPLES

A. Provide samples, along with the manufacturer's literature and certifications for the product, at least 14 days prior to installation.

1.04 RELATED SECTIONS

A. ASTM International (ASTM) Publications.
   1. D-3786 Hydraulic Bursting Strength of Knitted Goods and Non-Woven Fabrics - Diaphragm Bursting Strength Test Method (Mullen Burst)
   2. D-4439 Standard Terminology for Geosynthetics
   3. D-4491 Test Methods for Water Permeability of Geotextiles by Permittivity
   4. D-4533 Test Method for Trapezoid Tearing Strength of Geotextiles
   5. D-4595 Test Method for Tensile Properties of Geotextiles- by the Wide Width Strip Method
   6. D-4632 Test Methods for Grab Breaking Load and Elongation of Geotextiles
   7. D-4751 Test Methods for Determining Apparent Opening Size (AOS) of a Geotextile
   8. D-4833 Test Methods for Index Puncture Resistance of Geotextiles, Geomembranes & Related Products
   9. D-5261 Test Method for Measurement Mass per Unit Area of Geotextiles

B. Corps of Engineers Guide Specification
   1. CW-02215 Geotextile Used as Filters

PART 2 - MATERIALS

2.01 NON-WOVEN GEOTEXTILE

A. Fabric shall be a non-woven geotextile previously approved by EPA, Propex GEOTEX 801. Similar fabric may be proposed for approval by EPA. Previous approval and material cut sheet attached.

2.02 WOVEN GEOTEXTILE

A. The geotextile construction shall be woven slit film polypropylene geotextile; individual slit films woven together in manner to provide dimensional stability relative to each other including selvages.

B. Resistant to ultraviolet (UV) degradation and biological and chemical environments normally encountered in soils.

C. Minimum Average Roll Values:

Property	Test Method	Units	Property Requirement
Grab Tensile Strength	ASTM D 4632	N	1400
Grab Elongation	ASTM D 4632	Percent	15
Puncture Strength	ASTM D 4833	N	640
Mullen Burst	ASTM D 3786	kPa	4100
Trapezoidal Tear	ASTM D 4533	N	500
Apparent Opening Size	ASTM D 4751	mm	0.425
Permittivity	ASTM D 4491	Sec-1	0.05
UV Resistance (percent retained at 500 hours)	ASTM D 4355	Percent	70

PART 3 - EXECUTION

3.01 SHIPMENT AND STORAGE.

A. During all periods of shipment and storage, the geotextile shall be protected from direct sunlight, ultraviolet rays, temperatures greater than 140 degrees F, mud, dirt, dust and debris. The fabric shall be wrapped in a heavy-duty protective covering until immediately before installation. The material shall be carefully handled with proper equipment to avoid any damage to the material.

3.02 INSTALLATION OF GEOTEXTILE

A. Geotextile shall be placed on the finished subgrade or prepared surface in accordance with the manufacturer's recommended procedures. The subgrade surface shall be free of cavities, depressions, or projecting rocks. The fabric shall be laid flat but not stretched on the soil, and shall be secured with anchor pins or other suitable means or as recommended by the manufacturer. Overlaps shall not be less than the manufacturer's recommended overlap. If the geotextile must be cut to fit the installation, the cuts shall be made neat, trim, and in a single uniform straight line.

END OF SECTION

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-02: Vegetated Caps Barren Areas Sampling and Evaluation

Revision 1

1.0 Objective

This Standard Operating Procedure (SOP) has been prepared to detail the process of sampling and evaluating barren areas within the Railroads' Butte Reclamation Evaluation System (BRES) vegetated (Type 1) caps. Results of the evaluation allow for preparation of a corrective action plan (CAP) consisting of a vegetation improvement (VI) plan and/or a reclamation plan[1] in accordance with the U.S. Environmental Protection Agency's (EPA) guidance document *Butte Reclamation Evaluation System (BRES): Butte Priority Soils Operable Unit: Silver Bow Creek/Butte Area NPL Site* (BRES Guidance) (CDM Smith 2006).

2.0 Background

The Railroads have a 4-year BRES program cycle described in Section A.5.2.1 of the Quality Assurance Project Plan (QAPP). Vegetated cap inspections and evaluations are conducted in accordance with BRES Guidance (CDM Smith 2006) to verify performance and to identify trigger items. Vegetated (Type 1) caps typical construction includes a potential limestone layer of approximately 2 inches thickness over mining-related materials (only if pH of the underlying mining-related materials is 5.5 or lower) overlain with a minimum topsoil layer of 1.5 feet, and necessary organic amendments at the surface to allow for successful seed germination and vegetative growth. The specifications for the limestone, cover soil, soil amendments, and seed are provided in SOP-BPSOU-03 "Type 1 Materials Soil Testing Requirements" of this QAPP and the Butte Hill Revegetation Specifications (BHRS; CDM Smith 1999).

Barren cover soil within a vegetated cap can lead to increased erosion and may compromise cap integrity. Therefore, the presence of a barren area(s) may be considered a trigger item per BRES Guidance. If a barren area is considered a BRES trigger item, a VI plan and/or reclamation plan will be prepared for the associated BRES site "using all pertinent historic data or recent management records. If no usable data or records exist fill data gaps […]" (CDM Smith 2006). Soil sample collection may aid in determining the cause, or causes, of barren areas and support development of reclamation prescriptions to establish desired vegetative growth. This SOP provides guidance on data gap collection and evaluation through sampling and has been developed using the criteria outlined in the BRES Guidance.

3.0 Definitions

Barren Area – Per BRES Guidance (CDM Smith 2006), a barren area is exposed cover soil within a vegetated cap with the potential to lead to increased erosion and compromised cap integrity. Barren areas may be considered BRES trigger items if they are greater than 75 square feet, with 10 percent (or less) total plant cover (live cover + litter) (CDM Smith 2006).

BHRS – Butte Hill Revegetation Specifications. A set of revegetation specifications originally developed by CDM Smith in 1999 specifically for the Butte Hill. The BHRS were last updated in 2006 and are used as guidance for the Railroads' BRES sites per BRES Guidance. The BHRS include material and construction specifications for limestone, cover soil, organic amendment, seed, and fertilizer.

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[1] Per EPA's BRES guidance, reclamation will occur only within a polygon (i.e. BRES site) that has had VI fail and is not meeting the Butte Hill Revegetation Specifications (BHRS).

<u>BRES</u> – Butte Reclamation Evaluation System. An EPA-required program that includes assessment tools to evaluate the stability, integrity, and continued protection of human health and the environment within BPSOU attained by land reclamation over the long-term. BRES sites that are part of the Railroads' assets include vegetated and engineered (rock) caps.

<u>GPS</u> – Global Positioning System. A GPS device such as a Trimble™, sub-meter global navigation satellite system (GNSS) receiver paired with a tablet running ArcGIS Collector software, or similar will be used.

<u>Litter</u> – Per BRES Guidance, litter is the uppermost layer of organic debris composed of dead plant material from previous year's growth or other slightly decomposed organic materials. The BRES definition of litter also includes moss and straw mulch.

<u>Live Cover</u> – Per BRES Guidance, live cover is ground surface covered by the current season's plant growth; exceptions include undesirable weedy species (plants with certain life history characteristics that could undermine the integrity of the response action at the site) and noxious weeds (all plants on the Montana state and Silver Bow County noxious weed lists).

<u>QAPP</u> – Quality Assurance Project Plan. This report details the long-term operation and maintenance (O&M) of railroad assets to meet the intent of the 2006 BPSOU Record of Decision and the 2011 BPSOU Unilateral Agreed Order for the long-term management of ecological risk and human health risk.

<u>SOP</u> – Standard Operating Procedure.

4.0 Responsibilities

All field personnel performing the sampling described in this procedure are responsible for adhering to the tasks specified herein. The field personnel should have limited discretion with regards to collection procedures but should exercise their best judgment. All field personnel will be adequately trained by the Project Quality Assurance Manager (see Figure 1 of this QAPP).

5.0 Equipment

Equipment needed to sample and evaluate barren area cover soil includes but is not limited to:

- Field notebook
- GPS unit
- Notated figure or similar with pre-defined sample locations
- Geologist pick, sampling trowel, hand auger, or similar tool
- Alconox® or similar comparable equipment decontamination cleaning agent and clean rinse water
- 1-gallon Ziploc® bags
- Stainless steel mixing bowl

- Small container for making paste (e.g., disposable cup)
- Plastic spoon for mixing (or equivalent)
- YSI EcoSense pH100 hand-held meter (or equivalent)
- Distilled water
- Permanent markers
- Analytical laboratory-supplied sample containers, labels, and chain-of-custody forms
- Camera.

6.0 Approach and Procedures

6.1 Sampling Depths

Depth-specific composite soil samples will be analyzed for each contiguous barren area to allow for vertical profiling and reclamation prescription development. Composite samples will be collected for the following three depth intervals:

1. 0 to 2 inches below ground surface (bgs)
2. 2 to 6 inches bgs
3. 6 to 12 inches bgs

The composite soil samples will consist of soil from pre-defined subsample locations. Subsample locations will be identified as the centroid of 10-square-meter grids, where those centroids fall on a trigger item area (i.e., a barren area) at a vegetated cap site. Subsample location depth intervals will be combined to form a composite soil sample for each depth interval for the associated BRES cap.

6.2 Field Sampling Procedures

Field sampling procedures are as follows:

1. Navigate to pre-defined subsample locations using handheld GPS unit. Any individual centroids may be discarded if vigorous vegetative emergence or growth is observed at time of sampling.

2. To track subsample locations on the GPS, field staff will name subsample locations by BRES site and two-digit number in the order collected. For example, the second subsample for BRES site 992155A would be identified in the GPS as “992155A_02.”

3. To track subsamples between collection and prior to compositing all subsamples, field staff will label subsample containers (e.g., unused Ziploc® bags) by BRES site, two-digit number (01, 02, etc.; same as GPS), and depth interval (e.g. 0-2 for 0 to 2 inches bgs).

Therefore, the second subsample from BRES 992155A collected at 0 to 2 inches bgs would be labeled as 992155A_02_0-2.

4. Use a geologist pick, sampling trowel, or hand auger to loosen the surface soil. Use a stainless-steel trowel to collect depth-discrete subsample and place in Ziploc® bag labeled with the subsample identification; collect equal volumes per depth-discrete subsample. Decontaminate soil-loosening tools between subsample locations and subsample collection tools between sample depths using Alconox® or similar comparable cleaning agent and clean rinse water.

5. Once all subsamples for a given vegetated cap BRES site or individual large barren area of a vegetated BRES site have been collected, place equal volumes of depth-specific subsamples in either a fresh Ziploc® bag or in a clean stainless steel mixing bowl and mix thoroughly. Place composited sample into laboratory-provided sample containers, and use remaining composited material to conduct a pH paste test (see pH paste test procedure below). Field sieving will not be performed. Each composite sample will be labeled to represent the BRES site, sample depth interval, and collection date. Sample identification 992155_0-2_20180326 would designate a sub-sample collected from site 992155 from the 0- to 2-inch depth increment on 26 March 2018.Take a photograph of all composite samples and document lithology.

6. Fill out laboratory-provided chain-of-custody form. Designate which samples to analyze, specify turn-around time, and denote which samples are to be put on hold. Pack samples on ice and ship the samples in accordance with laboratory instructions.

Field pH testing procedures are as follows:

If the visual inspection indicated heavy metal impacts, a pH analysis will be performed using distilled water and a YSI EcoSense pH100 hand-held meter (or equivalent). The pH for the solid media will be collected using the *Saturated Soil Paste Method* (U.S. Department of Agriculture 1954). This method consists of the following steps:

- Collect discrete or representative composite solid media sample using clean, stainless steel sample collection equipment.

- Place solid media sample into clean container (e.g., disposable cup).

- Prepare a paste by adding distilled water to the solid media sample (fine to medium grain material) and mixing into a paste like texture by stirring with a sterilized instrument within a container.

- Verify the solid media is saturated. It is saturated when it (1) glistens and reflects light and (2) slides freely and cleanly off the mixing instrument (except in soils with high clay content).

- After mixing has been complete to yield saturated soils, the sample should set for at least an hour to allow for equilibrium conditions between soil and water.

  - During equilibration, free water should not pond on top of the sample, nor should the sample stiffen. If ponding or stiffening occurs, remix the sample with more distilled water.

- Insert the electrodes of the EcoSense pH100 sensor (or equivalent) into the sample and raise and lower repeatedly until a reproducible pH reading is obtained.

The amount of soil samples to be analyzed for pH will increase as solid media area or volume increases. Sample locations should be guided by the results of the visual inspection (e.g., locations suspected to have lead and arsenic should be sampled for pH testing).

6.3 Sampling Analysis Procedures

Cover soil intended for use as growth media for vegetated BRES caps (whether in situ or imported) must meet BHRS requirements. BHRS requires at least 3 soil samples be analyzed for the following parameters:

- Texture class and particle size
- Rock content/sieve analysis
- pH (between 5.5-8.5)
- Saturation percent (between 25-85%)
- Electrical conductivity (EC) in millimhos per centimeter (mmhos/cm) (less than 4 mmhos/cm)
- Sodium adsorption ratio (SAR) (less than 12)
- Organic matter percent
- NO_3 – nitrogen
- Available phosphorus (P)
- Available potassium (K)

The above parameters shall be analyzed using U.S. Department of Agriculture (USDA) classification and test methods as described in ASA/SSSA Monograph No. 9, Methods of Soil Analysis, Parts 1-2, most recent edition (ASA/SSSA 1986) or as described in EPA-approved Clark Fork River Superfund Site Investigations documents. Also, per BHRS requirements, the three samples will be analyzed for arsenic, cadmium, copper, and zinc by EPA 6010D.

In addition, the three soil samples will be tested for arsenic and lead by EPA 6010D (BPSOU solid media metals with RALs) and chlorinated herbicides [included due to routine, Federal Railway Administration (FRA) required vegetation suppression near active railroads].

-

All soil imported to vegetated caps for cover soil intended for use as growth media must include a Butte Hill Cover Soil Approval Submittal form (Attachment A) and meet the BHRS requirements (EPA, 2006b) prior to placement. Other parameters may be tested based on site-specific conditions observed in the field during BRES inspections (e.g., odors, staining, or observations made by others related to operational releases of a chemical). Such analyses, laboratory methods, reporting limits, and holding times would be specified in a proposed corrective action plan (CAP) for EPA approval.

6.4 Data Evaluation

Lead and arsenic concentrations will be compared to applicable solid media action levels from the ROD, presented in Section A.5.4 of this QAPP. Soils with lead and/or arsenic concentrations exceeding applicable solid media action levels may need to be removed and managed in accordance with SOP-BPSOU-01 “Solid Media Management” included with this QAPP.

Chemical concentration data associated with potential operational releases such as chlorinated herbicides will be used to clarify the nature and extent of potential operational release impacts. All other constituents listed above in Section 6.3 provide soil property information that will be used to clarify the ability of the soil to support plant growth and, thereby, determine what soil amendment(s) may be applicable. The analytical results will help determine appropriate reclamation prescriptions. Reclamation prescriptions will restore the vegetated caps (or Type 1 caps) to be in accordance with the 2006 BHRS.

7.0 References

CDM Smith Federal Programs Corporation. 1999. Butte Hill Revegetation Specifications as of March 1999. Prepared for EPA by CDM Smith. September.

_____. 2006. Butte Reclamation Evaluation System (BRES): Butte Priority Soils Operable Unit: Silver Bow Creek/Butte Area NPL Site.

U.S. Department of Agriculture. 1954. Diagnosis and Improvement of Saline and Alkali Soils – Handbook No. 60. February 1954.

BUTTE HILL COVER SOIL APPROVAL SUBMITTAL

11/13/2022

Source:
Sample #:

Description		Specification		Sample	Specification Met Yes	Specification Met No
Chemical (mg/kg)						
	As	<	97			
	Cd	<	4			
	Cu	<	250			
	Hg	<	5			
	Pb	<	100			
	Zn	<	250			
pH (s.u.)						
		>	5.5			
		<	8.5			
SAR						
		<	12			
Saturation (%)						
		<	85			
		>	25			
EC (mmhos/cm)						
		<	4			
Textural Classification (USDA) <2.0 mm						
	Loam					
	Sandy loam					
	Sandy clay loam					
	Sandy clay					
	Clay loam					
	Silty clay					
	Silty clay loam					
	Silt loam					
	Silt					
	*Per EPA Approval (Loamy sand)					
Rock Content (%) (by volume)		<	45			

Other Information Requested	
Organic Matter (%)	
WB	
Soil Nutrients	
NO_3 (ug/g)	
P (ug/g)	
K (ug/g)	
Particle Size	
Sand (%)	
Silt (%)	
Clay (%)	

Legend:

🟩 # Value - Criteria met

🟥 **# Value** - Does not meet Criteria

Railroad Representative: ____________________ Date: ____________________

EPA Representative: ____________________ Date: ____________________

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-03: Type 1 Material Soil Testing Requirements

Revision 0

1.0 Objective

This Standard Operating Procedure (SOP) has been prepared to detail the process of testing vegetated (Type 1) cap material that is imported for use in the Railroads' Butte Reclamation Evaluation System (BRES) vegetated (Type 1) caps. Results of the testing allow for the assurance that the material adheres to the Butte Hill Revegetation Specifications (BHRS) (CDM 1999) in accordance with the U.S. Environmental Protection Agency's (EPA) guidance document *Butte Reclamation Evaluation System (BRES): Butte Priority Soils Operable Unit: Silver Bow Creek/Butte Area NPL Site* (BRES Guidance) (CDM 2006).

2.0 Background

The Railroads have a 4-year BRES program cycle described in Section A.5.2.1 of the Quality Assurance Project Plan (QAPP). Vegetated cap inspections and evaluations are conducted in accordance with BRES Guidance (CDM 2006) to verify performance and to identify trigger items. Typical vegetated (Type 1) cap construction includes a potential limestone layer of approximately 2 inches thickness over mining-related materials (only if pH of the underlying mining-related materials is 5.5 or lower) overlain with a minimum top soil layer of 1.5 feet, and necessary organic amendments at the surface to allow for successful seed germination and vegetative growth. Type 1 material testing will be conducted prior to materials used in the Railroads' BRES Type 1 vegetated caps being imported to ensure they meet the requirements of the BHRS. The BHRS are a set of EPA-approved practices and specifications that guide the construction of vegetated (Type 1) caps. They were initially developed by CDM in 1999 specifically for the Butte Hill and were last updated in 2006. A copy of the BHRS is attached to this SOP.

3.0 Definitions

<u>BHRS</u> – Butte Hill Revegetation Specifications. A set of revegetation specifications originally developed by CDM in 1999 specifically for the Butte Hill. The BHRS were last updated in 2006 and are used as guidance for the Railroads' BRES sites per BRES Guidance. The BHRS include material and construction specifications for limestone, cover soil, organic amendment, seed, and fertilizer.

<u>BRES</u> – Butte Reclamation Evaluation System. An EPA-required program that includes assessment tools to evaluate the stability, integrity, and continued protection of human health and the environment within BPSOU attained by land reclamation over the long-term. BRES sites that are part of the Railroads' assets include vegetated and engineered (rock) caps.

<u>QAPP</u> – Quality Assurance Project Plan. This report details the long-term operation and maintenance (O&M) of railroad assets to meet the intent of the 2006 BPSOU Record of Decision and the 2011 BPSOU Unilateral Agreed Order for the long-term management of ecological risk and human health risk.

<u>SOP</u> – Standard Operating Procedure.

4.0 Responsibilities

All field personnel performing the sampling described in this procedure are responsible for adhering to the tasks specified herein. The field personnel should have limited discretion with regards to collection procedures but should exercise their best judgment. All field personnel will be adequately trained by the Project Quality Assurance Manager (see Figure 1 of this QAPP).

5.0 Equipment and Procedures

The BHRS cover the following subject areas:

- Limestone stabilization
- Cover soil
- Organic amendment
- Seeding and fertilizing.

The equipment necessary to perform imported vegetated (Type 1) cap material testing, as well as the procedures involved with this testing are outlined in the BHRS, which are attached to this SOP.

6.0 Attachments

Attachment 1 – Butte Hill Revegetation Specifications

7.0 References

CDM Smith Federal Programs Corporation. 1999. Butte Hill Revegetation Specifications as of March 1999. Prepared for EPA by CDM Smith. September.

CDM Smith Federal Programs Corporation. 2006. Butte Reclamation Evaluation System (BRES): Butte Priority Soils Operable Unit: Silver Bow Creek/Butte Area NPL Site.

BUTTE HILL REVEGETATION SPECIFICATIONS

as of September 2006

BUTTE HILL LIMESTONE STABILIZATION

GENERAL

Work described in this section shall consist of preparing the ground surface for limestone stabilization, hauling, placing, and spreading the limestone and fill on prepared areas in accordance with this Specification at the locations shown on the Drawings.

MATERIALS

Limestone sources will be approved by EPA. Limestone may be from any approved source and shall have a calcium carbonate equivalent content of not less than 65%. All limestone must be <1 inch in diameter and 50% (weight basis) must pass a 60 mesh (<0.25 mm) sieve.

CONSTRUCTION REQUIREMENTS

pH Testing of Subgrade

The responsible party (RP) Group shall test the subgrade soil pH of all areas to be revegetated. The frequency of testing shall not be less than one test per 40,000 square feet (approximately 200 x 200 foot grid). Limestone addition shall include areas to be revegetated where the subgrade soil has a pH of less than 5.5. Acid-base accounting (ABA) may be required by EPA under certain circumstances, such as the presence of acid-generating minerals, and the method used to determine ABA shall be as described in EPA-600/2-78-054. Documentation of this sampling effort, including a map showing sampling locations and sample results, shall be included in the final construction completion document(s) for the project.

Installation of Limestone

The surface of the subgrade in the area to be covered shall be brought to grade and finished smooth and uniform immediately prior to dumping and spreading the limestone. The limestone shall be placed prior to the placing of the cover soil. A minimum 350 tons/acre (approximately 2 inches) of limestone shall be placed on the low pH soil. Placement of the limestone layer on a site will be based on site-specific data and approved by EPA prior to placement of limestone.

Grades on the area to be covered shall be maintained in a true and even condition. Where grades have not been established, the areas shall be graded and sloped to drain. The surface shall be left smooth in an even and properly compacted condition to prevent, insofar as practical, the formation of low places or pockets where water will stand.

BUTTE HILL COVER SOIL

GENERAL

The work of this section covers all operations required for furnishing, excavating, hauling, stockpiling, spreading, and seedbed preparation of approved cover soil.

SUBMITTALS

Cover soil submittals will be provided in the Design Report or under separate cover and approved by EPA prior to use. The following submittals shall be provided to EPA for each cover soil source:

- The intended cover soil source site location, including details on the area and depth to be excavated at the source site location.

- For each cover soil source, the RP Group shall be required to secure at least 3 soil samples from the source area. EPA will be notified in advance of the sampling effort and the approximate location and depth where samples will be collected.

- Each of the above 3 soil samples shall be analyzed by an approved laboratory for the following parameters: texture class and particle size; pH; saturation percent; electrical conductivity (EC) in mmhos/cm; sodium adsorption ratio (SAR); organic matter percent; NO_3 - nitrogen; available phosphorus (P); and available potassium (K). The above parameters shall be analyzed using USDA classification and test methods as described in ASA/SSSA Monograph No. 9, Methods of Soil Analysis, Parts 1-2, most recent edition or as described in EPA approved Clark Fork River Superfund Site Investigations documents. Also, each of the above 3 soil samples shall be analyzed by an approved laboratory for the following soil metals parameters: arsenic, cadmium, copper, lead, and zinc. Cover soil placement shall not begin until test results of the soil samples are known.

MATERIALS

Cover soil sources will be approved by EPA. Cover soil thickness shall be a minimum of 18 inches, unless otherwise approved by EPA in writing. Eighteen inches is considered the minimum thickness required for long-term vegetation success. Sufficient cover soil should be applied to account for settling, sloughing, and erosion. Cover soil material shall be reasonably free of any trash, rocks, lumps of soil, stumps, and brush. Rock content (i.e., particles >2.0 mm) must constitute <45% (by volume) of the cover soil and the maximum allowable rock size is 6 inches in diameter. To the extent possible, the cover soil source should be free of any noxious weeds.

Cover soil shall be a friable material and the <2.0 mm fraction characterized as loam, sandy loam, sandy clay loam, sandy clay, clay loam, silty clay, silty clay loam, silt loam, or silt in accordance with the USDA Soil Conservation Service textural classification provided below. Per approval of EPA, loamy sand may be acceptable from 6 to 18 inches in certain circumstances.

The soil pH shall be between 5.5 and 8.5. The soil SAR shall be <12. Soil saturation percent will be less than 85% and greater than 25%. The soil shall have an EC less than 4 mmhos/cm. NO_3, P, and K will be used by EPA and the RP Group to verify fertilizer rates.

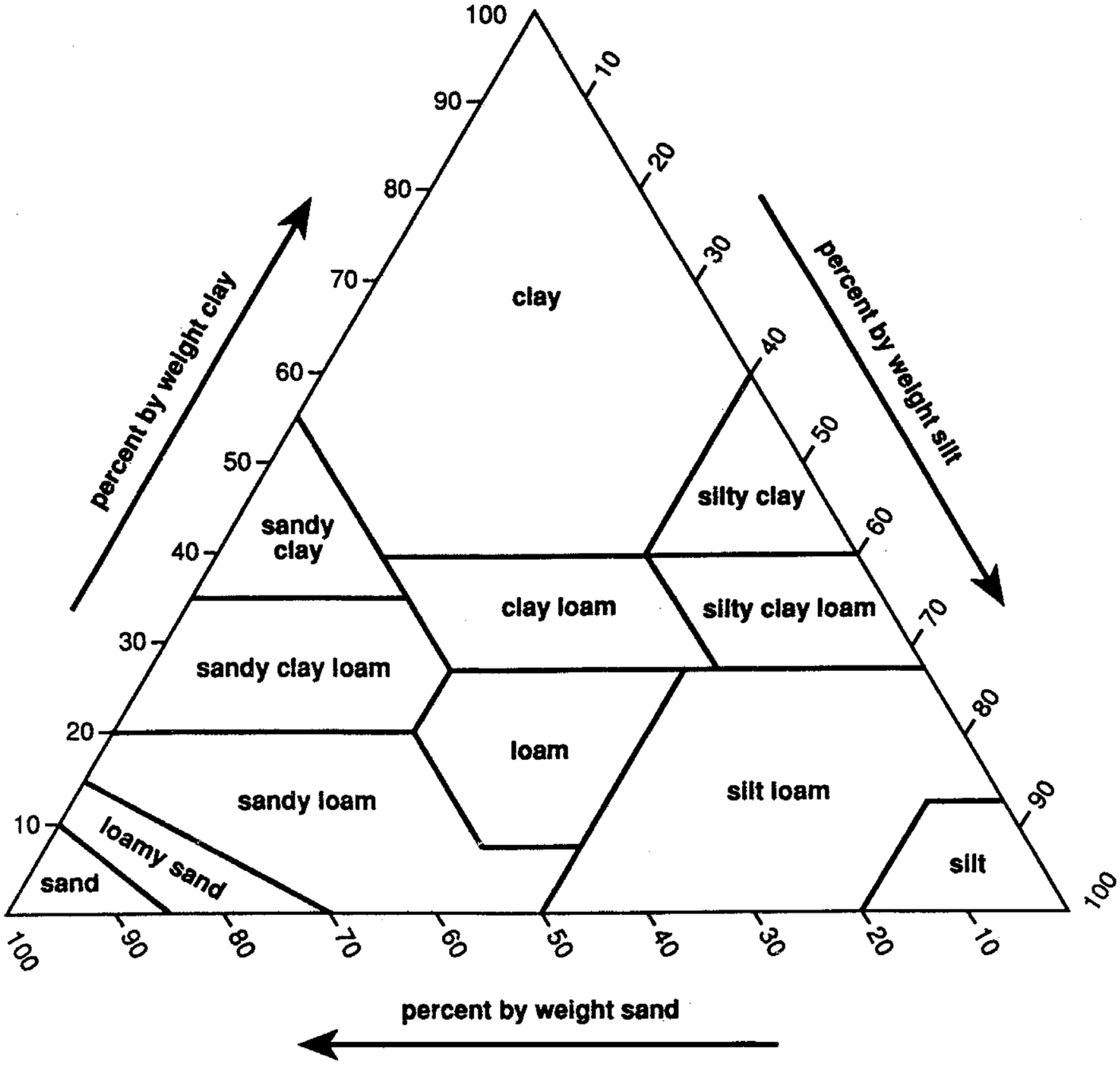


Figure 1. Graphic guide for textural classification of the less than 2 mm portion. (Source: USDA Soil Conservation Service)

The following chemical suitability criteria are general guidelines to be followed as screening standards:

As	<97 mg/kg
Cd	<4 mg/kg
Cu	<250 mg/kg
Pb	<100 mg/kg
Zn	<250 mg/kg

With the exception of zinc, these suitability criteria were established for parks, play areas, and residential yards in the Final Work Plan for Residential Areas, Butte Priority Soils Expedited Response Action prepared by ARCO dated May 1, 1995. These values were provided in a February 14, 1995, letter from Sara Weinstock (EPA) to Dave Sinkbeil (ARCO) providing final comments on the above work plan. The criterion for zinc was reduced to <250 mg/kg from <500 mg/kg to take into account potential phytotoxic effects noted at the higher level in the Final Baseline Ecological Risk Assessment, Anaconda Regional Water, Waste, and Soils Operable Unit, Anaconda Smelter NPL Site, Anaconda, Montana, prepared in October 1997 by CDM Federal Programs Corporation for EPA. The chemical suitability criteria listed above were established for the Butte Hill and may not be appropriate for use at other Clark Fork River Basin Superfund Sites.

It should be noted that some exceedances of the above criteria may still allow successful long-term vegetation. Therefore, if cover soil sampling shows a variance from the chemical suitability criteria, the RP Group will notify EPA and a plan to address the usability of that cover soil source will be discussed. EPA must approve in writing any cover soil sources which exceed the above suitability criteria.

CONSTRUCTION REQUIREMENTS

Visual inspection of excavated cover soil shall be a continuous process to carefully observe and recognize changes in source material characteristics. Visual inspection, in conjunction with hand-texturing of the <2.0 mm fraction, will be used to determine the adequacy of the borrow material ahead of excavation, to assure that current material meets textural criteria, and to identify areas to move to if material begins to fall out of specification. Each inspection shall record the location, test number for that day, date, time, estimated rock content percentage, and soil texture (<2.0 mm fraction). The frequency of inspection is dependent on the variability of the cover soil source material, but must be performed and recorded at least once daily during periods of source material excavation and transport. It is desirable to have the same person perform the inspections for the duration of excavation at a particular source area. In addition to the above visual inspections, textural analysis by laboratory hydrometer testing may be requested by EPA at a rate not to exceed one test for every 5,000 cubic yards of cover soil material excavated. These tests will be used for comparison and guidance for field testing and field observations. Copies of all inspection records and laboratory analyses shall be provided to EPA for review. Summaries of inspection records and analyses shall be included in the final construction completion documents for the project.

For revegetation purposes, slopes must not exceed a maximum of 3:1 (3 horizontal to 1 vertical) unless previously agreed to by EPA and the RP Group because of site specific requirements. Cover soil shall not be placed until the areas to be covered have been properly prepared, the limestone layer appropriately applied (if required), all construction work in the area has been completed and approved by the RP Group, and EPA notified that all subgrade preparations have been completed.

After the cover soil has been spread, large clods, hard lumps, rocks, and large roots over 6 inches in diameter; litter; or other foreign material (exposed iron, timbers, etc.) shall be raked up, removed from the cover soil and disposed of properly. Further preparation of the cover soil for seeding is provided in the specifications for Seeding and Fertilizing.

The RP Group shall grade the source area borrow site(s) to existing contours at slopes not to exceed 3:1 (unless previously agreed to by EPA and the RP Group because of site specific requirements) and to provide positive drainage. The RP Group shall replace stockpiled topsoil to the borrow area. The borrow area shall be prepared for seeding, mulching, and fertilizing as are other areas receiving cover soil.

BUTTE HILL ORGANIC AMENDMENT APPLICATION

GENERAL

Organic amendment application shall consist of furnishing, applying, and incorporating soil amendments, such as manure and compost, at locations and rates designated on the Drawings.

SUBMITTALS

Organic amendment submittals will be provided in the Design Report or under separate cover and approved by EPA prior to use. The following submittals shall be provided to EPA for each organic amendment source:

- Location of Supplier;
- For each supplier, at least three organic amendment analyses, including gravimetric water content, rock and other fragment content, and organic matter content, as described further under Materials; and
- Proposed organic amendment application and incorporation methods and equipment.

MATERIALS

Analyses for organic amendments (such as manure, compost, etc.) shall include the gravimetric water content (%, dry weight), the percentage of rock and/or other fragments >2.0 mm fraction (%, dry weight), and organic matter content of the <2.0 mm fraction (%, dry weight). The organic matter content of the <2.0 mm fraction shall be determined in the laboratory using Walkley-Black procedure, ASA, Meth. Soil Anal., 1986, Method 29-3.5.2.

If manure is used as the organic amendment source, cattle manure shall be the preferred manure type. Straw bedding material mixed into the manure is acceptable, but it shall not constitute more than 20% of the dry weight.

Application Rate

The field application rate shall be calculated using 3% organic amendment on a dry weight basis in the upper 6 inches of cover soil. Upon approval or direction from EPA, the 3% application rate may be modified to account for site-specific conditions. Analyses for organic amendments shall be submitted for each Supplier on a regular basis to determine if adjustments to the field application rates are necessary. The water and rock and/or other fragment content shall be deducted in calculating the field organic amendment application rate. Documentation of the organic amendment application, including application rate calculations, shall be included in the final construction completion documents(s) for the project.

CONSTRUCTION REQUIREMENTS

Stockpiling Organic Amendment

Prior to stockpiling organic amendment on site, the Contractor shall develop an acceptable stockpiling plan for the RP Group review and approval. The plan shall include the location of the stockpile and adequate measures to prevent contamination of underlying and adjacent soils and prevent air or water pollution.

Site Grading

Prior to placement of the organic amendment, all areas shall be graded as necessary to approximately restore the design contours of the ground or to produce a contour that will blend with contours of adjacent areas. This shall include grading erosion channels in revegetated areas that are to receive organic amendment.

Organic Amendment Application

Organic Amendment shall be applied with agricultural manure spreaders or other approved application equipment that enables spreading a uniformly regulated amount of material.

For a specified application rate, the Contractor shall apply the organic amendment in a uniform manner across the landscape. Localized organic amendment application thicker than 6 inches is unacceptable.

Contractor shall calibrate the organic amendment spreader prior to each use of the equipment unless site conditions have not changed and equipment settings have not been altered since previous calibration. Calibration records shall be furnished to the RP Group. Upon request, copies of equipment calibration shall be provided to EPA for review. All calibration records shall be included in the final construction completion document(s) for the project.

Under no circumstances shall the Contractor apply the organic amendment during wind conditions strong enough to displace material onto adjacent sites.

Organic Amendment Incorporation

Following organic amendment application, the soil shall be ripped to a 6-inch depth at 12-inch centers. The soil shall then be tilled to a depth of 6 inches with a disc, rototiller, moldboard plow, or chisel plow. An agricultural disc with a disc diameter of approximately 20 inches having cone-shaped discs at a spacing width of 6-8 inches is recommended. Multiple tilling equipment passes may be required to achieve adequate incorporation. Adequate incorporation will be a complete and uniform mixing of the manure and soil to a depth of 6 inches. All tillage procedures shall be completed as soon as practicable after amendment application.

BUTTE HILL SEEDING AND FERTILIZING

GENERAL

Revegetation work described in this section includes fertilization, seeding, and mulching on all project designated and disturbed areas upon completion of construction work. These areas include finished embankment slopes, borrow areas, areas to be revegetated, and disturbed areas.

MATERIALS

Seed

Seed mixes used must be in compliance with all applicable laws and regulations, including Section 80-5-123, MCA, (Label requirements for agricultural, vegetable, flower and indigenous seeds), 80-5-134, MCA, (Prohibitions), and other state and county restrictions and requirements relating to seed mixes and labeling. Weed species prohibited in the mix should include those species prohibited in the downstream Montana counties as well as those prohibited in the county of planting.

Hand collected native species and some of the special wetland species collected cannot meet the following requirements. All other seed shall comply with, and be labeled in accordance with Montana seed law, Title 80, Chapter 5, Montana Code Annotated (MCA). Indigenous seeds, as defined in Section 80-5-120(14), MCA, in amounts of one pound or more, whether in packages or bulk, must be labeled with the following information:

1. Name and mailing address of the seed labeler;

2. Lot number or other lot identification mark;

3. The Statement "Labeled only for reclamation purposes";

4. The common name, genus, species, and subspecies, when applicable, including the name of each kind of seed present in excess of 5 percent. When two or more kinds of seed are named on the label, the label shall specify the percentage of each. When only one kind of seed is present in excess of 5 percent and no variety name or type designation is shown, the percentage must apply to seed of the kind named. If the name of the variety is given, the name may be associated with the name of the kind. The percentage in this case may be shown as "pure seed" and must apply only to the seed of the variety named;

5. State or county of origin;

6. The percentage of viable seed, together with the date of the test. When labeling mixtures, the percentage viability of each kind shall be stated. The method used to determine viability shall be stated on the label;

7. The percentage by weight of pure seed;

8. The percentage by weight of all seeds;

9. The percentage by weight of inert matter;

10. The percentage by weight of other crop seeds; and

11. The name and rate of occurrence per pound of each kind of restricted weed seed present;

As required by ARM 4.12.3010, seed shall contain no "Prohibited" noxious weed seed. The seed shall contain no "Restricted" weed seed in excess of the maximum numbers per pound, as specified by ARM 4.12.3011, or as specified by the appropriate BSB County Weed Board, whichever is more stringent.

As defined by MCA 80-5-120(14), indigenous seeds include the seeds of those plants that are naturally adapted to an area where the intended use is for revegetation of disturbed sites. These species include grasses, forbs, shrubs, and legumes.

The Contractor must supply the RP Group with all seed bag tags and certification from the supplier stating that the seed complies with the Federal Seed Act and the Montana Seed Laws, Title 80, Chapter 5, MCA and applicable regulations. Upon request, copies of said tags shall be submitted to EPA for review. Copies of seed bag tags and certification shall be included in the final construction completion documentation the project.

When legumes are seeded as the predominant mixture, the seed supplier shall include inoculants (rhizobia) and provide documentation as specified in the Seed Certification. Seed Certifications shall be submitted to the RP Group prior to any seeding. The Contractor shall also submit a copy of the bill or other documentation from the seed supplier showing actual bulk weights of the individual seed types combined in the mix and verification of legume inoculation. The required certifications and documentation shall be provided to the RP Group at least three days prior to the seeding.

Fertilizer

Fertilizer shall be delivered in standard-size bags of the manufacturer showing weight analysis and manufacturer’s name, or in bulk quantities accompanied with written certifications from the manufacturer stating that the fertilizer supplied complies with applicable Specifications.

Fertilizer shall be soluble commercial carrier of available plant food element or combination thereof. The fertilizer to be used on the project shall supply the quantities of available chemical elements stipulated below. The fertilizer shall be of uniform composition and in good condition for application by suitable equipment. It shall be labeled with the manufacturer’s guaranteed analysis, as governed by applicable fertilizer laws. Any fertilizer that becomes contaminated or damaged, making it unsuitable for use, shall not be accepted. All required fertilizer certificates shall be provided to the RP Group a minimum of three days prior to fertilizing. The certification shall include the guaranteed analysis of the fertilizers stated in the terms of the percentages of nitrogen, and available phosphorous, potash, and boron, in that order.

Mulch

Vegetative mulch shall be either grass hay or straw. Grass hay material shall be composed primarily of perennial grasses. The grass hay mulch shall contain greater than 70 percent grass by weight and shall not contain more than 10 percent alfalfa, crested wheatgrass or yellow sweet clover. Grass hay shall be relatively free of noxious weeds and other undesirable species.

Straw mulch material shall be clean grain straw, shall be relatively free of noxious weeds and other undesirable species, and shall not contain greater than 5 percent cereal seed by weight, i.e., seed heads. Wheat straw will be used whenever possible. Harvesting will be performed with modern combines, which leave less grain in the straw. Written approval of straw and hay sources from the supervisor of the BSB County weed board shall be obtained.

Chopped or ground material is not acceptable. The mulch material is not acceptable if it is damaged by rotting, molding, etc. to seriously limit its use for mulch. It shall be relatively free of stones, dirt, roots, stumps, or other foreign material.

Application rates shall be 3,000 lbs/acre on flat non-critical erosion and potential dust generating areas and 4,000 lbs/acre on all critical runoff and potential dust generating areas. Exact application rates will be adjusted in the field to accommodate differences in mulch material and seedbed conditions.

CONSTRUCTION REQUIREMENTS

Seedbed Preparation

Prior to executing the seeding, fertilizing and mulching work items, the seed bed at all sites shall be prepared so these items can most efficiently be completed, with the areas resulting in reasonable conformity to specified line and grade. The fertilizing, seeding, and mulching work items shall be executed only after the seedbed condition has been approved by the RP Group. The cover soil shall be prepared as described in the Cover Soil specifications.

The seedbed surface must be in a condition that does not preclude growth at the time of application of seed. Conditions that may preclude growth include, but are not limited to: large clumps, clods, and impervious crusts of dirt; areas too tightly compacted to allow seed growth; and areas of loose soils which could possibly become too compacted during the seed applications to allow growth. The decisions on the conditions of the seedbed shall be made by the RP Group. If the RP Group determines the seedbed is inadequate for seeding, the Contractor shall treat the inadequate areas, as directed by the RP Group, to attain as nearly as practicable the adequate condition at no additional cost to the RP Group.

Excessively tight or compacted soils shall be loosened to the minimum depth of 6 inches. Disking, chiseling, or tilling of the soils shall be done at right angles to the natural flow of water on the slopes, unless otherwise directed or approved by the RP Group. Compaction of the soil, when required, shall be performed by equipment that shall produce a uniform rough-textured surface ready for seeding and mulching.

Existing structures and facilities shall be adequately protected and any damage done by the Contractor shall be repaired or adjusted to the satisfaction of the RP Group.

Seed Application

General

Slopes and areas finished during the period of October 15 through June 15 may be permanently seeded within this time period. The Contractor must obtain the RP Group permission to commence seeding operations. Slopes and areas finished during the period June 16 through October 14 shall receive an annual cover crop from the strawmulch seed to protect the in-place cover soils during this period. The control of noxious weeds and other undesirable species will also be addressed during this period. The perennial seed mix shall then be applied to the areas after October 15. EPA shall be notified prior to commencement of seeding activities.

Specifications of each type of seed mix are outlined below. The seeding of steep slopes, narrow medians, or small areas that are impractical to seed by drill may be performed by using the hydraulic seeding methods, when approved by the RP Group. The hydraulic seeding methods shall be used when the seedbed surface is too wet or swampy to permit seeding by drill. Hydraulic seeding methods shall not be used during adverse weather, as determined by the RP Group.

The applied seed, regardless of the method of application, shall not be covered by a soil thickness greater than 1 inch in depth.

Seed Application Equipment

Drill Seeding

Seeding equipment used for applying grass/forb seed must be designed, modified or equipped to regulate the application rate and planting depth of the seed mixture. Seed must be uniformly distributed in the drill hopper during the drilling operation. Acceptable drills are: custom seeders, furrow drills, disc drills or other drills approved by the RP Group. All seeding equipment shall be operated perpendicular to the slope. Contractor shall calibrate the drill seeder prior to each use of the equipment unless site conditions have not changed and equipment settings have not been altered since previous calibration. Calibration records shall be furnished to the RP Group. Upon request, copies of equipment calibration shall be provided to EPA for review. A summary of all calibration records shall be included in the final construction completion document(s) for the project.

Planting depth shall be regulated by depth bands or coulters. The drill box shall be partitioned by dividers no more than 24 inches apart, in order to provide for more even distribution on sloping areas. The rows or planted seed shall be a maximum of 8 inches apart. Drilling depth shall be from 1/4 to 1 inch.

Broadcast Seeding

Seeding by hand or mechanical broadcasting shall be permitted on areas inaccessible to drills or impractical to seed by other prescribed methods. The broadcast seeding rate shall not be less than twice the drill seeding rate. Following the seeding, the soil shall be hand-raked to cover the seed. Broadcast seeding requires the prior approval of the RP Group.

Hydraulic Seeding

The Contractor must provide one pound of wood fiber mulch per each 3 gallons water in the hydraulic seeder as a cushion against seed damage. The mulch used as a cushion may be part of the total required mulch with the remainder applied after the seed is in place. The Contractor may be required to use extension hoses to reach the extremities of slopes.

When using vegetative mulch, the Contractor may mix the seed with the fertilizer if his hydraulic seed equipment is capable of uniformly mixing water, fertilizer, and seed, in that order, and power blowing or spraying the mixture uniformly over the seedbed. After blending, the slurry shall be applied to the seedbed within 45 minutes after the seed has been added to the water-fertilizer mixture. If the slurry cannot be applied within the specified time, it shall be fortified, at no cost to the RP Group, with the correct ratio of seed to the remaining slurry and a new 45-minute time frame established for applying the fortified mixture. At no time shall seed and fertilizer remain in a slurry for more than 45 minutes.

<u>Seed Application Areas/Rates</u> - The revegetation mixes include:

Butte Hill 1997 Primary Seed Mixture
Revegetation Mix

Seed Mixture	Rate, #PLS/Acre
Slender Wheatgrass	3.0
Thickspike Wheatgrass	2.0
Sheep Fescue	2.0
Crested Wheatgrass	1.0
Ladak Alfalfa	1.0
Red Clover	2.0
Canada Bluegrass	1.0
Birdsfoot Trefoil	1.0
Total	**13.0**

Butte Hill

Alternate Seed Mixture No. 1 - Gentle Sloped Areas (Less than 10:1) Revegetation Mix

Seed Mixture	Rate, #PLS/Acre	Planting
Bozoisky Russian Wildrye	5.0	Initial seeding, drill seeded on 15-18 inch centers.
Ladak Alfalfa	2.0	Interseeded during following years as determined by vegetation monitoring.
Total	**7.0**	

Butte Hill

Alternate Seed Mixture No. 2 B Grass-lined Ditches

Seed Mixture	Rate, #PLS/Acre
Smooth Brome	5.0
Birdsfoot Trefoil	1.0
Red Clover	0.5

Pure live seed application rates shall be as specified in the tables.

The 1997 primary seed mixture was proposed by BSB County and is based upon their monitoring results for successful revegetation within the Butte area and has been reviewed and approved by BSB County, EPA and the State for use in upland areas of the Butte Priority Soils Operable Unit. The Alternate Seed Mixture No. 1 will only be used in areas with slopes of <10:1 that are particularly susceptible to weed infestation. Additional optimal conditions for use of the alternative seed mix include locations with high moisture holding capacity and shelter from strong wind conditions. The Alternate Seed Mixture No. 2 has been proposed by BSB County and is an option for hand seeding grass-lined ditches and detention basins.

Calculations of pure “live seed” may be made on the basis of either a germination test or a tetrazolium test in addition to the purity analysis. Seed shall be applied on a pure “live seed” basis. The quantity of pure “live seed” in a 100-lb. container shall be determined by the formula: 100 multiplied by germination percentage, and this product multiplied by the purity percentage. For example, if the seed is 85 percent pure and test 90 percent germination, then a 100-lb. container would contain 76.5 pounds of pure “live seed”.

Fertilizer Application

If surface soil nutrient availability data are not available, fertilizer will be applied at a rate to achieve soil concentrations of 60 lbs. of nitrogen (N) per acre, 80 lbs. of P_2O_5 per acre, and 150 lbs. of K_2O per acre. Mechanical or hydraulic methods of application are allowed, providing a uniform application at the specified rate is accomplished. The application method is subject to approval by the RP Group. When scheduling and soil conditions permit, the fertilizer shall be incorporated into the soil by disking, raking, or shallow plowing to the full depth of the topsoil or to a maximum depth of six inches, whichever is less.

Fertilizer shall be applied to the prepared seedbed prior to seeding or mulching and shall be blended with the top layer of soil or concurrently with the seed (as “no-till” drills allow). Upon EPA approval, fertilizer may be applied subsequent to seeding and mulching. Re-fertilization following seedling establishment will not require incorporation. In no instance shall subsoil be incorporated into the seedbed as a result of the fertilization operation.

Mulch Application

Mulch is usually applied during the summer and early fall and drill seeded after October 15th. The mulch shall be applied in a uniform manner by a mulch spreader at rates varying from 2,000 to 4,000 lbs. per acre. The actual rate utilized shall depend upon site conditions (i.e., slope, erosion potential, etc.) and shall be approved by the RP Group and EPA prior to application. The mulch spreader shall be designed specifically for this type of work. The vegetative material shall be fed in the mechanical spreader at an even, uniform rate.

The mulch shall be anchored into the seedbed by using a mulch tiller (crimper). Straw or hay shall be clean grain straw and shall be pliable.

Mulch tillers shall have round, flat, notched blades of these approximate dimensions: 0.25-inch thick by 18 inches in diameter and spaced 8 inches apart. The tiller shall have sufficient weight to force the vegetative mulch a minimum of 3 inches into the soil and shall be equipped with disc scrapers. Mulch tilling shall be done on all slopes capable of being safely traversed by a tracked vehicle. All mulch tilling shall be done perpendicular of the flow-line of the slope.

Mulch, where required, will be applied to seeded areas as close as possible to the completion of seeding operations for the area. Mulch shall not be applied in the presence of free surface water, but may be applied upon damp ground.

Mulch shall not be applied to areas having a substantial vegetative growth, such as grasses, weeds, and grains. Areas not to be mulched shall be determined by the RP Group. Mulching shall not be done during adverse weather conditions or when wind prevents uniform distribution. Application shall be in a manner to not seriously disturb the seedbed surface.

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-04: Rock Cap Materials Testing

Revision 0

1.0 Objective

This Standard Operating Procedure (SOP) has been prepared to detail the process of testing rock cap material that is imported for use in the Railroads' Butte Reclamation Evaluation System (BRES) engineered rock caps. Results of the testing allow for the assurance that the material imported is in accordance with the U.S. Environmental Protection Agency's (EPA) guidance document *Butte Reclamation Evaluation System (BRES): Butte Priority Soils Operable Unit: Silver Bow Creek/Butte Area NPL Site* (BRES Guidance) (CDM 2006).

2.0 Background

The Railroads have a 4-year BRES program cycle described in Section A.5.2.1 of the Quality Assurance Project Plan (QAPP). Engineered rock cap inspections and evaluations are conducted in accordance with BRES Guidance (CDM 2006) to verify performance and to identify trigger items. Rock cap material testing will be conducted prior to materials used in the Railroads' BRES engineered rock caps being imported to ensure they meet project requirements. The specifications for the materials imported for use on the Railroads' BRES engineered rock caps originate from the Railroad Bed Time Critical Removal Action (TCRA), A1 Work Plan, dated December 2000. Attachment 1 of this SOP is a summary of the applicable technical specifications as they relate to the Railroads' BRES engineered rock caps.

3.0 Materials Descriptions

Type 2 rock – Riprap cover. Specified to conform to Montana Department of Transportation (MDT) Specification Section 701.06.2, Class I gradation, and consists of stone that is hard, durable, angular in shape, resistant to weathering and to water action, free from overburden, spoil, shale, structural defects, organic material, and meets appropriate gradation for random Type 2 riprap.

Type 3 rock – Rock cover, sometimes called ballast. Engineered covers of Type 3 rock consist of 0.5- to 3.0-inch material functioning as railroad ballast that meets the American Railway Engineers Association (AREA) 1996 copy of the AREA Manual for Railway Engineering.

Type 3A rock – Graded rock cover; 3-inch minus pit run material.

Type 4 – Cellular Confinement. Free draining, 1.5-inch minus material to be used as backfill for the cellular confinement slope stabilization system used on steep slopes.

Type 8 rock – Roadbase/parking lots; ¾-inch minus crushed rock/gravel.

4.0 Responsibilities and Execution

All field personnel performing the sampling described in this procedure are responsible for adhering to the tasks specified herein. The field personnel should have limited discretion with regards to collection procedures but should exercise their best judgment. All field personnel will be adequately trained by the Project Quality Assurance Manager (see Figure 1 of this QAPP). The responsibilities associated with the execution of testing, furnishing, and installing rock material used for the Railroads' engineered rock caps are detailed in Attachment 1 of this SOP.

5.0 Attachments

Attachment 1 – Furnishing and Installing Aggregate Material

6.0 References

CDM Smith Federal Programs Corporation. 2006. Butte Reclamation Evaluation System (BRES): Butte Priority Soils Operable Unit: Silver Bow Creek/Butte Area NPL Site.

SECTION 02060

FURNISHING AND INSTALLING AGGREGATE MATERIAL

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Summary
B. Submittals
C. References
D. Materials
E. Quality control
F. Source of materials
G. Borrow source grading/reclamation
H. Preparation for placement
I. Placement
J. Compaction
K. Site restoration
L. Field quality control

1.02 SUMMARY

A. Section Includes: Requirements for providing fill materials, borrow areas/sources of fill materials, and fill placement requirements for the following:
   1. Structural Fill
   2. Beneficial Fill
   3. Rock Cover (Type 3 Rock)
   4. Rip Rap (Type 2 Rock)

1.03 SUBMITTALS

A. Submit data sheets and test results from compliance testing of materials to the Engineer for review and approval.

1.04 REFERENCES

A. Sampling and Preparation:
   1. ASTM D75 - Standard Practice for Sampling Aggregates.
   2. ASTM D420 - Recommended Practice for Investigating and Sampling Soil and Rock.

B. Classification:
   1. ASTM D422 - Standard Method for Particle-Size Analysis of Soils.
   2. ASTM D2488 – Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

3. ASTM D4318 – Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

C. Density:
   1. ASTM D698 or AASHTO T99 – Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures, Using 5.5 lb. (2.49 Kg) Hammer and a 12 inch (304.8 mm) Drop.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Sources of materials acceptable for use on this project are as follows:
   1. Structural Fill: The following granular materials may be utilized for structural fill: 3.4-inch minus washed crushed gravel, standard 3.4-inch minus road mix or sandy gravel meeting the following gradation:

Structural Fill Gradation Option

Sieve Size	Percent Passing by Dry Weight
3-inch	100
No. 4	30-70
No. 200	0-12
Liquid Limit less than 25% and Plasticity less than 6	

   2. Structural fill is available from a number of local sources, subject to approval by the Engineer.

B. Beneficial Fill: Consists of cover soil previously approved for use by EPA currently stockpiled at BNSF's Lower Yard (as shown on Drawings). Material is suitable for use for construction of the stormwater control berm shown on Drawings.

C. Rock Cover (Type 3): 0.5 – 3.0-inch material functioning as railroad ballast material that meets the following gradation or as approved by the Engineer.

Sieve Size	Percent Passing
2.5”	100
2”	95-100
1.5”	35-70
1”	0-15
0.5”	0-5

   1. Type 3 rock previously approved for use by the EPA is available near Butte, Montana, from: Conda Mine located near Pipestone interchange on Interstate 90.

D. Rip Rap (Type 2): Furnish stone that is hard, durable, angular in shape, resistant to weathering and to water action, free from overburden, spoil, shale, structural defects, organic material, and shall meet the appropriate gradation for random rip rap. Source and gradation shall be submitted to the Engineer for approval 7 days prior to placement. Rip Rap shall conform to State of Montana, Department of Transportation (MDT) Specification Section 701.06.2, Class I gradation (https://www.mdt.mt.gov/other/webdata/external/const/specifications/2014/2014_stand_specs.pdf).

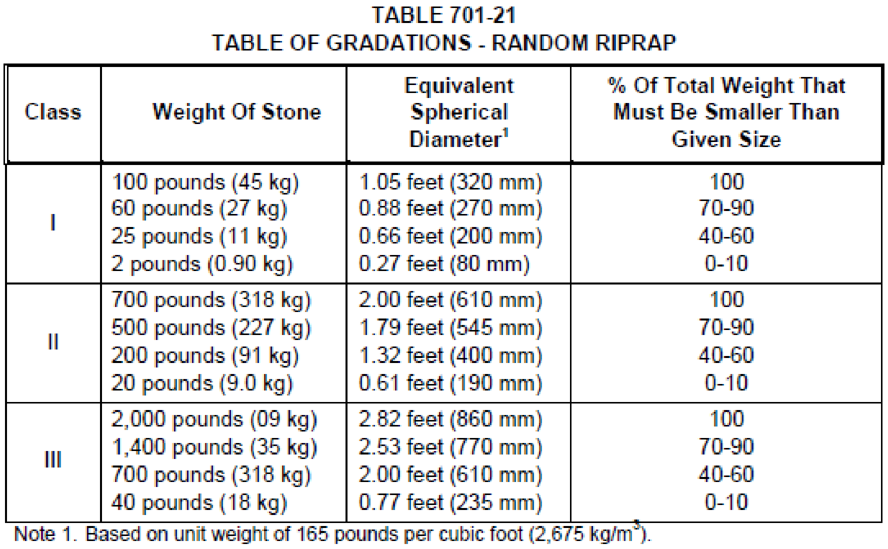


TABLE 701-21
TABLE OF GRADATIONS - RANDOM RIPRAP

Class	Weight Of Stone	Equivalent Spherical Diameter[1]	% Of Total Weight That Must Be Smaller Than Given Size
I	100 pounds (45 kg) 60 pounds (27 kg) 25 pounds (11 kg) 2 pounds (0.90 kg)	1.05 feet (320 mm) 0.88 feet (270 mm) 0.66 feet (200 mm) 0.27 feet (80 mm)	100 70-90 40-60 0-10
II	700 pounds (318 kg) 500 pounds (227 kg) 200 pounds (91 kg) 20 pounds (9.0 kg)	2.00 feet (610 mm) 1.79 feet (545 mm) 1.32 feet (400 mm) 0.61 feet (190 mm)	100 70-90 40-60 0-10
III	2,000 pounds (09 kg) 1,400 pounds (35 kg) 700 pounds (318 kg) 40 pounds (18 kg)	2.82 feet (860 mm) 2.53 feet (770 mm) 2.00 feet (610 mm) 0.77 feet (235 mm)	100 70-90 40-60 0-10

Note 1. Based on unit weight of 165 pounds per cubic foot (2,675 kg/m^3).

1. Riprap previously approved for use by the EPA was available near Butte, Montana, from: Conda Mine located near Pipestone interchange on Interstate 90.
2. A screen would need to be set up at the Conda (or Bernice) sources to screen riprap from the waste rock piles.
3. Alternative sources of riprap will require prior approval by the Engineer.

E. Graded rock cover (Type 3A): 3-inch minus pit run material.

F. Cellular Confinement (Type 4): Free draining, 1.5inch minus material to be used as backfill for the cellular confinement slope stabilization system to be used on steep slopes.

G. Parking Lots (Type 8): ¾-inch minus crushed rock/gravel.

2.02 ADDITIONAL REQUIREMENTS

A. In addition to gradation testing, structural fill source shall be sampled for RCRA 8 metals and results shall be submitted to Engineer prior to approval for import.

B. All Rip Rap shall conform to:
   1. Specific Gravity Requirements – Specific Gravity is a measure of the rock density
   2. (ASTM C127). The rock surface shall have a bulk specific gravity (saturated, surface dry) of 2.5 or greater.
   3. Absorption Requirements – Absorption is a measure of rock porosity (ASTM C127). The rock shall have an absorption value of 2 percent or lower.
   4. Los Angeles Abrasion Requirements – The Los Angeles Abrasion test is an indicator of hardness and structural soundness (ASTM C535). The rock shall have a test value of 35 percent or less for 500 revolutions.
   5. Sodium Sulfate Soundness Requirements – Sodium Sulfate Soundness test is an indicator of durability against disintegration (AASHTO T104-94). The rock shall have a test value of 12 percent loss or less for five cycles.

2.03 QUALITY CONTROL

A. Contractor is responsible to pay for and provide Compliance Quality Control Testing as identified below. The Owners' will pay for and provide for the services of a laboratory to provide Quality Assurance Testing during construction. The Quality Assurance testing will be random checks during construction for the benefit of the Owners' and should not be relied upon by the CONTRACTOR to ensure compliance with the Specifications. Contractor to rely on their Quality Control Plan to ensure compliance.

B. Tests and analyses of aggregate materials will be performed in accordance with applicable ASTM test methods, as listed under Part 1.05. The gradation testing method shall be ASTM D422.

C. If any tests indicate materials do not meet specified requirements, change material and retest at no cost to the Owners'.

D. Use a certified laboratory to determine material gradation as described in these specifications. All fill materials shall at a minimum be sampled for these analyses, unless otherwise stated herein by and at the expense of the Contractor.

PART 3 - EXECUTION

3.01 SOURCE OF MATERIALS

A. Contractor shall obtain aggregate materials from a licensed source, as approved by the Engineer.

3.02 PREPARATION FOR PLACEMENT

A. Identify required lines, levels, and contours.

B. Stake and flag locations of utilities.

C. Locate, identify, and protect utilities that remain from damage. Notify utility companies for utilities which may be affected by the work, or which cross the work area.

D. Protect benchmarks and existing structures from excavating equipment and vehicular traffic.

E. Conduct site grading and excavation (where applicable) per Section 02203 Site Grading and Excavation.

F. Compact subgrade or existing underlying fill to meet density requirements, where necessary due to over-excavation.

G. Cut out soft areas of subgrade or existing underlying fill that cannot be compacted as specified in paragraph E, above. Backfill with material type specified for subsequent fill, and compact to minimum density requirements for subsequent material as specified in Part 3.05.

3.03 PLACEMENT

A. Do not place the aggregate base before the subgrade is approved by the Engineer.

B. Spread the aggregate base material on the prepared subgrade by means of suitable spreading devices.

C. Segregation of large or fine particles of aggregate shall be avoided, and the material as spread shall be free from pockets of large and fine material.

D. Maintain positive surface drainage to avoid ponding of water on fill.

E. All surfaces upon or against which fill will be placed, including previously placed and compacted layers shall be clean of all objectionable materials, shall be moist but free of standing or ponded water.

F. Fill material requiring compaction shall not be frozen when placed. Material shall not be placed on ice or frozen material.

G. Install geotextile fabric (where specified) in accordance with Section 02277 Geotextiles.

H. Rip rap material shall not be placed until the surface has been prepared and approved. If specified, rip rap shall be placed on a prepared foundation of filter fabric (Section 02277) as shown on the Drawings. The material shall conform to the cross sections and profiles shown on the Drawings.

I. Rip rap material shall not be placed until the surface has been prepared and approved. If specified, rip rap shall be placed on a prepared foundation of filter fabric (Section 02277) as shown on the Drawings. The material shall conform to the cross sections and profiles shown on the Drawings. The stone shall be carefully handled and dumped to avoid material segregation. The rock shall be manipulated by hand or machine methods sufficiently to secure a regular surface and mass stability. Where the thickness of the rip rap is not shown on the Drawings, it shall be a least 6 inches measured perpendicular to the slope. Unless otherwise shown, rip rap shall extend from 2 feet below the toe of the slope to the elevation shown on the Drawings.

J. When rip rap is specified for placement around pipe openings or concrete structures, special care shall be taken in placing and handling. Manipulation of individual rocks during placement of rip rap shall be required as determined by the Engineer. Damage to pipe or structures shall be repaired or replaced at no expense to the Owners.

3.04 COMPACTION

A. Contractor shall add water or aerate material as required in placing compacted backfill to bring the material within 4% of optimum moisture content and 95% of the maximum dry density as determined by ASTM D698. The Contractor shall perform the necessary field test(s) to determine the *in situ* moisture content. The Contractor shall be responsible for determining moisture/density relationships of compacted backfill materials by supplying results of ASTM D698 to the Engineer.

3.05 POST-PLACEMENT GRADING

A. Grade all areas, including excavated, filled, and transition areas, to obtain the finished surface shown on Drawings. Finished surface shall be reasonably smooth, and free from irregular surface changes. Finished surfaces shall have positive drainage to minimize ponding of water.

3.06 SURFACE RESTORATION

A. Where surface restoration is not specified, the Contractor shall restore the work area to pre-construction conditions at no additional cost to the Owners.

3.07 FIELD QUALITY CONTROL

A. At the Engineer and Owners’ discretion, additional samples of fill materials may be taken to verify the sieve analyses data provided by the Contractor.

B. The Contractor and Engineer shall review and agree on layout locations for repair areas prior to beginning work. The Contractor and Engineer will review import and export quantities daily and agree upon payment quantities. Final compliance will be verified by the Owners’ representative. Contours and elevations not meeting the requirements of these Specifications shall be corrected at the Contractor's expense.

END OF SECTION

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-05: Backfill Material Testing

Revision 1

1.0 Objective

This Standard Operating Procedure (SOP) has been prepared to detail the process of selecting and testing backfill material that is imported for use in the Railroads' Butte Reclamation Evaluation System (BRES) caps.

2.0 Process and Responsibilities

Imported backfill must be pre-approved by EPA before it can be used onsite. The following specifications are required for backfill imported for use at the Railroads' BRES sites.

A. Location of Supplier.

B. Collect soil samples from the source material to be analyzed for applicable BPSOU solid media contaminants of concern (COCs): arsenic, lead, and mercury. In general, one five-point composite sample will be collected for every 400 cubic yards of backfill material. If large volumes of backfill material are needed, an alternative sample frequency may be adopted.

C. If the analytical data results show concentrations greater than the applicable BPSOU action levels, the engineer will reject the material, and the contractor will pursue a new source following the same acceptance criteria described above.

D. Analysis must be completed and reported prior to delivery of any material to BPSOU. Following the initial testing, additional testing is required if the coloration or odor of the imported material suggests that there may be, in the opinion of the Engineer, impacts in the imported material.

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-06: Sample Packaging, Shipping, and Custody

Revision 0

1.0 Objective

This guideline presents methods for shipping non-hazardous materials, including most environmental soil, sediment, and water samples, via United Parcel Service (UPS)and Federal Express. Many local laboratories offer courier service as well.

2.0 Equipment

- Coolers or ice chests
- Sorbent material
- Bubble wrap
- Zip ties
- Packing tape
- Labels and pens
- Chain-of-custody forms
- Chain-of-custody seals
- UPS or Federal Express shipping forms.

Samples shipped to the analytical laboratory can be sent via UPS or Federal Express on a next-day basis.

3.0 Procedures/Approach

1. Place absorbent pads in the bottom of the shipping container to absorb liquids in case of sample container breakage. Use one absorbent pad for each quart of liquid that is being shipped.

2. Wrap glass jars or bottles in plastic bubble wrap.

3. Leave a small amount of air space in any plastic sample container to prevent the cap from coming off if the container is compressed.

4. Choose a method of sample chilling that will not physically or chemically damage the collected samples. Reusable blue ice blocks, block ice, or ice cubes are acceptable methods. Use sufficient chilling material to keep the samples cool from the time of sample collection, throughout the sampling activities, and for the duration of the shipment (up to 48 hours) to the analytical laboratory. Samples should be chilled to 4 degree Celsius (ºC) ± 2 ºC.

5. Use waterproof pens and labels to identify the sample containers.

6. Band the cooler closed with strong adhesive tape and apply custody seals.

7. Cover the drain plug with adhesive tape to prevent any liquid from escaping.

8. Prior to shipping the samples, review the chain-of-custody form and bottle labels to check that the required entries are filled. Sign and date the chain-of-custody form and enter the time the samples are released to the shipping agency or analytical laboratory. When more than one chain-of-custody form is needed, they will be sequentially numbered.

9. If multiple coolers are needed for shipping a single batch of samples, one chain-of-custody form can be placed inside one cooler. However, a label should be attached to each cooler in the batch indicating the total number of shipping containers and which container contains the original chain-of-custody form.

10. Throughout the sampling activities and during transport to the analytical laboratory, the samples will be maintained in the secure custody of the sampling team, shipping agency, and/or analytical laboratory personnel. The sampling team will retain copies of all chain-of-custody forms. Original chain-of-custody forms will remain with the sample during storage, shipping, and analysis and will be forwarded with the final analytical reports to Kennedy/Jenks Consultants.

11. Original chain-of-custody forms will be enclosed in plastic and taped to the inside of the cooler lid.

APPENDIX B
Butte Priority Soils Operable Unit
SOP-BPSOU-07: Field Equipment Decontamination
Revision 0

1.0 Objective

This guideline describes field procedures typically followed by Kennedy/Jenks Consultants personnel during the decontamination of sampling and monitoring equipment. Proper decontamination procedures minimize the potential for cross-contamination among sampling points on a single site or between separate sites.

2.0 Equipment

- Two or three containers (e.g., 5-gallon buckets, or 5- or 10-gallon plastic tubs) for dip rinsing, washing, and collection of rinse water.
- Two or three utility brushes or test tube brushes for removal of visible contamination. A test tube brush (or similar) can be stapled to the end of a dowel and used to clean the inside of a bailer.
- Non-phosphate Alconox, Liquinox, or trisodiumphosphate (TSP) to be mixed with potable or distilled water.
- Rinse solutions, such as methyl alcohol (methanol), dilute nitric acid (0.1 molar), deionized or distilled water, and/or tap water. Deionized water is preferable to distilled water because the deionization process typically results in greater removal of organic compounds as discussed below:
    - Acid rinse (inorganic desorption) 10% nitric or hydrochloric acid solution reagent grade nitric or hydrochloric acid and deionized water (1% to be used for low carbon steel equipment).
    - Solvent rinse (organic desorption isopropanol, acetone, or methanol; pesticide grade).
    - Deionized water is preferable to distilled water because the deionization process typically results in greater removal of organic compounds.
- Multi-gallon storage containers filled with potable water to be used for rinsing or washing.
- Spray bottles, squirt bottles, or garden sprayers to apply rinse liquid. A separate bottle should be used for each liquid.
- Solvex or neoprene gloves that extend, as a minimum, halfway up the forearm. In cooler weather, it is advisable to use different resistant chemicals neoprene gloves that provide better insulation against cold temperatures.
- Paper towels to wipe off gross contamination.
- Garbage bags, or other plastic bags, and aluminum foil to wrap clean sampling equipment after decontamination, to store sampling equipment or and to dispose of decontamination debris.

- Sample bottles for rinsate blanks. For these blanks, Laboratory Type II (millipore) water should be used. Purified water from the selected analytical laboratory is recommended. This water is often filtered and boiled to remove impurities.

- DOT-approved container (e.g., 55-gallon drum) to store contaminated wash and rinse water. Contained decontamination should be labeled appropriately.

- Steamcleaner with power source and water supply.

3.0 Procedures/Approach

In most cases, the following procedures are adequate to remove potential contamination.

1. Preclean sampling equipment. If there is gross contamination on equipment, wipe it off with paper towels and/or rinse it off with water. Additional internal decontamination may be possible by circulation of water or cleaning solutions.

2. Wash all parts of equipment with detergent water and scrub with brushes. Take equipment apart when appropriate to remove visible contamination.

3. Rinse equipment by dipping in rinse solution, spraying, or pouring solution over it. Dip rinsing can introduce contaminants into solution. Spraying might not allow a thorough rinsing of the equipment, but it is a more efficient rinsing method because less rinse solution is used. Appropriate rinsing solutions are specified in the project sampling and analysis plan. Some typical solutions are indicated in the equipment section of this SOP.

    a. Methanol (used to remove organic compounds)

    b. Dilute acids (used to remove metals and other cations)

    c. Tap water

    d. Deionized/distilled water.

4. Rinse the sampler with generous amounts of deionized water. Pouring water over the sampler is best, although spraying or using a squirt bottle to apply rinse water might be adequate if you are trying to minimize waste.

5. Prepare rinsate blanks. To ensure proper decontamination, submit a rinsate blank for analysis. It is best to do this just before sampling. The blank should be analyzed for the same chemicals the samples are being checked for and for the chemical used to decontaminate equipment, if appropriate.

    To prepare a rinsate blank, pour millipore analyte-free water through or over the sampler. Collect the rinsate water in a clean bottle. Pour the collected rinsate water into the appropriate sample container(s). It is advisable to prepare one rinsate blank every day in the field. Use water specifically for blank preparation.

6. Wipe sampling equipment with a paper towel or allow it to air dry.

7. Place samplers in clean plastic bags or sealed containers, or wrap them in aluminum foil for storage in an undisturbed location that is free of contamination.

4.0 Special Notes

- To reduce the potential for cross-contamination, samples should be collected so that the least contaminated stations areas are sampled first. Subsequent sampling should be completed in the order of increasing contamination. Areas that typically have lower levels of contamination include those upgradient of source, background areas, and the periphery of the contaminated area.

- Prepare rinsate blanks. To ensure proper decontamination, submit a rinsate blank for analysis. It is best to do this just before sampling. The blank should be analyzed for the same chemicals the samples are being checked for and for the chemical used to decontaminate equipment, if appropriate.

- To prepare a rinsate blank, pour analyte-free water through or into the sampler. Pour the collected rinsate water into the appropriate sample container(s). It is advisable to prepare one rinsate blank every day in the field. Use water specifically for blank preparation.

- Monitoring instruments that come into contact with sampled materials must be decontaminated, along with sampling devices. They should be washed, or at least rinsed before monitoring other sampling sites.

- As determined from analysis of rinsate blanks, decontamination using soap and water is adequate in removing detectable quantities of contaminants. This type of decontamination has been compared to laboratory procedures for decontaminating sampling bottles. Using methanol as a rinse does help in cases of contamination with organic compounds.

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-08: Sample Collection from Excavations and Hand Dug Pits

Revision 1

1.0 Objective

This guideline describes the equipment and procedures typically used by Kennedy/Jenks Consultants personnel for collecting samples from excavations and hand dug pits.

2.0 Equipment

- Backhoe with 24-inch bucket (supplied by contractor)
- Shovel
- Stainless steel scoop
- Split spoon drive sampler with brass liners, drive rod and sliding hammer.
- Rubber mallet
- Stakes
- Measuring tape
- Appropriate sample containers with labels
- Field Notebook
- Hand trowel
- Decontamination supplies.

3.0 Procedures/Approach

1. Stake the test pit location(s).

2. Identify overhead obstructions and underground utilities which may interfere with the backhoe excavation.

3. The decontaminated backhoe will excavate the test pit to the desired depth. The excavated material will be placed on plastic sheeting adjacent to the excavation.

4. Relatively undisturbed material will be removed by the backhoe and brought to the surface for sampling. The sample will be collected by either driving a split spoon sampler into the unearthed material, driving a brass liner with a rubber mallet into the material, or by collecting a representative sample using a stainless-steel scoop. In either case, the sample will be collected in such a way as to minimize headspace in the sample container.

5. If the test pit is being sampled directly, Excavate the hole to 0-2 inches, 2-6 inches, and 6-12 inches below ground surface and collect a sample from each interval separately. Collect a sample from the freshly cleaned interval with the scoop by scraping from the base of the interval to the top of the interval removing material evenly from all around.

6. The physical and lithologic conditions of the test pit will be logged in the field notebook.

7. If buried objects are encountered (such as tanks or drums) which could result in a release of contaminated material, the excavation will be left open and secured to warn of the potential danger. A specific remedial action plan will be developed which will address the specific concerns at that location.

8. If no potential contamination sources (drums or tanks) are identified and there are no visible indications of contamination, the excavation will be backfilled with the material removed in the opposite sequence in which it was removed.

9. The backhoe or shovel and sampling equipment will be decontaminated prior to reuse.

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-09: Surface Soil Sampling

Revision 0

1.0 Objective

This guideline describes the procedures typically used by Kennedy/Jenks Consultants personnel to collect surface soil samples from 0 to 2 feet below ground surface (bgs) (DEQ 2003).

2.0 Equipment

- Stainless steel or plastic scoops.
- Stainless steel digging tool (such as a rock hammer).
- Stainless steel or plastic mixing bowls.
- Hand auger, slide-hammer, or powered sampling device.
- Split-spoon or similar drive sampler.
- Shovel.
- Posthole digger.
- Pick.
- Breaker bar.
- Measuring tape and/or measuring wheel.
- Stakes, flagging, or spray paint to mark sampling locations.
- Sample containers (laboratory-supplied).
- Sample labels, pens, and field logbook or other appropriate field forms (e.g., boring logs).
- Equipment decontamination supplies.
- Sample shipping and packaging supplies.
- Personal protective equipment as specified in Facility-Wide Health and Safety Plan (HASP).

3.0 Procedures/Approach

1. Mark sampling locations as necessary. If sampling locations are based on a grid pattern, use stakes, flagging, or spray paint to define the grid layout.
2. Clear sample locations for underground utilities and structures by notifying Montana’s one-call notification center (1-800-424-5555) (required) at least 2 but not more than 10 business days prior to commencement of field activities. In addition, contact knowledgeable site operations personnel and use a private utility locator service (if necessary) to identify possible underground utilities.
3. Collect soil samples for chemical analysis using the appropriate sampling device.
4. Classify the soils in general accordance with the visual-manual procedure of the Unified Soil Classification System (ASTM D 2488-90). The Munsell Color Classification may also be used.

5. Transfer soil directly from the sampling device to the appropriate sample container.
6. If compositing samples, place approximately equal volumes of soil from each sub-sampling location into a pre-cleaned mixing bowl. Mix soils thoroughly.
7. Place soil into the appropriate sample containers for the analyses being conducted. Fill the sample container and compact the soil to minimize head space. Minimize handling of the soil.
8. Place a completed sample label on the sample container.
9. Follow sample packaging and shipping procedures.
10. Follow equipment decontamination procedures.

4.0 Quality Control

Follow the quality control requirements specified in this Quality Assurance Project Plan (QAPP).

5.0 Investigation-Derived Waste

Investigation-derived waste (IDW), including decontamination wastes, must be contained and properly handled and disposed.

6.0 References

Montana Department of Environmental Quality. 2003. Montana Tier 1 Risk-Based Corrective Action Guidance for Petroleum Releases. October 2003. Montana Department of Environmental Quality, Remediation Division, Helena, Montana.

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-10: Handling and Disposing of Investigation-Derived Waste

Revision 0

1.0 Background

Environmental site investigations usually result in generation of some regulated waste, particularly if the project involves drilling and construction of monitoring wells. Any potentially hazardous or dangerous material that is generated during a site investigation must be handled and disposed of in accordance with applicable regulations (22 CCR, Chapter 30). This guideline provides a procedure to be used for dealing with investigation-derived wastes that have the potential of being classified as hazardous or dangerous, including soil cuttings, well development water, and decontamination water.

2.0 Equipment

- Department of Transportation (DOT)-approved packaging (typically DOT 17E or 17H drums) or other appropriate containers
- Funnel
- Bushing wrench
- 15/16-inch socket wrench
- Shovel
- Appropriate markers (spray paint, paint pen) and labels
- Plastic sheeting
- Drip pans
- Pallets
- Personal protective equipment as specified in Facility-Wide Health and Safety Plan (HASP) and associated task-specific HASP addenda.

3.0 Procedures/Approach

Preparing Containers

1. Place each container on a pallet if it is to be moved with a forklift after it is full.
2. Ensure that packaging materials are compatible with the wastes to be stored in them. Bung-type drums should be used to contain liquids. If a liquid is corrosive, a plastic or polymer drum should be used.
3. Solids should be placed in open-top drums. Liners are placed in the drums if the solid material is corrosive or contains free liquids (other than water). Gaskets are also used on open-top drum lids.

Known or Assumed Non-Hazardous Wastes

1. As waste materials are generated, place them directly into storage containers. Alternatively, depending on quantity, soils may be contained onsite on plastic sheeting

and covered pending analytical results. In certain instances, if it is known the IDW is not hazardous, it can be disposed of onsite (e.g., dispose the purge water on the ground, place soils back into test pits).

2. If the IDW is placed into a container, do not fill storage containers/drums completely. Provide sufficient space so that containers will not be overfull if their contents expand.
3. After filling a storage container/drum, seal it securely. Use a bung wrench or socket wrench, for a bung-type or open-top drum, respectively.
4. Label the container as to its content including date and origin/location.
5. If it is known that the IDW is not hazardous, arrange for disposal of the IDW as a solid waste.
6. If no information exists as to determine whether the IDW is hazardous (e.g., records, analytical results, of other knowledge of the IDW properties), the IDW must be profiled to determine disposal options.
7. To profile the waste:
   a. Contact the proposed disposal facility to obtain the type of information the disposal facility will need before accepting the IDW, including necessary analytical data. Note: The disposal facility will rely on you to provide information regarding the types of constituents that may be present in the IDW.
   b. If analytical data are needed, collect a sample or samples of the IDW and submit to an analytical laboratory.
8. Upon receiving the analytical results, arrange for the proper disposal of the IDW.

Hazardous Wastes

1. As waste materials are generated, place them directly into storage containers.
2. Do not fill storage containers/drums completely. Provide sufficient space for expansion.
3. After filling a storage container/drum, seal it securely. Use a bung wrench or socket wrench, for a bung-type or open-top drum, respectively.
4. Label drums or other packages containing hazardous waste. To comply with marking and labeling requirements, affix a properly filled out yellow hazardous waste marker. Do not mark drums with Kennedy/Jenks Consultants' name. All waste belongs to the client. Include the accumulation start date on the label.
5. During an ongoing investigation, use a paint marker to mark the contents, station number, date, and approximate quantity of material on each drum or other container.
6. Do not mix IDW with one another or with other materials. Do not place items such as Tyvek® suits, gloves, equipment, or trash into drums containing soils or liquids, and do not mix water and soil. Disposable protective clothing, trash, soil, and water materials should be disposed of in separate containers.
7. Place the containers in a secured area equipped with a secondary containment system, if appropriate.
8. While storing the IDW, the substantive standards in 40 Code of Federal Regulation (CFR) Parts 264 and 265 Subparts I and J or State equivalent must be complied with.

9. Dispose the IDW upon completion of the field work, or incorporate the IDW into the remedial action upon initiation of the final remedy. If the IDW will be disposed offsite, the IDW will need to be manifested for transportation in accordance with federal or state requirements. Prior to offsite shipment/disposal of IDW, a notification letter will be submitted to the Montana Department of Environmental Quality (DEQ) as outlined in Section 8.4 of the *Facility-Wide Sampling and Analysis Plan*.

   Note: DEQ has specified the following time limitations for storage of the various types of IDW:

   - F-listed hazardous IDW may be stored onsite for up to 2 years
   - Non-hazardous IDW may be stored onsite for up to 1 year.

   Storage limits for potential hazardous IDW other than F-listed waste shall be determined by DEQ based in the nature of the waste.

4.0 Reference

Montana Department of Environmental Quality. (Undated). Technical Guidance Document #10 - Options for Discharge of Hydrocarbon-Contaminated Wastewater. Montana Department of Environmental Quality, Remediation Division, Petroleum Release Section, Helena, Montana.

APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-11: Global Positioning System (GPS) Coordinate Collection and Handling

Revision 1

1.0 Objective

This guideline presents methods for using a sub-meter global navigation satellite system (GNSS) receiver paired with an Apple iPad tablet (or equivalent) running ArcGIS Collector software for field planning and field data collection activities. The GNSS receiver to be used is the EOS Arrow 100 receiver (or equivalent). The iPad/GNSS Receiver with ArcGIS Collector software (collectively herein termed the iPad/ArcGIS setup) will be used as an alternative to a traditional Trimble GPS with TerraSync or GPS Pathfinder Office software.

2.0 Definitions

ArcGIS Collector – App that runs on iPad for collecting location data, uploading collected data, and viewing pre-loaded basemaps and collected data. This is the software through which BPSOU Collector Map runs.

EOS Tools Pro – App that runs on iPads used to monitor the signal quality and accuracy the EOS Arrow 100 global navigation satellite system (GNSS) receiver is receiving. Also allows user to set alarms to notify the user if accuracy falls below a set level.

3.0 Discussion

Field data will have a latitude and longitude coordinate representing their location using the iPad/ArcGIS setup. All field personnel will be trained to collect GPS data using the iPad/ArcGIS setup and will be familiar with the contents of the BPSOU Collector Map.

4.0 Equipment, Software, and Configuration

Location coordinate data collection will take place using an iPad running ArcGIS Collector connected to an EOS Arrow 100 GNSS receiver. As discussed, this setup will be an equivalent alternative to the Trimble unit and associated software.

Figures 1 and 2 show comparable specifications for an EOS Arrow 100 GNSS receiver (Arrow receiver) and a Trimble GPS meeting the CDM-Libby-09 specifications. The real-time position correction of the Arrow receiver eliminates the need for data post processing, as compared to the post processing steps associated with the Trimble GPS and GPS Pathfinder Office. Additionally, the iPad's Collector application allows for a single step data upload process from collection to storage of the data on an ArcGIS server.

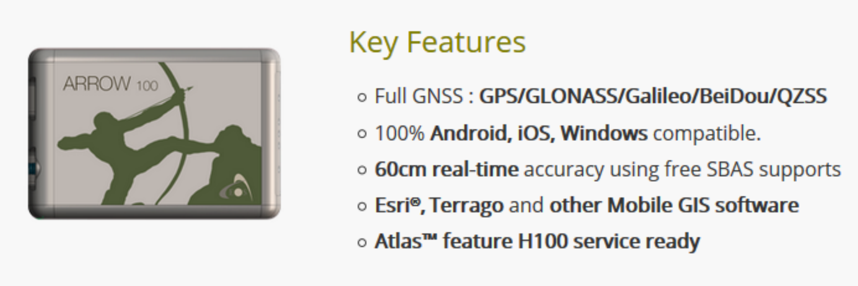
APPENDIX B

Butte Priority Soils Operable Unit

SOP-BPSOU-11: Global Positioning System (GPS) Coordinate Collection and Handling

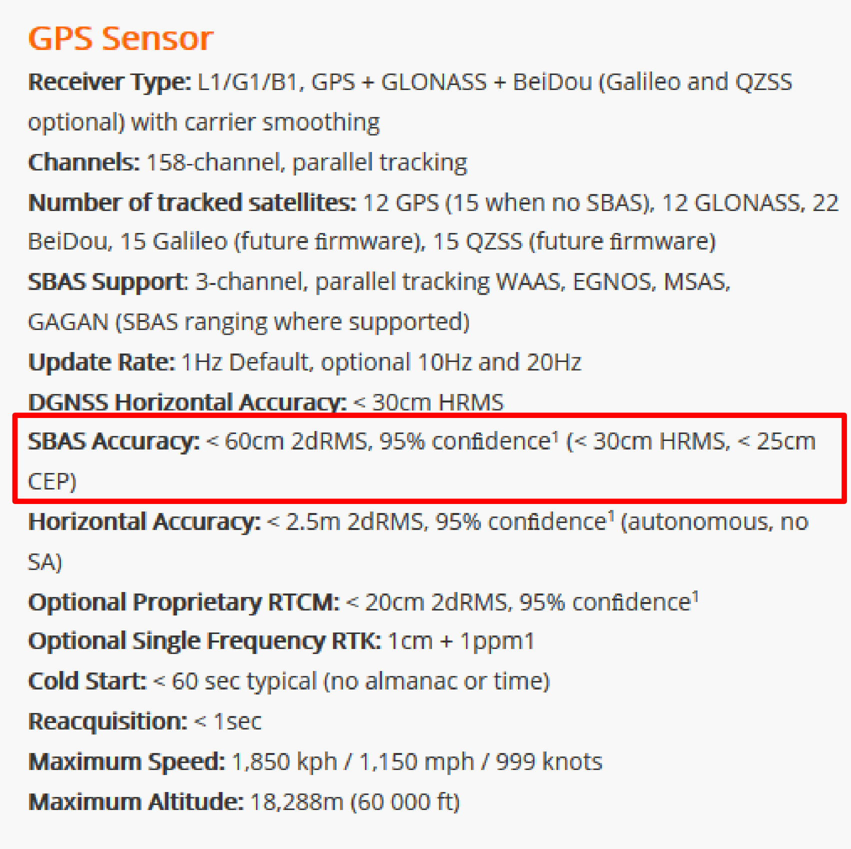
Revision 1

Figure 1: EOS Arrow 100 GNSS Receiver Specifications



Key Features

- Full GNSS : **GPS/GLONASS/Galileo/BeiDou/QZSS**
- 100% **Android, iOS, Windows** compatible.
- **60cm real-time** accuracy using free SBAS supports
- **Esri®, Terrago** and **other Mobile GIS software**
- **Atlas™ feature H100 service ready**



GPS Sensor

Receiver Type: L1/G1/B1, GPS + GLONASS + BeiDou (Galileo and QZSS optional) with carrier smoothing

Channels: 158-channel, parallel tracking

Number of tracked satellites: 12 GPS (15 when no SBAS), 12 GLONASS, 22 BeiDou, 15 Galileo (future firmware), 15 QZSS (future firmware)

SBAS Support: 3-channel, parallel tracking WAAS, EGNOS, MSAS, GAGAN (SBAS ranging where supported)

Update Rate: 1Hz Default, optional 10Hz and 20Hz

DGNSS Horizontal Accuracy: < 30cm HRMS

SBAS Accuracy: < 60cm 2dRMS, 95% confidence[1] (< 30cm HRMS, < 25cm CEP)

Horizontal Accuracy: < 2.5m 2dRMS, 95% confidence[1] (autonomous, no SA)

Optional Proprietary RTCM: < 20cm 2dRMS, 95% confidence[1]

Optional Single Frequency RTK: 1cm + 1ppm1

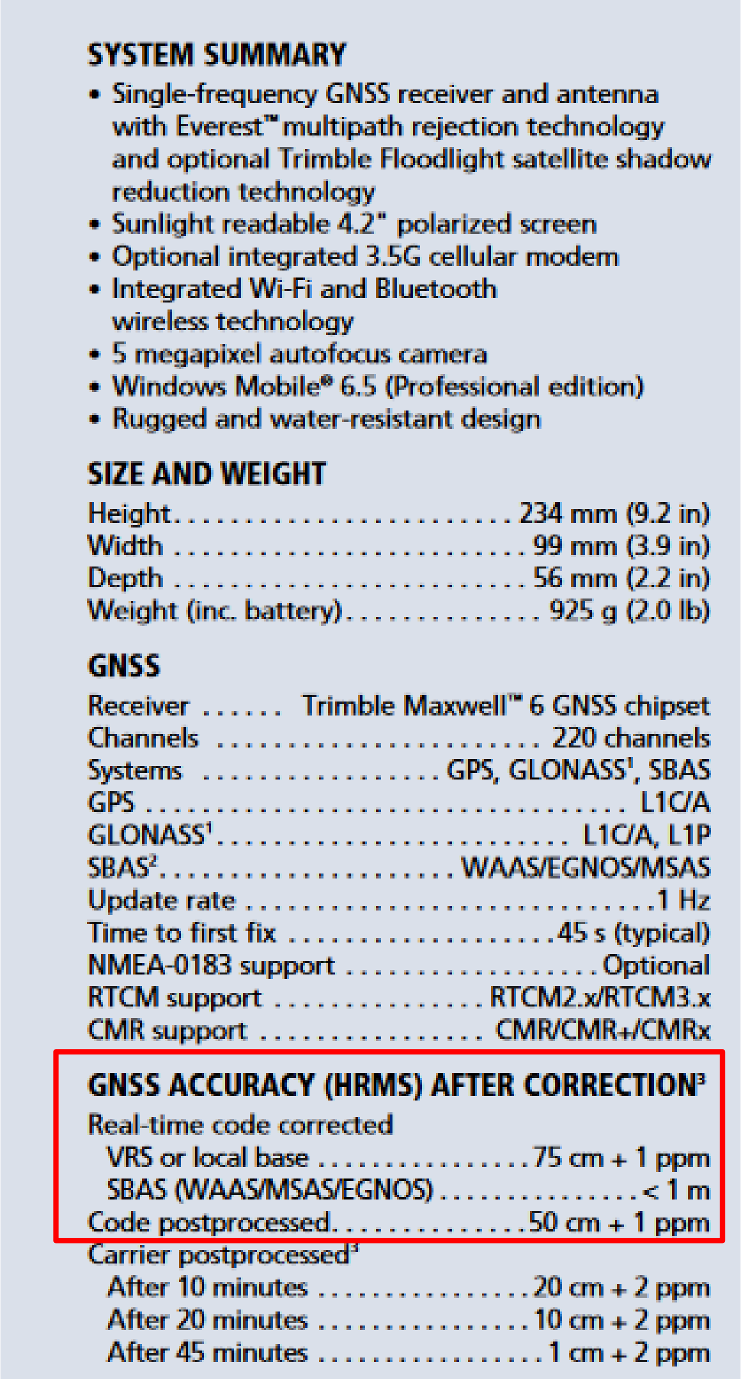
Cold Start: < 60 sec typical (no almanac or time)

Reacquisition: < 1sec

Maximum Speed: 1,850 kph / 1,150 mph / 999 knots

Maximum Altitude: 18,288m (60 000 ft)

Figure 2: Trimble GPS GeoXT Specifications



SYSTEM SUMMARY

- Single-frequency GNSS receiver and antenna with Everest™ multipath rejection technology and optional Trimble Floodlight satellite shadow reduction technology
- Sunlight readable 4.2" polarized screen
- Optional integrated 3.5G cellular modem
- Integrated Wi-Fi and Bluetooth wireless technology
- 5 megapixel autofocus camera
- Windows Mobile® 6.5 (Professional edition)
- Rugged and water-resistant design

SIZE AND WEIGHT

Height	234 mm (9.2 in)
Width	99 mm (3.9 in)
Depth	56 mm (2.2 in)
Weight (inc. battery)	925 g (2.0 lb)

GNSS

Receiver	Trimble Maxwell™ 6 GNSS chipset
Channels	220 channels
Systems	GPS, GLONASS[1], SBAS
GPS	L1C/A
GLONASS[1]	L1C/A, L1P
SBAS[2]	WAAS/EGNOS/MSAS
Update rate	1 Hz
Time to first fix	45 s (typical)
NMEA-0183 support	Optional
RTCM support	RTCM2.x/RTCM3.x
CMR support	CMR/CMR+/CMRx

GNSS ACCURACY (HRMS) AFTER CORRECTION[3]

Real-time code corrected	
VRS or local base	75 cm + 1 ppm
SBAS (WAAS/MSAS/EGNOS)	< 1 m
Code postprocessed	50 cm + 1 ppm
Carrier postprocessed[3]	
After 10 minutes	20 cm + 2 ppm
After 20 minutes	10 cm + 2 ppm
After 45 minutes	1 cm + 2 ppm

5.0 Procedures

The following sections describe how GPS points are collected and handled for features at BPSOU.

5.1 Operation of GPS/Tablet Handheld Units

GPS points at BPSOU will be collected using iPad tablets connected to an EOS Arrow 100 GNSS receiver unit. Equivalent GNSS receivers or tablets capable of running ArcGIS Collector may be used. Operators must be standing at the sample location before collecting the position data. All operators will be proficient at using the iPad, EOS Arrow 100 GNSS receiver, the ArcGIS Collector app, and the EOS Tools Pro app.

6.0 Accuracy Criteria

The EOS Tools Pro app (Figure 3) will be used to continuously monitor GPS signal quality and to verify the horizontal accuracy remains within 5 meters, in order to comply with U.S. Environmental Protection Agency (EPA) Policy CIO 2131.0 National Geospatial Data Policy, Tier 2 standards (EPA 2005). The EOS Tools Pro app provides an H RMS value which is the horizontal position accuracy. Per the manufacturer, multiplying the H RMS value by two yields the 95% confidence level for the horizontal position.

An alarm (Figure 4) will be used to warn the operator anytime the position accuracy is outside the EPA-required 5 meters with 95% confidence. Specifically, the alarm will be set to an alarm of 2 meters so the operator will know that the data being collected is at or under 4 meter accuracy with 95% confidence. If the alarm goes off, the operator will reboot the iPad and receiver, and re-establish satellite connection and position accuracy.

Figure 3: EOS Tools Pro App Position Screenshot

Fix: DGPS

UTC Time: 19:37:05.00

Latitude: 46.59315413
Longitude: -112.03441212
Ellip. Height: 1223.094

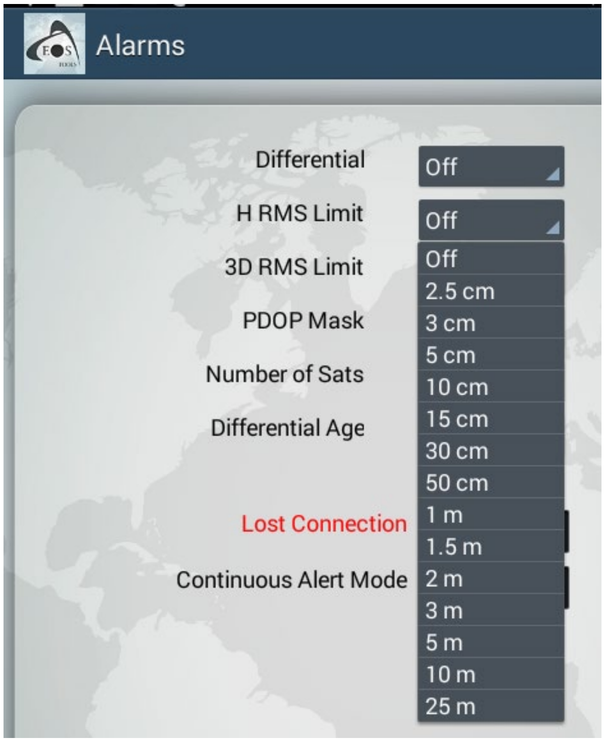
H RMS: 0.292
V RMS: 0.588
3D RMS: 0.656

Speed: 0.1
Heading: 339.7
Mode: 3D

SATS in View: 23
SATS Used: 11
PDOP: 2.2

Diff Status: DGPS
Diff Age: 7.0
Diff Station ID: 0138

Figure 4: EOS Tools Pro App Alarm Screenshot



Alarms

Differential: Off
H RMS Limit: Off
3D RMS Limit
PDOP Mask
Number of Sats
Differential Age
Lost Connection
Continuous Alert Mode

Recordkeeping Requirements

Serial numbers of the EOS Arrow 100 GNSS receiver unit, iPad, and antenna will be recorded in a field logbook.

Upgrades to GPS Equipment and Software

Hardware and software are subject to change according to availability and/or application updates. The Team Leader (TL) or designee is responsible for contacting the technical support of the vendor if there are any questions regarding setup, operation, or data transfer of models not previously used at OU6.

6.1 GPS Data Transfer from Handheld Units

iPad units connect to the ArcGIS server using Wi-Fi or a cellular data network. The tablets will use the Collector app in online mode where all data collected are live-updated on the server. This will allow the QA Manager to review project geographic data as it is collected.

6.2 GPS Data Processing

Data is uploaded from the Collector app to the ArcGIS server. All differential correction is done at the time of collection. Continually monitoring the GPS signal position accuracy using the EOS Tools Pro alarm feature ensures that all position data are within EPA's required 5 meters with 95% confidence.

6.3 GPS Data Transfer

Features are exported from the ArcGIS server into an ESRI shapefile format in the WGS84 Datum.

7.0 Quality Assurance/Quality Control (QA/QC)

All GPS data points are visually reviewed and verified during collection and after uploading.

Visual review involves verifying points as they are collected based on GPS position and using aerial imagery base maps. Secondary review takes place using the uploaded data in a geographic information system (e.g., ArcMap), by the TL. Mapped points are viewed to ensure they represent the expected area at the expected property or BNSF MP. Points with obvious errors are omitted and/or recollected.

Verification involves comparing data attributes against EPA-established accuracy criteria, which is performed by onsite data management staff during the data collection process by continually monitoring the position accuracy of the GNSS unit.

Appendix C

BRES Evaluation Field Forms

Site ID		**Site Name**	
Design Thickness		**CAPTYPE**	
Inspection Date		**Team Members**	
Checked by:			

Type of rock		**Measured ave. thickness**	
Surface staining	Y/N	**Stain pattern/color**	
Displaced rock	Y/N	**Pattern of displacement**	
Apparent cause of displacement			
Does rock cap have geotextile liner?	☐	**Condition of liner**	
Exposed subgrade materials?	☐	**Describe exposed subgrade**	
Maintenance conducted during inspection?	☐	**Maintenance performed**	
Post-inspection corrective action required?	☐	**Describe proposed action**	

Comments

Site ID		Site Name	
Team Members			
Inspection Date		Checked by:	

Corrective Action Plan Required for

Vegetation (% live)	Y/N	Erosion (BLM score)	Y/N		
Site Edges	Y/N	Exposed Waste	Y/N	Land	Y/N
Barren Areas	Y/N	Gullies	Y/N		

Vegetation % of ground covered by

Live (desirable) species	
*Undesirable (weedy) species	
*Noxious weeds	
Litter	
Rocks > 2"	
Bare Ground	
TOTAL	
ADJUSTED LIVE %	

Erosion (BLM Form)

Surface Litter	
Surface Rock Movement	
Pedestalling	
Flow Patterns	
Rills Depth	
Rills Frequency	
Gullies Depth	
Gullies Frequency	
Soil Movement	
Total BLM Score	

Site Edges

Are outer edges of the site significantly different thanremainder of site ☐

☐ Lime Rock Barrier

☐ More Weeds

☐ Increased Erosion

☐ Gullies

☐ Depositional Area

☐ Steeper Slope

☐ Less Vegetation

Other

Estimated Width of edge (ft.)

Exposed Waste Material

Is there Exposed Waste Material ☐

Approximate Area in square feet

Number Of Areas With Exposed Waste

Soil Condition

bulk soil failure ☐

land slumps ☐

subsidence ☐

Barren Areas

Is there barren areas ☐

Number of barren areas

Do areas cover over 25% of polygon ☐

Gullies

Are there gullies over 6" in depth? ☐

Are any gullies actively eroding? ☐

Number of gullies

Species Present

Dominant Species	
Frequent Species	
Infrequent Species	

Weeds Present

Dominant Weeds	
Frequent Weeds	
Infrequent Weeds	

Site ID		Site Name	
Team Members			
Inspection Date		Checked by:	

Corrective Action Plan Required for

Vegetation (% live)		Erosion (BLM score)			
Site Edges		Exposed Waste		Land	
Barren Areas		Gullies			

Comments

Appendix D

Stormwater Best Management Practices Evaluation Field Forms

APRON – ENERGY DISSIPATER
INSPECTION AND MAINTENANCE FORM

Structure GIS Code: _________________

Type: _________________

Outlet to apron: _________________

Apron discharges to: _________________

Annual Inspection
Completed By: ___________________________ **Date:** ___________________________

Maintenance Inspection
Completed By: ___________________________ **Date:** ___________________________

Property Classification: On-track Off-track Non-Railroad

Material: Concrete Riprap Concrete set riprap

Inspection			**Notes:**
Sediment/Trash present	Y	N	
Oily Residue present	Y	N	
Rocks missing	Y	N	
Rock diameter possibly too small	Y	N	
Sediment from pipe present	Y	N	
Erosion or scouring present	Y	N	
Damaged (describe)	Y	N	
Other (describe)	Y	N	
Maintenance			
Remove trash, debris or sediment	Y	N	
Determine cause of soil erosion	Y	N	
Replace rocks	Y	N	
Other (describe)	Y	N	

APRON – ENERGY DISSIPATER
INSPECTION AND MAINTENANCE FORM

Sketches or comments, if necessary:

BERM
INSPECTION AND MAINTENANCE FORM

Structure GIS Code: ___________________

Type: ___________________

Annual Inspection
Completed By: ____________________________ **Date:** ____________________________

Maintenance Inspection
Completed By: ____________________________ **Date:** ____________________________

Property Classification: On-track Off-track Non-Railroad

Surface Material Type: Barren Grass Riprap Rock

Inspection			**Notes**
Evidence of trash, or pollution (oil, gas or illicit discharge)	Y	N	
Evidence of noxious weeds or vegetative growth	Y	N	
Signs of erosion / scour	Y	N	
Sediment accumulation > 6-inches or preventing flow	Y	N	
Missing areas of vegetation or rock cover	Y	N	
Other (describe)	Y	N	
Maintenance			
Remove trash, determine source of illicit discharge	Y	N	
Remove nuisance, obstructive vegetation	Y	N	
Determine cause of soil erosion	Y	N	
Remove sediment accumulation	Y	N	
Regrade berm	Y	N	
Replace/reseed vegetation	Y	N	
Replace/repair rock cover	Y	N	
Other (describe)	Y	N	

BERM
INSPECTION AND MAINTENANCE FORM

Sketches or comments, if necessary:

DITCH
INSPECTION AND MAINTENANCE FORM

Structure GIS Code: ___________________

Type: ___________________

Annual Inspection
Completed By: ____________________________ **Date:** ____________________________

Maintenance Inspection
Completed By: ____________________________ **Date:** ____________________________

Property Classification: On-track Off-track Non-Railroad

Surface Material Type: Barren Grass Riprap Rock

Inspection			**Notes**
Evidence of trash, or pollution (oil, gas or illicit discharge)	Y	N	
Evidence of noxious weeds or vegetative growth/obstruction in channel	Y	N	
Soil erosion / scour	Y	N	
Sediment accumulation > 6-inches or preventing flow	Y	N	
Concrete deterioration or rip rap voids	Y	N	Riprap apron Y N
Other (describe)	Y	N	
Maintenance			
Remove trash, determine source of illicit discharge	Y	N	
Remove nuisance, obstructive vegetation	Y	N	
Determine cause of soil erosion	Y	N	
Remove sediment accumulation	Y	N	
Regrade flowline	Y	N	
Replace/repair/clear out inlet or outlet	Y	N	
Replace/ repair concrete or rip rap	Y	N	
Other (describe)	Y	N	

DITCH
INSPECTION AND MAINTENANCE FORM

Sketches or comments, if necessary:

INLETS, MANHOLES, AND COMBINATION MANHOLE/INLETS INSPECTION AND MAINTENANCE FORM

Structure GIS Code: ___________________

Type: ___________________

Annual Inspection
Completed By: ____________________________ **Date:** ____________________________

Maintenance Inspection
Completed By: ____________________________ **Date:** ____________________________

Property Classification: On-track Off-track Non-Railroad

Inspection			**Notes:**
Lid openings plugged with debris/sediment	Y	N	
Lid cracked, worn or structurally damaged	Y	N	
Pipe plugged more than 30%	Y	N	
Catch basin more than 1/3 full with sediment	Y	N	
Vertical Structure structurally damaged	Y	N	
Other (describe)	Y	N	
Maintenance			
Remove debris/sediment from lid	Y	N	
Replace lid	Y	N	
Jet/Vac pipe inverts/sump	Y	N	
Clean catch basins if more than 1/3 full of sediment to maintain sediment-trapping capabilities	Y	N	
Replace vertical structure	Y	N	
Other (describe)	Y	N	

Number of inflow pipes: Direction: N E W S

INLETS, MANHOLES, AND COMBINATION MANHOLE/INLETS INSPECTION AND MAINTENANCE FORM

Sketches or comments, if necessary:

STORMWATER CONVEYANCE PIPE/CULVERT INSPECTION AND MAINTENANCE FORM

Structure GIS Code: ________________

Type: ________________

Pipe from inlet: ________________

To outlet: ________________

Annual Inspection Completed By: __________________________ **Date:** __________________________

Maintenance Inspection Completed By: __________________________ **Date:** __________________________

Inspection			**Notes**
Sediment/debris in pipe	Y	N	
Length of pipe as measured with wheel above ground			___________feet
Length of pipe CCTV inspected			___________feet
Length of pipe unable to be inspected			___________feet
CCTV log attached	Y	N	
Other (describe)	Y	N	
Maintenance			
Sediment/debris removed from pipe	Y	N	
Entire length of pipe jetted	Y	N	
Hours required to jet and remove sediment			___________hours
CCTV log attached	Y	N	
Other (describe)	Y	N	
Localized Rehabilitation			
Pipe replaced by excavation	Y	N	
CIPP Spot Repair	Y	N	
Other (describe)	Y	N	

STORMWATER CONVEYANCE PIPE/CULVERT INSPECTION AND MAINTENANCE FORM

Sketches or comments, if necessary:

SEDIMENT BASIN
INSPECTION AND MAINTENANCE FORM

Structure GIS Code: ___________________

Type: ___________________

Annual Inspection
Completed By: ____________________________ **Date:** ____________________________

Maintenance Inspection
Completed By: ____________________________ **Date:** ____________________________

Property Classification: On-track Off-track Non-Railroad

Pond Liner: HDPE Unlined

Scoring Breakdown

N/A = Not Applicable	**1 = Monitor (potential for future problem exists)**	*** Use open space in each section to further explain scoring as needed**
N/I = Not Investigated	**2 = Routine Maintenance Required**	
0 = Not a Problem	**3 = Immediate Repair Necessary**	

Overflow Structure

Outfall/spillway channel functioning	N/A	N/I	0	1	2	3
Manholes, Frames and Covers	N/A	N/I	0	1	2	3
Released water undercutting outlet	N/A	N/I	0	1	2	3
Erosion	N/A	N/I	0	1	2	3
Displaced rip rap	N/A	N/I	0	1	2	3
Excessive sediment deposits	N/A	N/I	0	1	2	3
Other:	N/A	N/I	0	1	2	3

Emergency Spillway

Weeds	N/A	N/I	0	1	2	3
Erosion or back cutting	N/A	N/I	0	1	2	3
Obstructions / debris	N/A	N/I	0	1	2	3

SEDIMENT BASIN
INSPECTION AND MAINTENANCE FORM

Riser Built to Plans

Size: ________________________ CONC CMP or MASONRY (Circle One)

Minor spalling or parging (<1”)	N/A	N/I	0	1	2	3
Major spalling (exposed rebar)	N/A	N/I	0	1	2	3
Joint failure	N/A	N/I	0	1	2	3
Loss of joint material	N/A	N/I	0	1	2	3
Leaking	N/A	N/I	0	1	2	3
Manhole access and steps acceptable	N/A	N/I	0	1	2	3
Corrosion	N/A	N/I	0	1	2	3
Protective material deficient	N/A	N/I	0	1	2	3
Misalignment or split seams / joints	N/A	N/I	0	1	2	3
Anti-vortex device secure / acceptable	N/A	N/I	0	1	2	3
Sediment Accumulation within riser	N/A	N/I	0	1	2	3
Woody or vegetative growth within 25’ of riser	N/A	N/I	0	1	2	3
Safety Rebar/pipes in place	N/A	N/I	0	1	2	3
Safety Rebar/pipes corroded	N/A	N/I	0	1	2	3
Other:	N/A	N/I	0	1	2	3

Weir Trash Rack

Structurally sound	N/A	N/I	0	1	2	3
Debris removal necessary	N/A	N/I	0	1	2	3
Corrosion	N/A	N/I	0	1	2	3

Basin

Vegetation sparse	N/A	N/I	0	1	2	3
Undesirable woody or vegetative growth	N/A	N/I	0	1	2	3
Low flow channels obstructed	N/A	N/I	0	1	2	3
Standing water or spots	N/A	N/I	0	1	2	3
Sediment or debris accumulation	N/A	N/I	0	1	2	3
Bathometric study recommended			No		Yes	
Other:	N/A	N/I	0	1	2	3

Inflow Points

Number of inflow pipes: ____________________ Direction: N E W S

Endwalls, headwalls, end sections	N/A	N/I	0	1	2	3
Outfall pipes	N/A	N/I	0	1	2	3
Discharge undercutting outlet or displacing rip-rap	N/A	N/I	0	1	2	3
Discharge water is causing outfall to erode	N/A	N/I	0	1	2	3
Sediment accumulation	N/A	N/I	0	1	2	3

N/A = Not Applicable
N/I = Not Investigated
0 = Not a Problem

1 = Monitor for Future Repairs
2 = Routine Repairs Needed
3 = Immediate Repair Needed

SEDIMENT BASIN
INSPECTION AND MAINTENANCE FORM

Special Structures

Manhole access (steps, ladders)	N/A	N/I	0	1	2	3
Vehicular access	N/A	N/I	0	1	2	3
Concrete/masonry condition	N/A	N/I	0	1	2	3
Trash racks	N/A	N/I	0	1	2	3
Elbows	N/A	N/I	0	1	2	3
Sediment / trash removal	N/A	N/I	0	1	2	3
Manhole lockable nuts	N/A	N/I	0	1	2	3

Liner

Punctures	N/A	N/I	0	1	2	3
Tears	N/A	N/I	0	1	2	3
Seam Separation	N/A	N/I	0	1	2	3

Miscellaneous

Fence condition	N/A	N/I	0	1	2	3
Safety signs	N/A	N/I	0	1	2	3
Public hazards	N/A	N/I	0	1	2	3
Were any pad locks cut and replaced			No	Yes	How Many? ____________	
Other (describe)	N/A	N/I	0	1	2	3

N/A = Not Applicable
N/I = Not Investigated
0 = Not a Problem

1 = Monitor for Future Repairs
2 = Routine Repairs Needed
3 = Immediate Repair Needed

SEDIMENT BASIN
INSPECTION AND MAINTENANCE FORM

Overall Condition

Total number of concerns receiving a:	(1)	- Need Monitoring
	(2)	- Routine Repair
	(3)	- Immediate Repair Needed

Inspector's Notes

Pictures (as needed)	Clock/Degrees
1	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	

SEDIMENT BASIN
INSPECTION AND MAINTENANCE FORM

Sketches or comments, if necessary:

N/A = Not Applicable
N/I = Not Investigated
0 = Not a Problem

1 = Monitor for Future Repairs
2 = Routine Repairs Needed
3 = Immediate Repair Needed

TRASH RACK
INSPECTION AND MAINTENANCE FORM

Trash Rack from: ______________________________
Combination manhole and inlet GIS Code

Of Facility: ______________________________
Pond or ditch GIS Code

Annual Inspection Completed By: ______________________ **Date:** ______________________

Maintenance Inspection Completed By: ______________________ **Date:** ______________________

Inspection			**Notes**
Trash, debris, or sediment held in trash rack	Y	N	
Bars or racks missing or damaged	Y	N	
Other (describe)	Y	N	
Maintenance			
Remove trash, debris, or sediment	Y	N	
Replace/repair bars or racks	Y	N	
Other (describe)	Y	N	

Sketches or comments, if necessary:

Appendix E

Corrective Action Report Template

Corrective Action Plan (CAP)

Map ID	
Site Name	
Inspection Date	/ /
Date Prepared	/ /
Inspyear	

Corrective Action Required for			
Vegetation	Y/N	**Land Slumps**	Y/N
Erosion	Y/N	**Barren Areas**	Y/N
Site Edges	Y/N	**Gullies**	Y/N
Exposed Waste	Y/N		

Vegetation Score =

Erosion Score =

Vegetative Related Action Items

Reclamation Related Action Items

Erosion and Storm Water Related Action Items

Site Edge Related Action Items

Exposed Waste Related Action Items

Land Slump Related Action Items

Barren Area Related Action Items

Gullies Related Action Itmes

Administrative Related Action Items

U.S. EPA Representative: **Date:**

BNSF/UPRR Representative: **Date:**

Corrective Action Plan (CAP)-Rock

Map ID		**Date Prepared**	
Site Name		**Year**	
Inspection Date			

Vegetative Related Action Items

Erosion and Storm Water Related Action Items

Administrative Related Action Items

U.S. EPA Representative:		**Date:**	
BNSF/UPRR Representative:		**Date:**	

Appendix F

pH Paste Method

Lauren Knickrehm

To:	Lauren Knickrehm
Subject:	RE: RDU8 - pH Paste Method and pH Meter

From: Kenneth Brockman [mailto:kbrockman@usbr.gov]
Sent: Monday, November 17, 2014 2:28 PM
To: Lauren Knickrehm
Cc: Rob Hagler; Chris LaRose
Subject: Re: RDU8 - pH Paste Method and pH Meter

The method and meter are fine. It sounds like we will need the mini excavator for the test pits. The previous pits were backfilled for safety. The 320 will be needed to continue with tailings excavation.

Ken

Sent from my iPhone

On Nov 17, 2014, at 1:35 PM, Lauren Knickrehm <LaurenKnickrehm@kennedyjenks.com> wrote:

> **Hi Ken,**
> **Thanks for chatting with me about the subject items. Attached is a write up on the pH paste field sampling method (Method 3 in document) that we plan to implement. Do you concur with this method?**
>
> **Regarding field meter, we plan to use the "eco Testr pH2 Waterproof Pocket Tester" for which I have attached the operating instructions. It has a 3-point calibration (pH 4.01, 7.00, and 10.01). Please let us know if you have any questions about our meter.**
>
> **I'll be in touch regarding schedule shortly.**
>
> **Thanks,**
>
> **Lauren Knickrehm** | Environmental Engineer
> **Kennedy/Jenks Consultants**
> 116 Lupfer Avenue, Suite B | Whitefish, MT 59937
> P: 406.578.4505 | F: 406.730.1345
> ***Celebrating 95 years of service to our clients, staff, and communities***
>
> <Soil-Sample-Analysis-for-pH.pdf>
>
> <pH Meter_35423-10.pdf>

EcoSense®

Soil Sample Analysis for pH:

Methods to Determine Soil pH with the EcoSense pH100

Overview

The choice of a proper method to measure pH in soils is a contentious issue. Discussions abound concerning large variations in readings, depending upon the method, while others claim the errors are negligible. Regardless, it is widely accepted that there are three recognized methods of analysis:

Method 1

pH of Soil Suspension Using 1:1 Soil to Water Ratio-Soil Survey Manual (U.S. Department of Agriculture Handbook No. 18).

- For routine work, add 5 grams of soil and 5 mL of distilled water to a 50 mL beaker and stir vigorously. Allow mixture to stand without agitation for 30 minutes. Stir well immediately before immersing electrodes and measure pH.
- For organic soils, a soil water ratio of 1:5 is recommended with a standing time of 2 hours.

Method 2

pH of Soil Suspension Using a 1:1 Soil to $CaCl_2$ Salt Methods of Soil Analysis Part 2, 2nd Edition (American Society of Agronomy, Inc., Soil Science Society of America, Inc.).

- Add 5 grams of soil and 5 mL of distilled water to a 50 mL beaker and mix thoroughly. Let stand 10 minutes and stir again before measuring the pH in water suspension.
- Add one drop of 1 M $CaCl_2$ solution and stir intermittently for 30 minutes.
- Immerse the electrodes and record the soil pH in 0.01 M $CaCl_2$, which is called pHs.
- Lime requirement may be performed directly on this preparation of soil.

YSI pH100 instrument and 112-1 flat tipped electrode.

Method 3 used for BPSOU solid media pH testing.

Method 3

pH readings of Saturated Soil Paste (U.S. Department of Agriculture Handbook No. 60).

- Prepare a saturated soil paste by adding distilled water to a sample of soil while stirring with a spatula. The soil-water mixture is consolidated from time to time during the stirring process by tapping the container on the workbench. At saturation, the soil paste glistens as it reflects light, flows slightly when the container is tipped, and slides freely and cleanly off the spatula for all soils except those with a high clay content. After mixing, the sample should be allowed to stand for an hour or more, at which time the criteria for saturation should be rechecked. Free water should not collect on the soil surface nor should the paste stiffen markedly or lose its glistening appearance on standing. If the paste does stiffen or lose its glisten, remix with more water. If the paste is too wet, additional soil may be added.
- Insert the electrodes into the paste and raise and lower repeatedly until a reproducible pH reading is obtained.

All three of these methods give repeatable results but each method may give slightly different values for the same soil sample. Due to this difference, the method used should be described when reporting soil pH values.

The YSI pH100 instrument with optional 112-1 flat tipped pH electrode with extremely reliable double-junction electrode is ideal for pH soil analysis. The flat tipped electrode does not become clogged by soil particles and is easily wiped clean.

Appendix G

XRF User Manuals

PORTABLE XRF FOR ENVIRONMENTAL ASSESSMENTS

- Screen Sites for Heavy Metal Pollutants Quickly and Effectively
- Monitor Contaminants and Nutrients for Safe and Appropriate Land Use
- Reduce the Time and Cost of Regulatory Compliance

www.olympus-ims.com

The DELTA Line

Rugged, High-Performance Handheld XRF

See and feel the DELTA difference. Our analyzers are compact and robust from probe to trigger to display, with sophisticated XRF technology that's better, faster and more responsive. From initialization to the final result, the DELTA is the optimum solution for all your analytical needs.

The DELTA line gives you the ultimate experience in field-portable handheld XRF analysis, providing fast measurements with accuracy, precision, detection-limit, and light-element capabilities built into a compact single-chassis frame wrapped in robust industrial-grade casing.

The DELTA Line

When you need reliable, intuitive and customizable environmental analysis solutions, bring portable XRF analyzers from Olympus Innov-X with you into the field. These analyzers provide anywhere, anytime testing with faster, more accurate results.

The ultimate in handheld XRF: built tough on the outside, and designed to be smart on the inside. Ideally suited for field work, the DELTA is equipped with our trademark weatherproof, dust-proof, protective housing. Its ruggedized casing is manufactured to industrial standards, and because there is no PDA or moveable screen, it offers superior reliability. The DELTA is engineered with advanced technology, but is amazingly simple to use, for both non-technical and advanced operators alike. Choosing the optimal DELTA analyzer for all your environmental analysis needs is easy.

DELTA Premium

The Premium combines a large-area, high-performance silicon drift detector (SDD), and a 4 watt optimized X-ray tube, making it the ideal solution for ultra-quick, analytically demanding applications, and superior light element (LE) analysis.

DELTA-50 Premium

With a 4 watt, 50kV X-ray tube, the ideal handheld analyzer for optimized sensitivity of Cd, Ag, and Sb, in addition to Ba and rare earth elements (REEs) is the DELTA-50. The large-area, high-performance SDD works in conjunction with the higher voltage output of the tube to enable better sensitivity for important high-Z elements.

DELTA Standard

The new standard in handheld XRF. The Silicon Drift Detector provides excellent speed and LODs, in addition to good light-element analysis capabilities.

DELTA Classic

Our classic DELTA analyzer is equipped with an Si PIN detector. A high-tech, flexible analyzer for typical XRF analysis.

Incorporating Everything You Need in Handheld XRF

with State-of-the-Art Innovations. The DELTA Line from Olympus Innov-X.

4 W, X-ray tube, 200 µA current (max), plus optimized beam settings

Tight geometry for exceptional LODs and high analysis throughput

Large-area SDD option provides great precision and sensitivity

Patent-pending automatic barometric pressure correction that adjusts calibration as needed

Lightning-fast bootup and data acquisition: faster testing, more results

Floating Point Processor: provides more calculations in less time, and leverages more advanced calibration algorithms

Integrated Bluetooth for data input and output

Ergonomic rubberized handle for enhanced grip

Integrated heat sink for high-power use in extreme temperatures

Analysis indicator lights with 360° visiblity

Bright, responsive, color touch screen display

Accelerometer technology puts the unit into sleep mode when not in use to conserve power; logs impacts for tool management

USB interface port for high-speed data download and seamless PC control

Hot Swap: the rechargeable battery can be replaced without having to turn off or re-standardize the unit

Docking and Charging Station

Portable Workstation

Beam #1: 39/40 sec test

PC Software


DELTA mounted on hands-free Soil Stick

Portable XRF Solutions

Test soils, sediments, solids, runoff streams, snow, ice, sludge, mixed waste and debris, wood, bagged soils, corings, filters, wipes, coatings, and more. Identify, monitor, screen, and quantify material composition with confidence. For even greater convenience in the field, outfit your DELTA with a holster for easy transport, a soil foot for long measurement times, or mount it on a soil stick for hands-free, extended in situ testing.

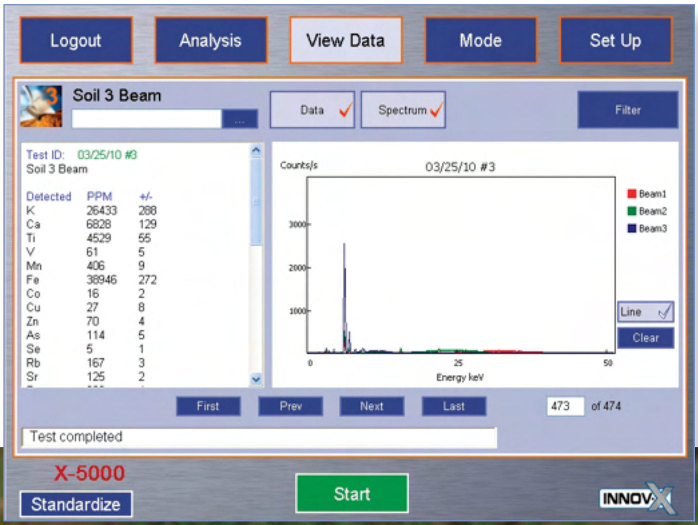

DELTA in Soil Foot


DELTA in Holster

X-5000 – Powerful Portable XRF

If you prefer your portable XRF to be closed-beam with onboard computing, and/or you primarily analyze bagged or prepped samples, the rugged X-5000 is ideal. It features a large-area Silicon Drift Detector (SDD) and an array of filtering and excitation options offering impressive analytical performance not usually available in the field:

- 50 kV, 200 μA X-ray tube = 10 watt system.
- High-resolution, large-area silicon drift detector (SDD).
- Self-contained, closed beam with safety interlocks.
- Fully integrated onboard Windows XP PC with a large touch screen.
- Easy-to-use, intuitive Olympus Innov-X PC Software Suite.
- True portability at less than 10 kg with the battery option.
- Enhanced performance for REEs, Ag, Cd, Sn, Sb and Ba.



Test ID: 03/25/10 #3
Soil 3 Beam

Detected	PPM	+/-
K	26433	288
Ca	6828	129
Ti	4529	55
V	61	5
Mn	406	9
Fe	38946	272
Co	16	2
Cu	27	8
Zn	70	4
As	114	5
Se	5	1
Rb	167	3
Sr	125	2

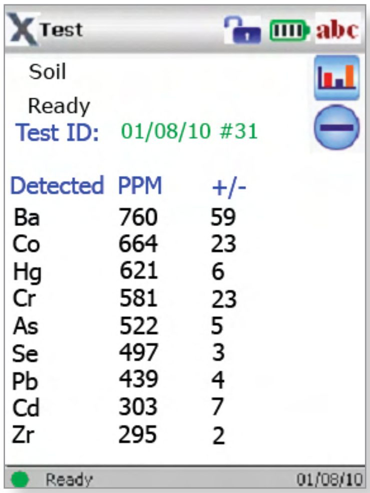
473 of 474

Test completed

X-5000 Software Screenshot

Olympus Innov-X Knows Portable XRF Environmental Analysis

Factory-calibrated DELTAs or X-5000s can be used immediately for environmental site-assessment screening. Or, you can utilize the data analysis software to optimize the factory calibration models for improved precision and accuracy of quantitative analysis for your samples.



Soil
Ready
Test ID: 01/08/10 #31

Detected	PPM	+/-
Ba	760	59
Co	664	23
Hg	621	6
Cr	581	23
As	522	5
Se	497	3
Pb	439	4
Cd	303	7
Zr	295	2

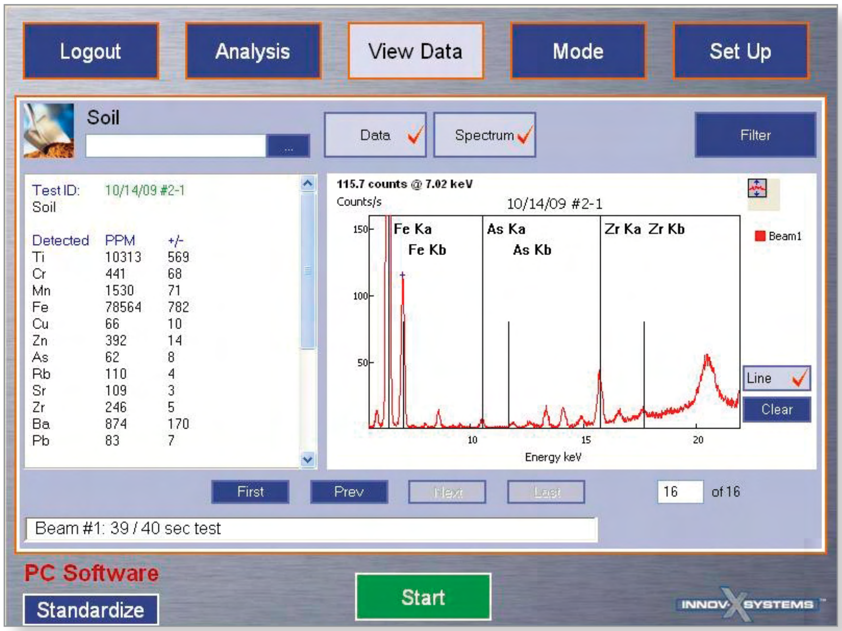
DELTA Handheld Screenshot

Data Analysis

- Fast qualitative identification of elements
- Rapid site screening with semiquantitative analysis of elements
- Compton Normalization: “Internal Standard” for quantitative analysis without site-specific calibrations
- Fundamental Parameters available: “standardless” for samples with high and low concentrations of several elements
- Reevaluate stored data sets with added elements, new parameters, models or calibrations curves
- Moisture-content corrections

Collect and View Data, Optimize Quantitative Analysis, and Create Reports

- Intuitive PC software can be utilized to remotely control the DELTA analyzer in a benchtop configuration
- Sort comprehensive analysis results, quickly create reports, view and export spectra
- Empirical Calibrations: Refine factory calibrations with user-generated, site-specific factors (slope, y-intercept), including ore-matrix-specific calibrations
- Combination algorithms: Fundamental Parameters with Empirical for light elements (LE) and complicated matrices
- Transfer new PC calibration models to your DELTA



Test ID: 10/14/09 #2-1
Soil

Detected	PPM	+/-
Ti	10313	569
Cr	441	68
Mn	1530	71
Fe	78564	782
Cu	66	10
Zn	392	14
As	62	8
Rb	110	4
Sr	109	3
Zr	246	5
Ba	874	170
Pb	83	7

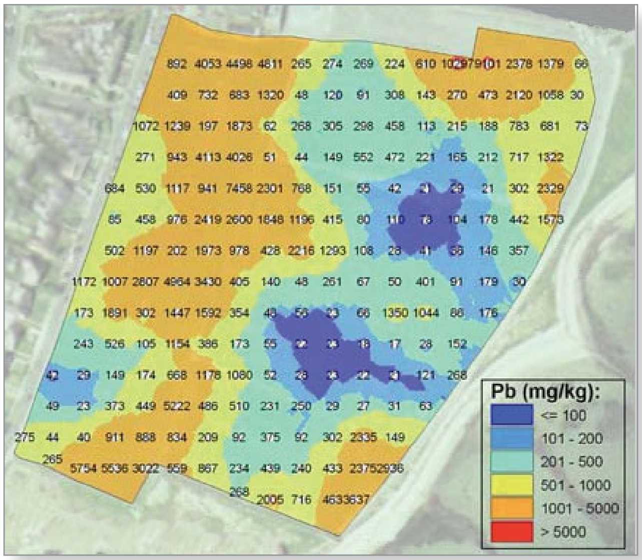
Beam #1: 39 / 40 sec test

Enhance the capabilities of your DELTA with the PC Software

The DELTA Xplorer

Metal Characterization Contour Mapping

Get the big picture with GPS-XRF. Get quick snapshots, instant visualization of data trends, or analyze for comprehensive, defendable reports. From rapid, infield decision making to command-center monitoring, you get instant, pinpoint, location-specific sample chemistry or multidimensional metal content intensity plots. You can optimize sampling plans to reduce lab costs and reporting times for site assessments, delineate RCRA, heavy and priority pollutant metals, identify metal pollutant hot spots, screen cores to determine metal pollutant depth, track metal pollutant plume contours, establish contamination boundaries, and perform due diligence phase assessments, remediation and long-term monitoring.

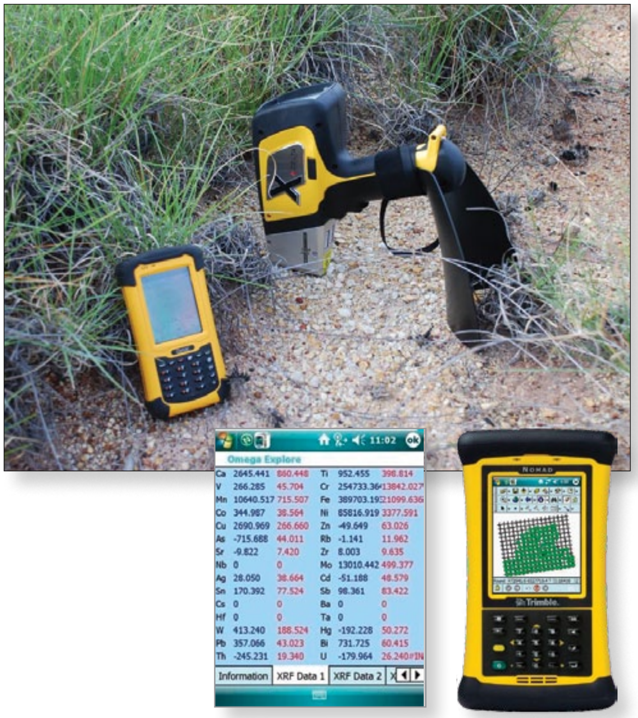


Lead (Pb) Concentration Contour Map of 20x20m Park

GPS-GIS XRF for Instant Metal Mapping

The most cost-effective tool for large sites, handheld XRF enables large, inexpensive, geochemical data sets to be generated very quickly. The Xplorer provides important data management and validation frameworks to ensure the quality and integrity of your sampling program in the field. Olympus Innov-X XRF/GIS integration, the first of its kind in the industry, addresses the needs of the total project.

- Field Portable XRF data is transferred wirelessly, and spatially registered in real time using industry standard Mobile GIS & state-of-the art Trimble GPS Hardware and GIS Software (ArcPAD or Discover Mobile)
- The result is live geochemical mapping in the field, which enables visualization, gridding and contouring in GIS for rapid, informed decision making
- Seamless integration into powerful geochemical analysis software such as ioGAS for first class data validation and QA/QC
- Reduces human error related to XRF data transfer, GPS coordinate merging, and GIS integration



Omega Explore

Ca	2645.441	860.448	Ti	952.455	398.814
V	266.285	45.704	Cr	254733.36	13842.027
Mn	10640.517	715.507	Fe	389703.19	21099.636
Co	344.987	38.564	Ni	85816.919	3377.591
Cu	2690.969	266.660	Zn	-49.649	63.026
As	-715.688	44.011	Rb	-1.141	11.962
Sr	-9.822	7.420	Zr	8.003	9.635
Nb	0	0	Mo	13010.442	499.377
Ag	28.050	38.664	Cd	-51.188	48.579
Sn	170.392	77.524	Sb	98.361	83.422
Cs	0	0	Ba	0	0
Hf	0	0	Ta	0	0
W	413.240	188.524	Hg	-192.228	50.272
Pb	357.066	43.023	Bi	731.725	60.415
Th	-245.231	19.340	U	-179.964	26.240#IN

Key Portable XRF Environmental Applications

DELTA handheld XRF analyzers have completely revolutionized environmental testing. In the past, assessments relied exclusively on expensive and time-consuming lab analyses that were based on samples collected at and shipped from the site. You can now assess the environment immediately on-site. DELTA handheld XRF analyzers provide cost-effective, timely analysis of data in real time, leading to rapid and comprehensive investigations that can be used to determine the next course of action. This means you can take action at the site and won't lose precious time or resources collecting non-representative samples, or running up unnecessary lab costs.

Community and Residential Development

The DELTA immediately identifies heavy metals in soil at low PPM levels, and is an important tool to help ensure safety prior to developing or renovating schools, community centers, residences, playgrounds and athletic fields. The DELTA is an essential tool for developing properties built on former landfills, industrial sites, orchards, animal farms, Brownfields, or any other site where toxic metals are likely to be found in high concentrations. In addition, during renovation, redevelopment, restoration and painting of buildings and older homes, the DELTA can quickly detect lead (Pb) in soil and dust, on surfaces, and in lead-based paint (LBP), thereby helping to reduce regulatory compliance analysis costs and time.

Peri-Urban Farming and Agronomy

The safety of food sources is becoming increasingly important as the human population expands. With this growing demand, peri-urban farming is gaining in popularity. However, farming in areas adjacent to industrial and other urban facilities raises the risk of food crops being grown in soil, or irrigated with water contaminated with elevated levels of arsenic (As), mercury (Hg), cadmium (Cd), chromium (Cr) and lead (Pb). DELTA handheld XRF offers rapid detection of these toxic metals, in addition to confirming the presence of nutrients and fertilizers, such as calcium (Ca), magnesium (Mg), phosphorus (P) and potassium (K). The DELTA XPLORER GPS-XRF is ideal for precision agriculture, as it allows for high-intensity soil analysis in the field with results obtained and spatially modeled on-site.

Regulatory Compliance

Portable XRF is a well documented and valuable tool for both private and government regulatory-driven analysis of heavy and priority pollutant metals in residential and industrial soils. This non-destructive method, with its quick analysis time and high-quality measurement capability, make it ideal for field assessments, particularly those covering large areas. In fact, US EPA Method 6200 encourages portable XRF screening for high-density, high-volume sampling for correct site characterization.

Dangerously High Levels of Toxic Metals in Developing Countries

Dangerously high levels of Pb, As, Hg, Cr, Cd and other toxic metals can be found in residential and recreational areas in developing countries, where knowledge of their dangers is not well-known, or where regulations are not in force. Handheld XRF analyzers can be used to quickly identify the presence and quantity of such contaminants, thereby enabling world health advocacy groups to determine a course of corrective action to help developing countries prosper with local resources, and with safe working practices and living conditions.

Hazardous Waste Screening and Sustainable Industry

Most industries are now under pressure to follow a sustainable development plan to help minimize the environmental and health impact of their manufacturing and packaging processes. Handheld XRF systems are used on-site by industry, engineering firms, and regulators to ensure that any heavy metal contamination is quickly identified, and that remediation steps are working effectively.

Your Partner...

Olympus Innov-X is your partner. We understand the issues and regulatory implications involved in environmental testing. We have engineered our analyzers to be rugged and reliable. Whether you need to screen a small area for dangerously high levels of heavy metals, perform high-intensity soil analysis in the field for on-site spatial modeling with GIS-GPS-XRF, or generate reports for regulatory remediation or compliance, our aim is to keep you up and running with the best portable XRF analyzers and support available.

Return on Investment

The DELTA is FAST. We know that the faster the test, the more tests you can run. The DELTA will maximize your field-testing throughput and assessment process. The DELTA is also SMART. You can screen a large site quickly for 25+ potential toxic metal pollutants with excellent LODs in the fastest testing time possible, or you can get the lowest LODs possible by fully optimizing on a specific element or group of elements. Olympus Innov-X makes your investment easy with simple purchases, rentals , rental buyouts, and leasing options. (May not be available in all regions. Contact your local distributor for available options.) We can also configure analyzers specific to your analysis requirements.

Outstanding Customer Support

From initial demonstration, to identification of your testing needs, to thorough user training, and fielding any questions or needs going forward, we are here to support you. We take pride in the comprehensive training provided by our local representatives, distributors, and support department, as well as our responsiveness to our customers' needs. We are committed to your satisfaction.

Global Support Coverage

With offices around the world, we have local support centers to support you and your analyzers wherever they're being utilized.

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Product group from well-managed forests, controlled sources and recycled wood or fiber
Cert no. XXXXXXX
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CE

User Manual

Delta™ Family: Handheld XRF Analyzers

PN_103201
Rev_A: June/2010

General

This Manual is solely the property of Innov-X Systems, Inc. and, along with the Delta™ XRF analyzer to which it applies, is provided for the exclusive use of Innov-X clients under contractual agreement for Innov-X test and analysis equipment and services.

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Innov-X Systems, Inc. reserves the right to make changes in the product design without reservation and without notification to its users.

Revision History

Release Date for this document and its individual sections is June, 2010. This enters the Innov-X document control system as Revision A

The material is available as Adobe PDF-type files. Distribution of the files or hard-copy representations is at the discretion of Innov-X Systems, Inc.

GO TO

See "*A7. Legal Information"* for information concerning Innov-X Systems, Inc.'s warranties, licenses, and liabilities.

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CONTENTS - Page 1 of 3

CONTENTS - Page 2 of 3

SECTION **TOPIC** **PAGE**

C5. Alloy Analysis Modes, Continued

CONTENTS - Page 3 of 3

Delta Family End User Documentation Resources

During Delta's development and initial product shipments several End User documents have been created. They are listed in the table below.

Delta Documentation Resources		
Innovx Part #	Release Date	-----------------------------Title-----------------------------------
103202_RevA	July/2010	Delta User Interface Guide (UI version 2.5))
103201_RevR	June/2010	Delta Family User Manual (This document)
103076_RevA	3/2010	Delta Family Quick Start
101593_RevA	11/2007	Window Replacement: Hinged Plate HandHeld Analyzers
102922_RevA	2/2010	Delta Family User Manual (Canadian Edition)
103158_RevA	3/2010	HOW TO: Setup and Configure A-020-D Teststand/Workstation for Delta Analyzer
TBA	6/2010	HOW TO: Convert A-020-A or A-020-O Teststand/Workstation to Support a Delta Analyzer

Preface

This *Preface* provides the following information:

- "Manual Structure"
- "Document Conventions"

Manual Structure

This *User Manual* consists of eight chapters, ten appendices, this Preface, Table of Contents, and a Cover. Individual chapter material is summarized below:

C1. Introduction describes the basics of the system:

- The Innov-X Delta™ Family
- Visual tour of the instrument noting all the major components

C2. Safety Information describes general safety information:

- Priority Information
- General Precautions
- Electrical Precautions
- X-ray Safety
  - Safety Interlock Structure
  - Safe and Unsafe Usage Scenarios
  - Radiation Doses for Several Scenarios
  - Comparative Analysis of Typical Exposure
  - Common Questions and Answers
- Delta Radiation Profile
- Required Certification
- Analyzer Shut-down Procedures

C3. Safety Administration describes safety program information:

- Radiation Safety Training Recommendations
- Dosimeter badges
- A typical dosimeter monitoring program
- Dosimeter service contractors
- Registration requirements

C4. Operations describes operations and testing procedures:

- Configure and Use Delta Docking Station (DDS)
- Start-up Procedure
- Cal Check Issues
- Battery Issues
- Conducting and Ending Test Operations

NOTE

Information concerning the Delta Family's user interface is supplied in the companion document ***"Delta User Interface Guide"*** (PN103202_Rev2.5 June/2010).
The goal is to provide revised Delta UI Guides when a substantial software change is released.

C5. Alloy Analysis Modes describes five specific modes and calibrations including:

— Alloy
— Alloy Plus
— FastID
— Pass/Fail
— Precious Metal Additions

C6. Mining Analysis Modes describes three specific modes and calibrations including:

— Mining
— Two Beam Mining
— Car Catalyst

C7. Soil Analysis Modes describes two specific modes and two calibrations including:

— Soil
— Three Beam Soil
— Environmental
— Exploration

- LEAP issues for Classic Delta (PiN detector)
- Check Standards
- Sample Preparation

C8. Consumer Goods Modes describes two specific modes including:

— RoHS
— Consumer Products

- *RoHS Mode* provides a details from EU regulation directives which list the limits for RoHS elements and information for qualitative measurements.
- *Consumer Products Mode* is dedicated to testing for Lead (Pb)

A1. Overview: X-Ray Fluorescence (XRF) Spectrometry presents background information and general knowledge, including:

- Basic Theory and X-ray History
- Elemental Analysis
- EDXRF Spectrometers

A2. Soil Testing presents information on using the analyzer for soil analysis within certain accepted guidelines, including:

- Status for Field Portable XRF and Overview of Field Usage
- Quality Assurance
- Calibration for Innov-X Portable XRF
- Effects of Moisture on XRF Results
- Comparing XRF Results to Laboratory Results
- Common Interferences
- Sample Prep Procedures and Testing Protocols

A3. Specifications presents analyzer hardware and software specifications.

A4. Typical Delta Test Sequence

- Prerequisites noted by Mode
  - Grade Libraries
  - Check Standards
  - Sample Presentations
- Typical Test Sequence

A5. User Maintenance provides a key procedure/technique:

- Using the AC Power Adapter kit to replace a Li-ion battery
- Using the stand-alone battery charger
- Replacing a Prolene, Mylar, or Kapton Window

A6. Packing and Shipping gives the procedure for returning a unit to Innov-x.

- Warning Label for shipping products with Li-ion batteries

A7. Legal Information presents material, including:

- Analyzer Limited Warranty including:
- Limitation of Liability
- Warranty Period, Returns, and Repairs
- Instructions for Contacting Innov-X
- End User Software License Agreement including:
  - Use, Restrictions, and Termination of Software
  - Liability Limitations

A8. Alloy Grade Libraries including the Alloy Factory Grade library for each Model, and a “Tramp” Library with seven base alloys.

Document Conventions

Messages

There are four messages used in this Manual:

WARNING, CAUTION, NOTE, and **GOTO.**

They are characterized by an icon and a message box topped with a colored banner. The message text is on a gray background. An example of each message is below:

WARNING

DEMANDS that you observe the actions given in the text.
The **WARNING** message has a **bold** type style.

Remember:
The WARNING icon signifies information that denotes a potentially hazardous situation, which if not avoided, may result in serious injury or death.

CAUTION

SUGGESTS that you review the referenced details and heed the instructions offered.
The CAUTION message has a regular type style with *emphasized keywords*.

NOTE

REQUESTS that you pay particular attention to a specified procedure or piece of information. Adds details that make it easier to use the system and this manual.
The NOTE message has a regular type style.

GO TO

DIRECTS the user to another portion of this manual, or to other reference materials containing relevant data.
The **GOTO** (or Pointer) message has a regular type style.

Type Styles

These conventions are used to present information:

Convention (Type Style)	Description
Bold	Indicates an action taken on a button or other item.
Italic	Menu commands, names of keys, buttons, tabs, or items from picklists. User-entered text. It is used for references to other documents, C(hapter) titles, and A(ppendix) titles (for example, "… see *"C2. Safety Information"*). Labels on unit's I/O panels; panel or window names of the UI (User Interface).
`Courier` typeface	Computer displayed text or filename.

Pagination

Page numbering in this Manual is consecutive with the Front Cover being assigned Page Number 1. This enables the PDF document file and any hard-copy print to map to the Page field information in the Adobe Reader.

C1. Introduction

C1 includes a:

- Description of the Innov-X *Delta*™ family of handheld XRF analyzers.
- Visual tour of the instrument(s) noting all the major features, and accessories.

Description of *Delta* System

What Is It?

The *Delta* is a handheld energy dispersive X-Ray fluorescence spectrometer, generally referred to as an XRF analyzer.A complete **Delta** package consists of:

- Handheld analyzer using an integrated group of instrument components that are sealed in an ergonomically designed, light-weight body. They include --
    - Controller
    - Color touchscreen (ergonomically mounted interactive display)
    - Membrane navigation keys
    - Choice of detectors (**PiN or SDD**) to meet wide-ranging application goals

Coordinated with these robust characteristics, the instrument's *key feature* is Innov-X's proprietary control, data acquisition, and analysis software with customer configured options.

Additional accessories (standard and optional) include:

- Li-Ion batteries (2) - {Standard}
- Delta Docking Station (DDS) Dedicated charging and calibration unit - {Standard}
- Rugged waterproof carry case - {Standard}
- Portable test stand to create a Delta workstation (A-020-D) {Optional}
- Soil foot (A-035) (Optional)
- Soil extension pole (990055) (Optional)
- Trimble Xplorer Package (Optional)

What Does It Do?

The expanded *Delta* family of handheld XRF instruments delivers fast and precise identification and analysis for elements from magnesium to uranium (Mg to U) depending on the selected model. A weatherproof/dustproof ultra rugged design including an **integral heat sink** permits users to conduct diverse analysis testing under severe operating conditions. An added convenience feature for field use is battery **"Hot Swapping."**

Applications

The analyzer gives accurate chemical analysis for commercial or industrial areas, such as:

- Positive Material Identification
- Mining and Exploration
- Consumer Safety
- Scrap Processing
- Environmental Testing
- Light Element & Aluminum Analysis

Delta Family: Types, Models, Modes and Calibrations

Delta Types and Models

Type	Modes	Models
Premium	Alloy	DP-2000
	Environmental	DP-4000
	Mining	DP-6000
	RoHS	DP-6500
Standard	Alloy	DS-2000
	Environmental	DS-4000
	Mining	DS-6000
	RoHS	DS-6500
Classic	Alloy	DC-2000
	Environmental	DC-4000
	Mining	DC-6000
	RoHS	DC-6500

Modes and Calibrations

ALLOY Analysis	Alloy	**MINING**	Mining Mode	**LEAD PAINT**	Lead in Paint (HUD)
	Alloy Plus		2 Beam Mining		Lead in Paint (Industrial)
	FastID & Pass/Fail		Car Catalyst		
	Precious Metals			**THIN**	Filter Analysis
		CONSUMER GOODS	RoHS		Dust Wipe
SOIL Analysis	Environmental		Consumer Products		
	Exploration				

Inspection

Inspection

Use this procedure:

1. Remove the carry case from the shipping cartons; save cartons.
2. Open the carry case
   Remove the shipping documentation
3. Verify that all the parts and accessories are included.
   Remember that the case has **TWO FOAM LAYERS**.
4. Verify that no visible damage occurred during shipping.

WARNING

If there is damage to any of the components, DO NOT attempt to use the instrument.
Immediately contact Innov-X Customer Support at:

- **United States: 1-781-938-5005**
- **Europe: +31 (0)73 62 72 590**
- **Canada: 1-778-960-6279**
- **Australia: 02-9577-9500**

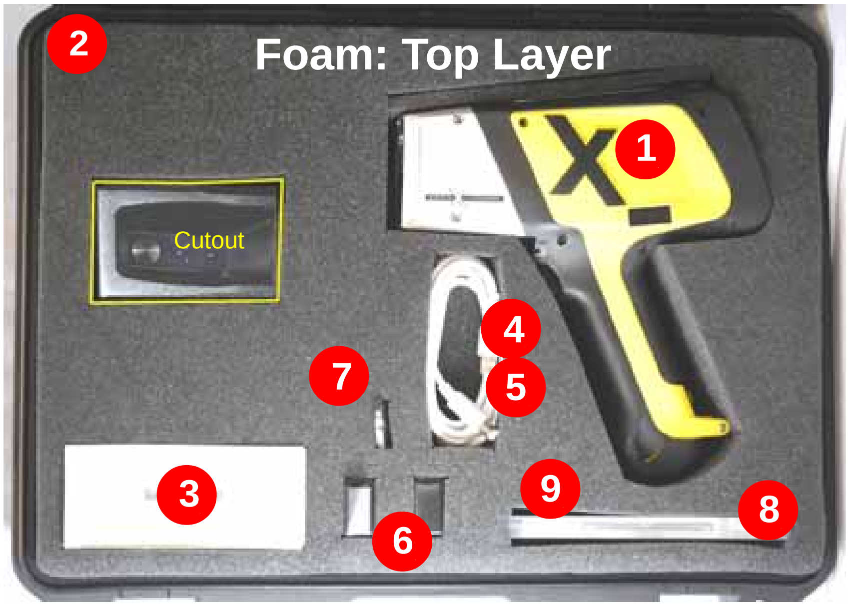
Or call your local distributor.

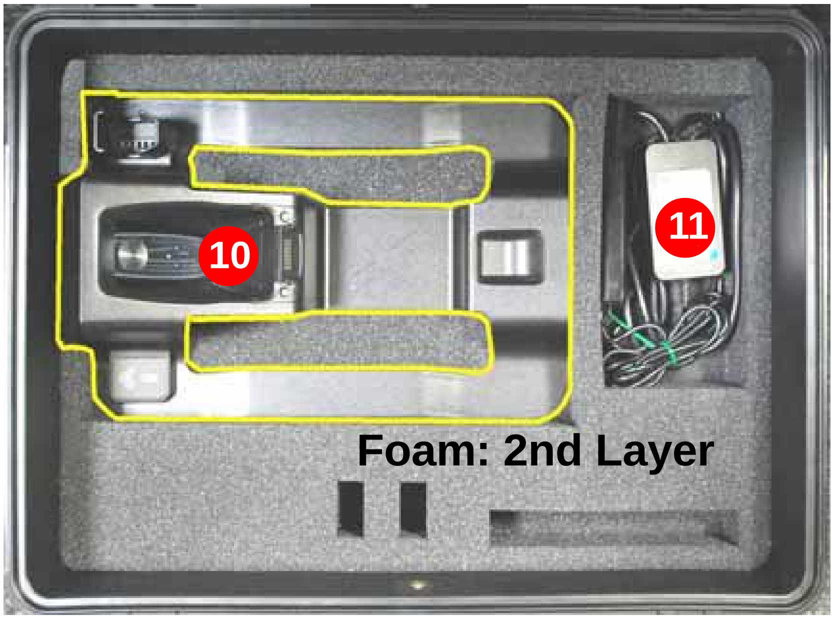
GO TO

- See *C4. Operations, Page 45 & 50 Battery Issues* for battery charging information.
- See **"***Delta User Interface Guide"* (PN 103202) for a complete description of the *Innov-X* application's User Interface.
- See *A7. Legal Information* for warranty, liability, and software licensing information.

Tour of the *Delta* Package

The figure below depicts *Delta's* major components as initially shipped to a customer. Note that the protective foam in the Carry Case has **TWO LAYERS**.





Component Key

—Foam: Top Layer—	
1	Delta Analyzer
2	Carry Case
3	Docking Station Charger
4	USB Cable #1
5	USB Cable #2
6	Li-ion Batteries (2)
7	Cal Check Coupon
8	Extra Windows (Bag of 10)
9	End/User Documentation
—Foam: 2nd Layer—	
10	Docking Station
11	AC Power Adapter (Optional)

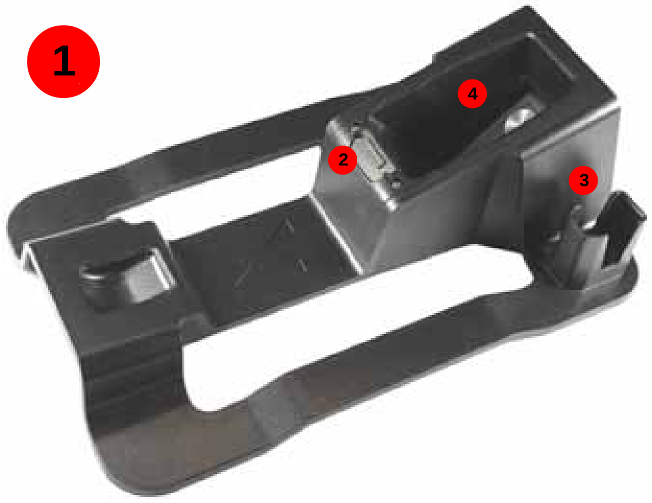
Tour of Instrument

1. Handheld Analyzer

Component Key

	Delta - All Models
1	Delta Analyzer (Premium Model Shown)
2	Probe
3	Measurement Window (Prolene Film)
4	Hinged Window Plate
5	Docking Station Connector
6	Trigger
7	Handle - Non-Slip Rubber Grip
8	Battery Boot
9	Data Port w/ Rubber Cover
10	Heat Sink
11	I/O (Power) Switch w/ LED Indicator
12	X-ray Warning Light Array
13	Touchscreen for User Interface
14	Navigation Buttons

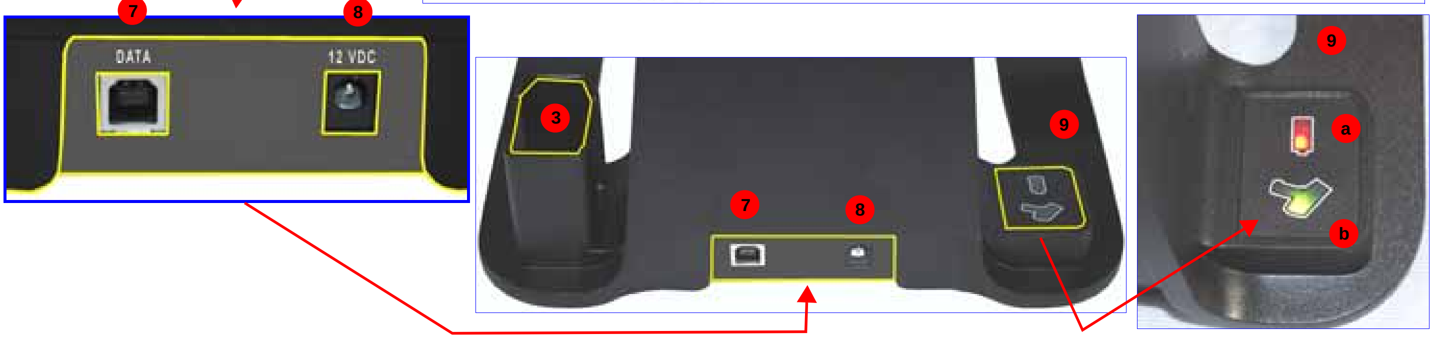
2. Delta Docking Station (DDS)



Component Key

	Delta - All Model
1	Delta Docking Station (Empty)
2	Analyzer Signal/Control Connector
3	Spare Battery Charge Socket
4	CalCheck Test Cup (316 stainless steel coupon)
5	Docking Station (Loaded)
6	Second Battery in Socket
7	Data Port(s): — Docking Station ->Rear
	— Analyzer -> Left Side
8	Input Power (12 VDC)
9	Indicator Lights
a	Second Battery Charging
b	Analyzer Engaged

See C4/Pages 44-45
for more information



3. Accessories- List the Standard and Optional Accessories

Standard

- Batteries
- Delta Docking Station (DDS)
- DDS Power Adapter
- USB Cables 1 - USB mini to USB A
- USB Cable 2 - two part powered data cable
- Windows- Bags of Kapton and Prolene films
- Cal Check (Standardization) Coupon

Optional

- AC Power Adapter (Battery Replacement)
- A-020-D TestStand/Workstation for Delta

STANDARD Accessories

Batteries

Two removable Li-ion batteries are standard accessories for the Delta.

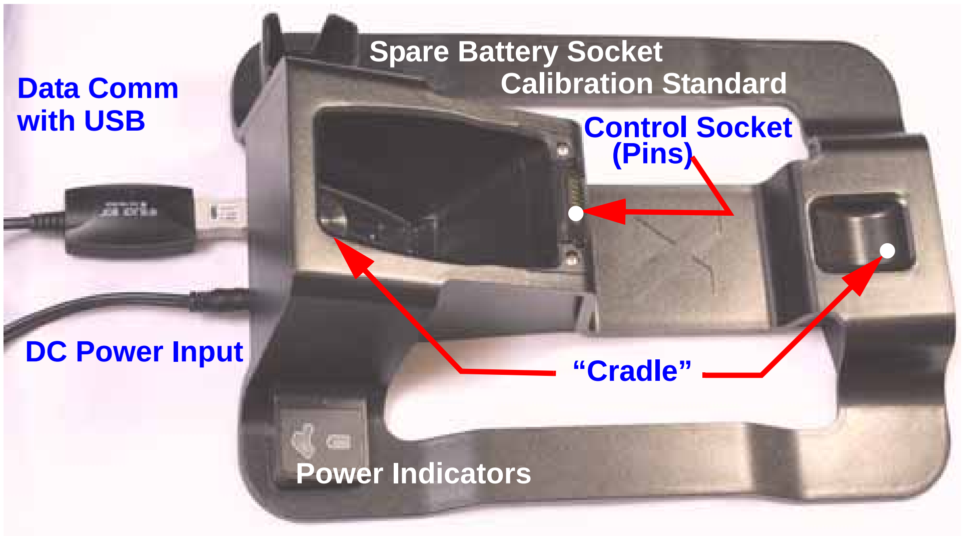
Push the white *Push* button and the LEDs indicate the- percentage of charge.

See Chapter 4, Page 50
“Battery Issues”

Delta Docking Station (DDS)

This is key accessory. It provides **three** functions:

- Cal Check by one of two means - “On Demand” or Automatically
- Charge internal battery in handle
- Charge additional battery in auxiliary socket



See Chapter 4, Page 46
“Use DDS for Start Up &
Initial Cal Check”

Power Adapter for DDS

See Chapter 4, Page 44
“Configure DDS”

I/O Cables

PN 101310: This *standard accessory* provides a means to transfer information into or out of the sealed analyzer. It is good practice to export the current day’s testing results to your PC.

PN 101310
USB Data Cable
  Mini USB B Connector
  USB A Connector

PN 103209 and 103210: This is a two part assembly that supports communication between the Delta Docking Station and a PC.

.

Data Cable Assembly

Part One
PN 103209
USB Repeater Cable
  USB A Female Connector
  USB A Male Connector

Part Two
PN 103210
USB Adaptor
Male to Male
  USB A Connector
  USB B Connector

Cal Check (Standardization) Coupon

This part is used as a reference sample to provide a test standard for a Cal Check procedure if the Docking Stations is not available. The instrument indicates when a Cal_Check is necessary.

See Chapter 4, Page 51 *"Cal Check Information"*

Measurement Window Films

A bag of 10 window films are a standard accessory. The composition of the film is model and application dependent

PN 103115 REV A
Kapton Windows
for Classic

PN 102999
Prolene windows for
Standard and Premium

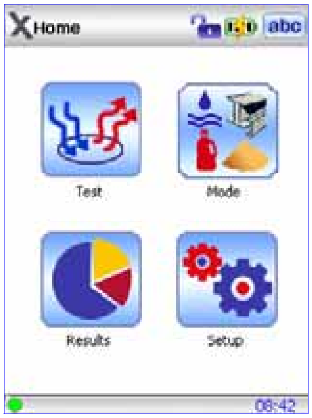
Application Software

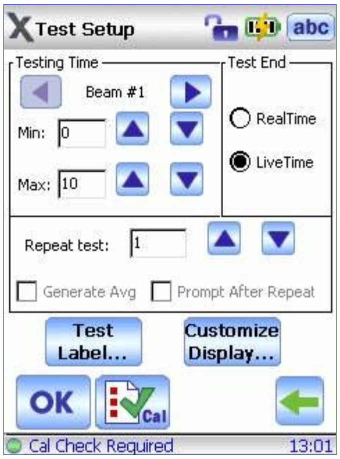
The *Delta* instrument is shipped with proprietary InnovX data acquisition and processing software and Windows Embedded CE® operating system. The User Interface employs an icon-based home page graphic style. Factory calibration has been completed on all purchased modes.

NOTICE!

This instrument produces ionizing radiation. It should only be used by trained technicians.

Select START if you are a certified user.





Test Setup

Testing Time

Beam #1

Min: 0

Max: 10

Test End

○ RealTime

● LiveTime

Repeat test: 1

☐ Generate Avg ☐ Prompt After Repeat

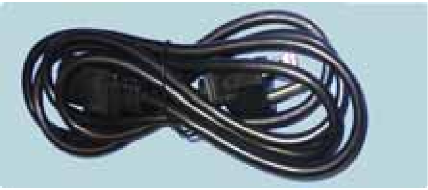
Cal Check Required 13:01

Sedately *User Interface Guide"* (PN 103202) for a complete description of the Innov-X application's User Interface.

OPTIONAL Accessories

AC Power Adapter

PN 100043: This accessory enables the user to operate the instrument without the limitation of battery charge status. The unit comes with approximately ten feet of power cord that defines the effective range of use.



PC Software

This application package permits an operator to execute Innovx S/W functions from a PC. With cable PN 101310, a user can connect from the Delta's mini-USB data port to a PC's USB port.

This package is optional for a handheld instrument and standard for A-020-D TestStand/Workstation. When used with the A-020-D the proper configuration cable is the powered USB assembly (PN 103209 - PN 103210)

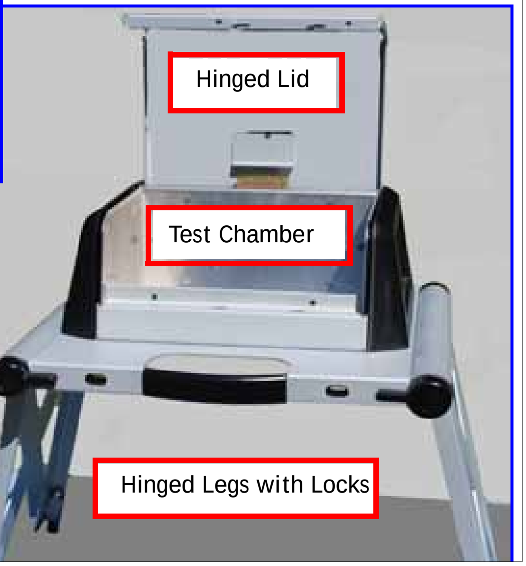
XRF Workstation

The Delta XRF Workstation is comprised of two major components:

- A-020-D Test Stand, and
- Any Delta analyzer

In this configuration, the Delta is controlled by Innovx Delta PC Software. The open-beam handheld instrument is converted to a closed-beam workstation.

See PN 103158 document: *"HowTo-Setup & Configure Delta XRF Workstation"* for complete instructions.



Tour of XRF Workstation

The **XRF Workstation** offers the following features:

- Portable, light-weight, shielded enclosure
- A rugged and repeatable testing environment
- Easily erected in laboratory or at remote field site

In this configuration the Delta (an open-beam handheld instrument) is converted to a safe closed-beam system

C2. Safety Information

C2 presents the following information:

- Radiation Safety Information
- General Precautions
- Electrical Precautions
- X-Ray Safety
- Compliance
- Instrument Usage Scenarios
- Radiation Dosage for Several Scenarios
- Radiation Safety: Common Questions and Answers
- Analyzer Shut Down Procedure

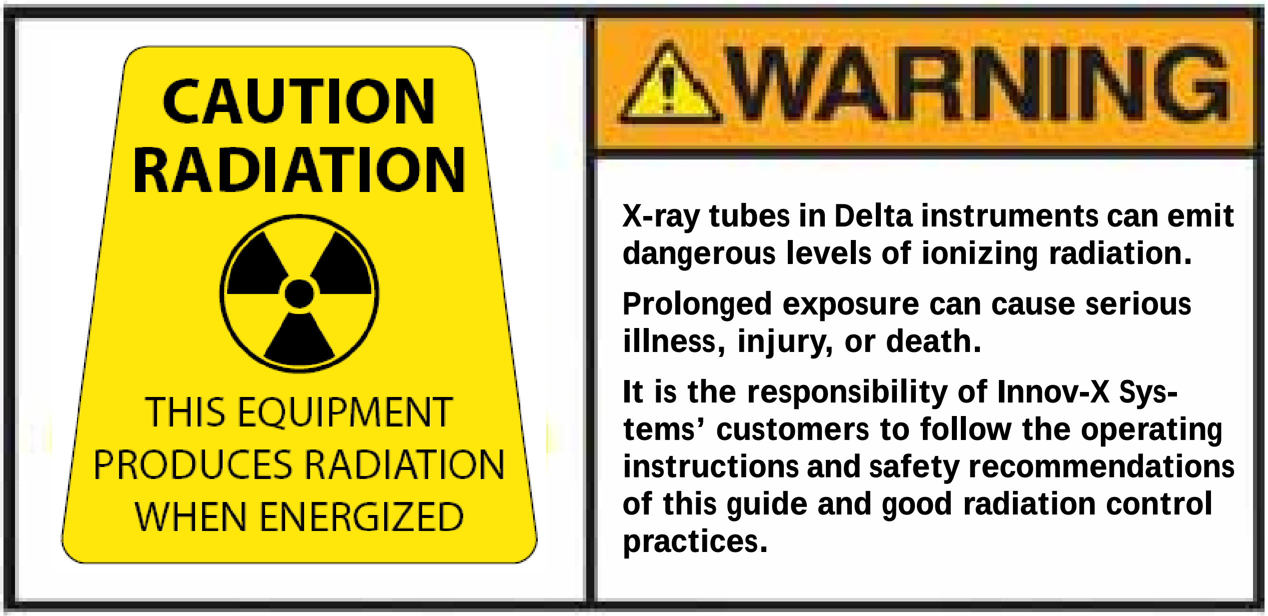
Radiation Safety Information

Always make Operational Safety your HIGHEST PRIORITY.

The *Delta* Handheld XRF Analyzer is a secure and dependable instrument when used according to Innov-X's recommended testing techniques and safety procedures. However, this instrument produces ionizing radiation; only individuals trained in correct operating techniques and authorized to use X-ray producing devices should be permitted to use it.

The radiation detected at any outside surface (excluding the Prolene, Mylar, or Kapton window area) is below that required for an unrestricted area.

- Heed all warning labels and messages
- Observe the safety interlock features



X-ray tubes in Delta instruments can emit dangerous levels of ionizing radiation.

Prolonged exposure can cause serious illness, injury, or death.

It is the responsibility of Innov-X Systems' customers to follow the operating instructions and safety recommendations of this guide and good radiation control practices.

Radiation Safety Program

Innov-X strongly recommends that organizations using *Delta* analyzers implement a formal *Radiation Safety Program* that includes:

- Dose monitoring of critical personnel.
- Monitoring of area radiation levels.
- Information specific to the site and application of the XRF system.
- An annual review (and update, if necessary).

"C3. Safety Administration" provides a more comprehensive safety discussion for operators and managers.

X-Ray Safety

X-ray safety is a priority at any time and in any testing situation.

WARNING

- **Innov-X analyzers must be used by trained and authorized operators, according to proper safety procedures. Improper usage may circumvent safety protections and could potentially cause harm to the user.**
- **Heed all warning labels and messages.**
- **DO NOT USE the instrument if there is any chance that it is damaged or might leak radiation. In such a case, arrange for qualified personnel to perform a radiation safety test and repair any analyzer damage.**

General Precautions

Apply these general safety guidelines when managing or operating the *Delta* instrument:

- Retain and follow all product safety and operating instructions.
- Comply with all warnings on the product and in the operating instructions.

Comply with the precautions listed in this section to reduce the risk to:

- Users
  - Physical injury
  - Electric shock
  - Radiation exposure
- Equipment damage
  - Measurement window
  - Overheated electronics and other internal components

Service Considerations

Except as expressly noted here, do not service any Innov-X product yourself. Opening or removing the external housings may expose you to electric shock and the instrument to mechanical damage. It also voids the warranty.

CAUTION

If service is required, it must be performed by Innov-X or its authorized service representatives. Failure to observe this can result in loss of warranty. The **ONLY EXCEPTION** is replacing a damaged measurement window (see ***“A5. Window Replacement”***).

Damage Requiring Service

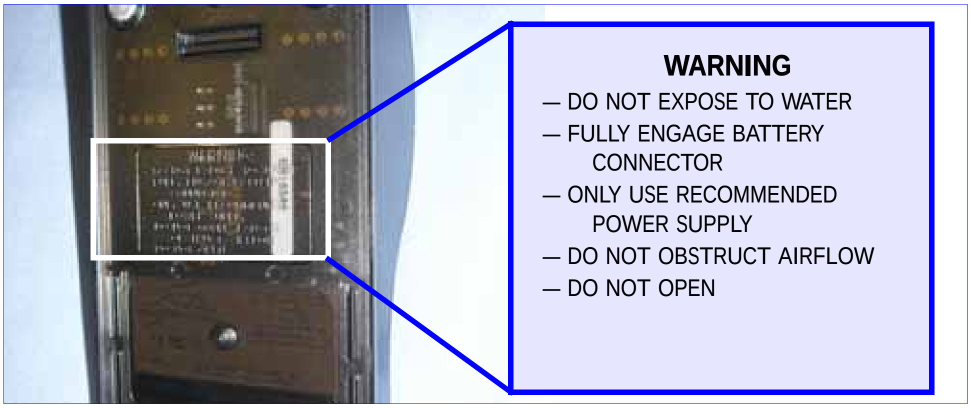
Types of problems or conditions that require service are (*but not limited to*):

- Power cords are damaged.
- Excessive or corrosive liquids spilled on the instrument or accessories.
- Instrument impacted, dropped, or physically damaged.
- Noticeable signs of overheating.
- Instrument or docking station does not perform normally when you follow the usual operating instructions.

Electrical Precautions

Guidelines for safe electrical operation of a *Delta instrument*:

- Use the correct battery or AC power adapter.
    - Install the battery or AC power adapter carefully, don’t damage connections.
- Use the correct external AC power sources for the Delta Docking Station (DDS) (battery charging and Cal Checking) and the AC power adapter:
    - Ensure that the voltage is appropriate (100V-240 V/ 50-60 Hz) for operating either accessory.
      See *“A3. Specifications”* for electrical specifications.
- Do not overload an electrical outlet, power strip, or convenience receptacle.
- Do not exceed 80% of the branch circuit rating.
- Comply with the warning messages on the under side of the Battery Charger.
    - Similar precautions should be observed for the Delta Docking Station (DDS).



WARNING

— DO NOT EXPOSE TO WATER
— FULLY ENGAGE BATTERY CONNECTOR
— ONLY USE RECOMMENDED POWER SUPPLY
— DO NOT OBSTRUCT AIRFLOW
— DO NOT OPEN

Cables and Cords

The *Delta* instrument and docking station is delivered with:

- AC power adapter (1) for Docking Station (standard)
- AC power adapter (2) as battery replacement for instrument (optional)

Each device has a standard IEC 3 conductor power cord which includes a safety grounding plug.

- If necessary, have an authorized individual replace these plugs to conform to local conventions.

Two data cables are supplied:

- Data cable (1) with connectors — USB A to USB B
- Data cable (2) with connectors — USB A to mini USB B

Cable Guidelines

Use these guidelines to ensure safety and proper equipment performance:

- The power cords MUST be connected to a properly grounded and easily accessible power outlet.
- Use a surge protector device, if possible.
- Do not defeat or bypass the ground conductor.
- Do not pull on cords or cables. Grasp the plug housing when removing the cord from the electrical outlet.
- Install all cords in accordance with applicable regulations.
- If you substitute a USB cable, ensure that the length doesn't exceed 10 feet.

Delta Docking Station (DDS) and Li ion Battery Packs

Plug the Delta Docking Station (and optional battery charger, if utilized) into a grounded electrical outlet that is easily accessible at all times.

- To handle battery packs properly do not:
  - Disassemble
  - Crush
  - Puncture
  - Short external contacts
  - Dispose of in fire or water
  - Expose to temperatures higher than 60 ^{o}C (140 ^{o}F).

GO TO

See ***"C4. Battery Issues"*** for instructions concerning Batteries, the Battery Charger, and the AC Power Adapter.

WARNING

Danger of explosion if battery is incorrectly substituted.
Replace only with Innov-X specified batteries.

Used batteries may be returned to Innov-X Systems for disposal.
If returning batteries, or equipment with batteries installed, the shipping container must display a special caution label.
See *"A6. Packing and Shipping"* for label details.

Indicator and Warning Lights

Power Switch w/ Integral Indicator Light

The Delta power switch is located at the upper rear of the unit.

POWER ON

- Press the I/O switch to turn on the power.
  - A green LED indicator comes on.
- This switch *DOES NOT* turn on the x-ray tube.
  - No tube power supplied until the Innov-X software is launched and a test is initiated.

POWER OFF

- Press and hold switch for >3 seconds.
  - Unit powers off. (See page 36 for more Exit options)

X-Ray Indicator Light Array

An indicator light array (six red LEDs) alerts the operator when the tube is receiving power, and when x-rays are emitted from the analyzer through the measurement window.

- When the unit is initially powered ON, the Indicator array remains Off.
- As test is conducted, array is in a **flashing** state.
- At the test's conclusion, the array stays **on continuously** until the beginning of the next test.

X-Ray Indicator ON (*Blinking*)

When the indicator array is flashing, this signifies:

- X-ray tube is powered to full operational level
- Internal filter wheel is in operational position
- Analyzer is emitting x-ray radiation through the analysis window.

In this condition, the analyzer must be pointed at a test sample.

X-Ray Indicator ON Continuously (*Not Blinking*)

When the indicator array is on continuously, this signifies:

- X-ray tube's current is set to 0.0
- X-ray tube is producing a minimum level of x-rays
- Internal filter wheel is closed so there is no radiation exposure to you or bystanders.

The instrument is *safe* to be carried or set down in this condition.

Back of Analyzer

In addition to the I/O switch and the X-Ray indicator array, the back of the Delta analyzer has:

- **Touch screen** which displays and controls the Delta User Interface.
- **Three Navigation Buttons** below the screen.
  They permit the user to conveniently step through the Test Results Spectrum screens.

Navigation Buttons

X-Ray Label

The Delta has a warning label affixed to the lower surface of the probe.

The analyzer has a label on the lower surface of analyzer's probe/nose.

- This label is *required* by most regulatory agencies. Do not remove it.
- The label term "*WHEN ENERGIZED*" refers to the condition where the tube is fully energized and the filter wheel is open.
    - This condition corresponds with the blinking red LEDs that comprise the X-ray indicator array.

Other Safety Features

Proximity Sensor

The Delta automatically detects when it is engaged with a test sample.
It immediately shuts off the X-ray tube if:

(a) Initially there is no sample in front of the window,

— or —

(b) Instrument is pulled away from the sample before the test time has expired.

Safety Interlock Structure

For controlling the Delta's X-ray emissions and therefore minimizing the possibility of accidental exposure, there is a standard safety interlock structure consisting of the three features listed below.

Software Trigger Lock

- If five minutes elapse between tests (default time), the trigger locks automatically and you must tap on the lock icon 🔒 to unlock it. See Safety Software instructions in "*Delta User Interface Guide*".

Software Proximity Sensor

- Within two seconds of a test start, the analyzer detects a sample in front of the measurement window. If not, the test aborts, the filter wheel closes, and the x-rays shut off. The tube is placed in standby and the red light stops blinking.

Safeguards

As an owner of an Delta handheld XRF instrument, your safeguards are:

A. Limited Access
B. Trained Operators
C. Shielding Issues

A. Limited Access

Keep the instrument in a controlled location, where only trained and authorized users are likely to have access.

B. Trained Operators

Keep a sign with the analyzer indicating that in order to use it an operator must have completed a training class provided by your company, or must have attended an Innov-X training course and completed any other requirements as dictated by the local regulating authority. When the Innov-X system is turned on, the controller screen displays a message indicating that the system should only be used by authorized personnel.

C. Shielding Issues

Background

The Delta emits a tightly collimated beam of X-ray radiation. The beam projects many meters when only air attenuates it.

> **NOTE**
>
> Refer to governing regulations on compliance in the jurisdiction installed, dose limits, etc. Requirements differ from state to state, region to region, country to country. *DO NOT* rely solely on this manual for instruction.

Action

Adequate shielding is achieved by:

- Establishing a *no-admittance zone* sufficiently distant from the instrument's measurement window that allows air to attenuate the beam.
- Enclosing the beam working area with *protective panels* (for example, 1/8" stainless steel can attenuate the beam to background levels)

Contact your Innov-X Systems representative for assistance and suggestions on interlocks and applications for limiting radiation exposure.

Instrument Usage Scenarios

The Delta is used in several testing configurations. Obey the guidelines listed below.

Practical Safety Guidelines for Handheld Analyzers

WARNING

- DO NOT POINT the unit at yourself or any other person during operation.
- Never perform a test by holding the sample with your fingers or in the palm of your hand.
- Always wear both a ring-style and a badge-style dosimeter.

Correct Usage

Test in Place

Test targets can include pipes, valves, large pieces of scrap metal, soil, or any sample large enough to be tested in place.

In this configuration the proper procedure is as follows:

1. Always observe the relevant parts of the *Practical Safety Guidelines* shown above.
2. Point the instrument at the sample such that *no part* of your body (including hands and/or fingers) is near the measurement window.
3. Ensure that the Delta's nose (with window) is firmly placed on the target.
4. Perform the test using one of these methods:
    - Tap **Start** on the UI

    — or —

    - Pull the trigger (this toggles the instrument to ON state)

    — or —

    - Pull-and-hold the trigger with the "deadman trigger" active.

Employing Steps 3 & 4 assures that no operator's body part is exposed to an excess radiation dose. The radiation detected at user interface areas is < 5 µSv/h.

Take care that during testing, personnel are not located within three feet (one meter) of the Delta's probe head, in the direction of the x-ray beam. Provided the window is completely covered, there is minimal radiation being emitted around the area of the sample.

Small Component Testing

Examples of small component targets include metal turnings, weld rod, wires, fasteners, nuts and/or bolts.

For analysis of these types of components, use this procedure:

1. Always observe the relevant parts of the *Practical Safety Guidelines* shown above.
2. Place the sample on a flat surface.
3. Carefully place the nose/window over the sample.
4. Perform the test using one of these techniques:
    - Tap **Start** on the UI

    — or —

    - Pull the trigger (this toggles the instrument to ON state)

    — or —

    - Pull-and-hold the trigger with the "deadman trigger" active.

1. Sample lying on a flat surface

SAFETY PRECAUTIONS

WARNING

Do not test samples while sitting at a desk or table If the desk is made of wood or another non-metallic material, some radiation will penetrate the desk and may provide exposure to legs or feet.

ANALYTICAL PRECAUTIONS

NOTE

If the sample does not completely cover the window, ensure that your *background surface* does not contain metals or even trace levels of metals, as this may affect the accuracy of the XRF result. The XRF may report the presence of additional metals in the surface material.

2. Clamp-held sample

NOTE

A handheld plastic locking clamp can be an effective and safe tool when analyzing small, irregular shaped samples.

Incorrect (Unsafe) Usage

⚠ **WARNING**

Never hold a sample in your hand such that any part of your body or appendages are exposed to the x-ray beam. Testing samples in this way may generate significant radiation exposure to your fingers.

Unsafe Testing Technique

Unsafe Testing Technique

The sample is held up to the measurement window with fingers. The sample does not completely cover the window.
Even though the analyst is wearing a ring dosimeter, this is an unsafe testing technique.
Here, the only value that the ring provides is to validate the level of unnecessary radiation exposure that has been experienced.

The sample is held up to the measurement window with fingers. The sample does not completely cover the window.
To compound the danger, the analyst is not wearing a ring dosimeter.
There is no measure of the radiation exposure endured.

Summary

InnovX repeats the Warning ---

NEVER hold a sample in your hand.

Testing samples in this way generates significant radiation exposure to your fingers.

Compliance

Complying Agency Statements

United States of America: FCC

Changes or modifications not expressly approved by Innov-X Systems, Inc. could void the user’s authority to operate the equipment.

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.

Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Radiation Doses for Several Scenarios

In this section we provide data, concrete examples of use and misuse of the analyzer and common questions and answers we encounter when training personnel on the safe use of the Innov-X analyzer. The goal is to explain scenarios of safe versus improper usage.

WARNING

For the x-ray energy emitted by portable XRF analyzers (8-60 keV region), the bone in the fingers will absorb radiation about 3-5 times more than soft tissue, so the bone would be at an elevated radiation risk compared to soft tissue.
For this reason, no person shall hold a test specimen in front of the window with the fingers in the direct beam, or direct the beam at any part of the human body.

Reference: *Health Physics 66(4):463-471;1994*.

The table below presents radiation doses for normal operating conditions and also for examples of misuse of the analyzer and even extreme misuse. Innov-X provides installation training that includes detailed radiation safety training and documentation designed to prevent misuse of the analyzer.

Although the doses shown below are derived from experiments with TLD (thermo-luminescent dosimeters) and may or may not represent actual absorbed dose in human tissue and bone in each scenario, they are examples of the level of x-ray radiation being emitted from the device.

The message is simple:

USE CAUTION AND PROPER TECHNIQUE when operating the device.

Example: Instrument Usage	Radiation Exposure and Comments
Normal Operation- Dose to Hand User analyzes samples according to standard operating procedures described in this manual. Assumption: Operator using system with x-ray tube ON for eight hours/day, five days/week, 50 weeks/year. (Alloy sample).	Maximum exposure is to operator's hand, at the trigger is < 1µSv/h. Annual exposure to hand is then < 2mSv. Maximum exposure under ICRP regulations is 500 mSv for radiation workers and 50 mSv for the general public. Thus continuous operation provides a dosage 250 times lower for a radiation worker and and 25 times lower for the general public.
Normal Operation- Dose to Torso Analyzer is used under the same operating conditions described above.	Exposure to Torso is so low it cannot be measured (essentially background). To be conservative we use 1/2 the value as the trigger, < 0.5µSv/h. Annual exposure using operating conditions above is then estimated at less than 1 mSv. Maximum allowed is 20 mSv under ICRP for radiation workers (1 mSv for general public).
Misuse Example 1: Operator holds samples in front of window with fingers, such that fingers are directly in the primary beam. Presumption is sample does not block any radiation. **Do not do this!**	At the window, in the primary beam, the maximum dose to the fingers is 20,000 mSv/hr. Assume an operator performs a 10 sec. test (typical). The dose to the operator's fingers or hand is 20,000 x (10/3600) = 550 mSv. If the operator did this just once a year he would exceed the allowable annual dose of 500 mSv to an extremity. Take the extra time to test a sample on a surface or use a testing stand. **Note: If the operator takes a shortcut and places his/her fingers within the primary x-ray beam at the window, they will exceed the annual dose rate.**
Misuse Example 2: Operator places analyzer against body and pulls the trigger to start a test. Analyzer tests to preset testing time (usually ten seconds) unless operator pulls trigger again to stop test. This applies to analyzer being in contact with operator or with bystander. **Do not do this!**	Dose at exit of sampling window is 20,000 mSv/h. Dose for a ten second exposure with analyzer in contact with Torso: 550 mSv. If an operator did this act just once, he would exceed the annual safe dosage to the torso of 20 mSv/year by a significant amount! **PLEASE NOTE:** The maximum dose of 20 mSv/year is a whole body limit, which does not truly apply in this case because the x-ray beam size is small (about 25 mm^2 area at the port). Applying correction factors for the beam size is complex and beyond the scope of this manual. The important point is that for proper operation there is no reason to ever expose any part of the human body directly to the x-ray source. This example serves to provide estimated exposure in the event this occurs.

Misuse Example 3:

Operator manages to initiate a test for ten seconds running normal soil mode and exposes a bystander that is standing ten cm away from analyzer port.
What is exposure to bystander?

Note: The **proximity sensor** would automatically shut down the x-ray tube immediately, so this is an extremely improbable occurrence. It would require a malfunction of the instrument - this safety feature in NOT modifiable.

Note 2: Equations to scale these to other scenarios involving longer or shorter tests, and bystander being at distances other than ten cm are provided at right.

Dose to bystander at ten cm is 215 mSv/hr. For a ten second exposure the dose is 0.6 mSv. This is 33 times lower than the allowable dose to a nuclear worker in a year. This would have to happen 33 times to for that worker or bystander to obtain the maximum allowable dose.

Formula for calculating other scenarios:

$$\text{DOSE (in mSv)} = 6T/D^2$$

D = distance from port in inches
T = testing time

Example: Bystander is 30 cm away from port for a 30 second test. In this case the dose is calculated as:

$$\text{DOSE} = 6(30)/30^2 = 0.2 \text{ mSv}$$

Comparative Analysis:

Radiation Doses from Typical Exposures to Ionizing Radiation

Activity	Typical Dose
Smoking	*2.8 mSv per year*
Dental x-ray	*100 µSv per x-ray*
Chest x-ray	*80 µSv per x-ray*
Drinking water	*50 µSv per year*
Cross country round-trip by air	*50 µSv per trip*
Mammogram	*1-2 mSv per examination*
Yearly exposure from background* radiation * depends on geographic location	*3.6 mSv*

Radiation Safety: Common Questions & Answers

Question: When I'm shooting a piece of pipe or valve on a rack or on a table top, is there any exposure to people standing several feet away from the analyzer?

Answer: Even a thin amount of a dense metal sample (three to four mm thickness, not Al alloy) is enough to completely attenuate the emitted x-ray beam. Shooting a piece of material that covers the sampling window on the analyzer completely shields any bystanders from radiation exposure.

However, use good practice: Keep the area clear of people for at least four to five feet in front of the analyzer.

Question: If I forget to lock the trigger, I pick up the analyzer and accidentally pull the trigger, is that dangerous to nearby personnel?

Answer: No, this example of misuse is not dangerous, but it may produce a non-negligible radiation exposure to nearby personnel. For an exposure to occur, the following things must happen.

First, you must be holding the analyzer so that a bystander is actually standing in the x-ray beam being emitted. Just being near the analyzer is totally safe otherwise.

Second, the bystander must be within one meter from the nose of the analyzer to receive any appreciable dose. If all of these conditions are true, the dose received by a bystander is still extremely low. Please see Misuse Example 3 in the table above.

Third, it would require failure of the proximity hardware and software.

Question: Do I need to create restricted areas where I am using the analyzer?

Answer: No, provided you are following normal operating procedures there is no reason to restrict access to an area where the analyzer is in use. However, the operator should take precautions to keep any personnel more than three feet away from the sampling window of the analyzer in the event of accidental misuse as detailed above. Should operators also elect to test small samples as shown on pages 34 and 35, they should also be sure that no personnel are standing within about four to five feet of the sampling window.

Question: How does the x-ray tube in the Innov-X system compare to a radiography system used for taking images of metal parts?

Answer: The x-ray tube used in the Innov-X system produces between 1,000 and 10,000 times less power than most radiography systems (0.5-1 watt versus multiple-kW). A portable XRF is designed to perform surface analysis of alloys and other samples, whereas a radiography system is designed to shoot x-rays entirely through metal components in order to obtain an image on the other side of the test object. For example, many tube-based radiography systems use a 300-400 kV tube and currents in the tens or hundreds of milliamperes (mA). The Delta uses a tube operating at a maximum of 40kV and typically 6 -10 µA.

The radiation levels produced by an Delta are thousands, or tens of thousands, times lower than a radiography unit.

Question: Should we use dosimeter badges with the Innov-X analyzer?

Answer: Dosimeter badges are required by some provincial regulatory agencies, and optional with others. Innov-X recommends that operators wear badges, at least for the first year of operation, as a general precaution to flag any misuse of the analyzer. Dosimeter badges are available for the torso (generally worn in a shirt pocket) and also as "ring" badges.

The best practice is to wear a ring badge on a finger on the opposite hand used to hold the analyzer. This records accidental exposure for the most likely case – an operator grabbing a small sample and holding it in one hand while analyzing it.

Note: These badges generally have a threshold of 100 µSv and are renewed monthly. So it takes several cases of misuse even to obtain a reading on a typical badge. When purchasing a badge, obtain the type used for x-ray and low energy gamma ray radiation.

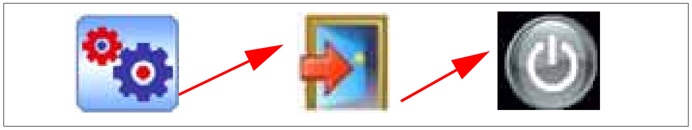
Analyzer Shut Down

There are several techniques for shutting off the Delta. They can be categorized by whether the action is taken under normal or emergency conditions. *Shut down* or *turned off* is defined as: *The analyzer cannot provide X-ray emissions*.

Under normal conditions

Use one of following actions:

- Press the trigger.
- Tap **STOP** icon on the UI touchscreen.
- Navigate from **Setup > Exit**, then choose the Power OFF icon.



- Release the trigger if in "Deadman Trigger" mode.
- Press the I/O power switch; ensure that the On/Off LED goes off.

In an emergency

Because the Innov-X system is a battery-operated, x-ray tube-based analyzer, the Emergency Response plan is simple. If you believe that the analyzer is locked up in an *OPEN* position, the red X-ray indicator array remains illuminated or blinking:

1. Press the I/O power switch as noted above. If the power does not turn off, continue to Step 2.
2. Open the battery cover and immediately remove the battery.

If you are using the AC Power Adapter:

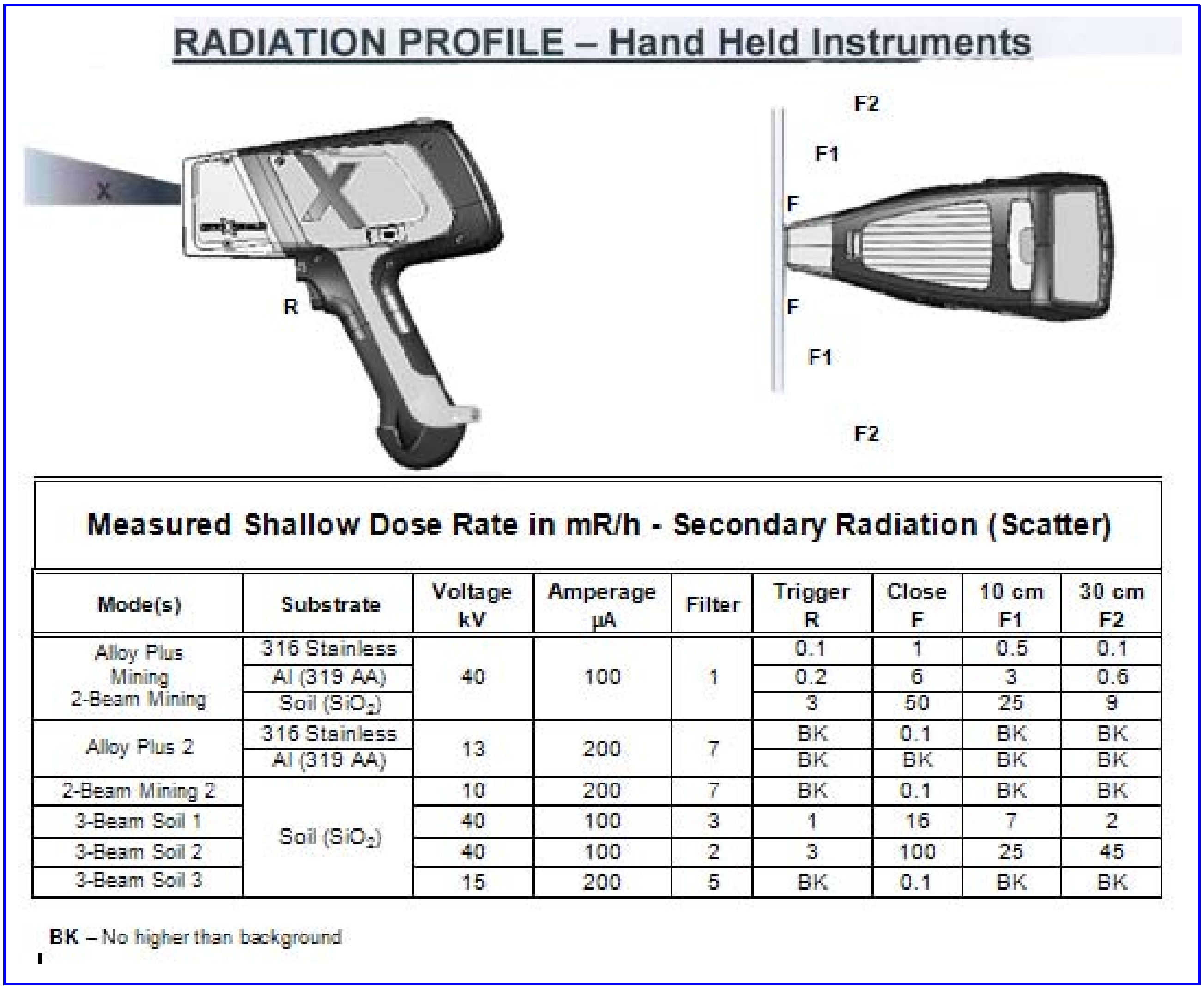
- Remove the Battery Eliminator from the Delta's handle

— or —

- Pull the AC cord from the AC Power Adapter or pull the plug from the receptacle.

Delta Radiation Profile

This is the current Delta Radiation Profile.



RADIATION PROFILE – Hand Held Instruments

Measured Shallow Dose Rate in mR/h - Secondary Radiation (Scatter)

Mode(s)	Substrate	Voltage kV	Amperage µA	Filter	Trigger R	Close F	10 cm F1	30 cm F2
Alloy Plus Mining 2-Beam Mining	316 Stainless	40	100	1	0.1	1	0.5	0.1
	Al (319 AA)				0.2	6	3	0.6
	Soil (SiO_2)				3	50	25	9
Alloy Plus 2	316 Stainless	13	200	7	BK	0.1	BK	BK
	Al (319 AA)				BK	BK	BK	BK
2-Beam Mining 2	Soil (SiO_2)	10	200	7	BK	0.1	BK	BK
3-Beam Soil 1		40	100	3	1	16	7	2
3-Beam Soil 2		40	100	2	3	100	25	45
3-Beam Soil 3		15	200	5	BK	0.1	BK	BK

BK – No higher than background

TEST CONDITION: Instrument run at normal setting for mode and represents typical production unit.

NOTES

C3. Safety Administration

C3 provides information regarding:

- Radiation safety training recommendations
- Dosimeter badges
- A typical dosimeter monitoring program
- Dosimeter service contractors
- Typical registration requirements for operating XRF equipment (in the USA)

Radiation Safety Training Recommendations

Individual companies and states have specific regulations and guidelines for using ionizing radiation generated by an X-ray tube.

NOTES

For the convenience of clients, Innov-X has compiled a list of recommendations that:

- Provide generic guidance for an ALARA (*as low as reasonably achievable)* approach to radiation safety.
- Do not replace the requirement to understand and comply with specific policies of any state or organization.

Personal Monitoring

Radiation control regulations may require implementation of a radiation monitoring program, where each instrument operator wears a film badge or TLD detector for an initial period of one year to establish a baseline exposure record. Continuing radiation monitoring after this period is recommended, but may be discontinued if accepted by radiation control regulators. See *Dosimeter Suppliers* for a list of film badges providers.

Proper Usage

Never point the instrument at a person. Never point the instrument into the air and perform a test. Never hold a sample in your hand during a test.

Establish Controlled Areas

Restrict access to the location of instrument storage and use to limit potential exposure to ionizing radiation. In use, the target should not be hand held and the area at least three paces beyond the target should be unoccupied.

Specific Controls

When not in use, store the instrument in a locked case or locked cabinet.
When in use, keep it in the direct control of a factory trained, certified operator.

Time - Distance - Shielding Policies

Operators should minimize the time around the energized instrument, maximize the distance from the instrument window, and shoot into high density materials whenever possible.

Prevent Exposure to Ionizing Radiation

All reasonable measures, including labeling, operator training and certification, and the concepts of time, distance, & shielding, should be implemented to limit radiation exposure to *as low as reasonably achievable* (ALARA).

Dosimeter Badges

A dosimeter badge consists of a radiation-sensitive material, generally an aluminum oxide crystalline layer, which is worn in a small container. It is most often attached to a person's clothing, on a belt loop, or shirt pocket. It is worn on the body in location(s) that most closely simulate the pattern of potentially absorbed dose.

The protection can also be provided in a plastic ring format. Here the detection material is lithium fluoride crystal.

Dosimeter
Clip-on Style

Dosimeter
Ring Style

These devices record a person's accumulated radiation exposure over a period of time. They monitor individuals working with, or near someone working with devices which emit ionizing radiation.

Dosimeter badges are required by some regulatory agencies, and are optional with others.

Innov-X recommends that (at a minimum) all *Delta* operators wear badges (both clip-on and ring styles) for the first year that their system is in use.

NOTE

- When purchasing a badge or ring, always select the type used for *X-ray* and *low energy gamma* radiation.
- Innov-X suggests that the ring badge be worn on a finger of the *opposite hand* used to hold the analyzer. This records accidental exposure for the most likely case: An operator grabbing a small sample and holding it in a hand while analyzing it.

Every country (including every region, state, or province within a country) can have differing regulations. Always consult your local radiation protection authority or Innov-X Systems for information and recommendations.

Dosimeter Safety Program

A typical dosimeter-based safety program uses the following steps:

1. The company develops a dosimeter program with an independent service contractor.
    - They establish the quantity of badges needed and the frequency of analysis (a monthly or quarterly interval)
2. The company receives the first lot of badges and provides them to their analyst/operators.
3. At the end of the interval:
    - The company collects the badges and returns them to the service contractor for analysis.
    - Simultaneously, the service contractor delivers another lot.
4. The company provides the new set of badges to maintain a continuous protection /monitoring program for their employees.
5. The service contractor prepares a report for the company that tabulates any X-ray dose received and identifies any personnel with readings higher than typical background radiation.
6. The safety monitoring cycle repeats with Steps 1 through 5.

NOTE

The service contractor's written records are very important to a company's overall safety documentation plan.

Dosimeter Suppliers

Some dosimeter service companies are:

Company	Location	Telephone
AEIL	Houston, TX	713-790-9719
Global Dosimetry Solutions	Irvine, CA	800-251-3331
Landauer	Glenwood, Il	708-755-7000
• Landauer, Inc.	Oxford, England	+44-1 86-537-3008
• Nagase Landauer, ltd.	Japan	+81-3-36 66-4300
• LCIE Landauer	Paris, France	+33-(0)1-40 95 62 90
• Landauer	Beijing, China	+86-10-62 21 56 35

Registration Requirements

Contact Innov-X for assistance with locating registration requirements information.

- Most states require some form of registration. Generally they require the registration to be received within 30 days of receipt of the system.
- Some states require no registration.
- Some states require notification in advance.

Customers are advised to consult their local radiation protection authority for specific regulatory information.

Typical Device Registration Information

The following information is usually requested by a licensing agency:

Purpose of device:

Response is *Analytical or Industrial.*

Be sure to inform the government registration office that the system will NOT be used for radiography or for medical uses.

Radiation Safety Officer:

List person who monitors training, safe use, and controls access to the system.

Authorized Users:

List the analyst/operators who have been trained and authorized by the instrument owner and/or regulating agency to operate the XRF equipment.

Operating parameters of the Delta XRF analyzer:

8— 40 kV, 5 - 200 uA max.

Type of system:

Response is: *Handheld/Portable*

User Training Specified:

Indicate that only individuals receiving manufacturer training, *documented by a manufacturer's training certificate*, will operate the system. Additional training may be required. Verify with the local regulating agencies the level and type of training required.

Personal Monitoring

Many government agency registration forms require that you indicate whether or not you intend to perform dosimeter monitoring.

See "Dosimeter Safety Program" on previous page for information regarding typical personal radiation monitoring.

CAUTION

Always keep the following documentation at the job site:

- Copy of *License Registration*
- Other pertinent *government agency* documentation
- Copies of any *dosimeter analysis* reports
- Copy of this equipment's *User Manual*.

C4. Operations

This chapter provides information regarding:

- Configure the Delta Docking Station (DDS)
- Use DDS for Initial Cal Check
- Operation - General
- Start Up Procedure
- Snapshot of Delta User Interface
- Typical Test Procedure
- Ending Test Operations
- Battery Issues
- Additional Cal Check Information
- TIPS - Things You Should Know About the Delta

Safety First !

As emphasized in *"C2.Safety Information,"* it is a priority to keep the analyzer operator's safety in mind at all times.

- Operators, *before turning on the analyzer or using the Delta Docking Station,* should review the safety procedures (*"C2.Safety Information"*).

Set Up and Use the Delta Docking Station

Background

The Delta Docking Station (DDS) provides several key functions:

- Supports an automatic or on-demand Cal_Check procedure
- Charges the "Main" battery located in the instrument's handle
- Simultaneously charges a "Spare" battery in an auxiliary socket
- Provides control information so that both batterys' status can be monitored
- Allows data communication from the Delta to a PC via a powered USB cable

The first phase for preparing to operate a Delta involves:

1. Configuring the DDS with its power and communication cables
2. Using the DDS to support the Delta's initial:
    a. Start up sequence, and
    b. Cal Check procedure.

NOTE

A new instrument is shipped with two fully charged Li Ion batteries. Therefore, prior to **initially** using the analyzer, it is not necessary to charge a battery.

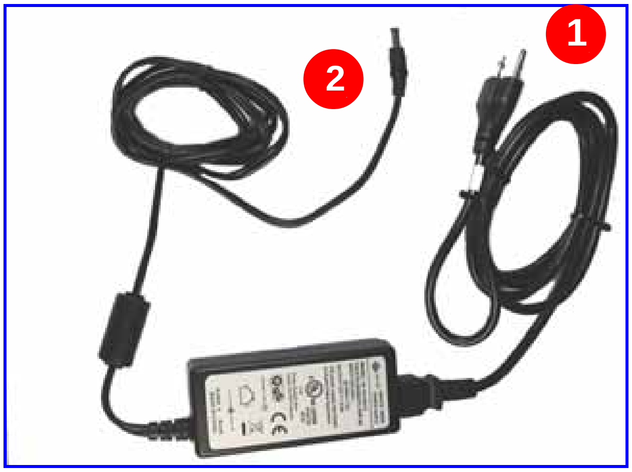
GO TO

- See *Pages 45 and 50* for battery information, including charging, changing, determining status, and Hot Swap techniques.
- See *Page 51* for Cal Check background information.

Configure Delta Docking Station

Rear View - DDS

PN 103209 & PN 103210
Powered Hub USB Cable Assembly



Power Adapter for DDS

Configure DDS with this procedure:

1. Plug the AC power adapter’s line cord (1) into suitable AC outlet.
2. Plug the AC power adapter’s DC jack (2) into the 12 Vdc socket on the rear of DDS
3. {Option at this point: Powered USB cable assembly}
   — Insert connector B (3) into DATA port
   — Insert connector A (4) into USB port of PC

Use the Delta Docking Station for Charging Batteries

The Delta analyzer has a multi-purpose standard accessory:

the **Delta Docking Station** or **DDS**.

In addition to providing an automatic Calibration Check, the DDS delivers **two** charging functions:

1. It charges the installed “Main” battery in the instrument’s **handle**.
2. Simultaneously, it charges a spare or “Dock” battery when its inserted into the special auxiliary charging **socket**.

Charge status is shown in real-time on the Delta’s display screen.

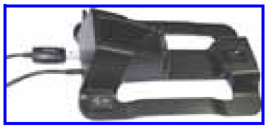
The second docked battery’s status is also shown by the battery icon located on the rear left side of the DDS.

(either “charging = red” or “full = green”)

Battery Status Screen
(Delta inserted in DDS)

Delta Docking Station Procedure for
Battery Charging Functions:

1. Ensure that the DDS has DC power cable installed
   See *page 44*
   The Icon lights are Off **{1}**
2. With Delta Off, place instrument in cradle.
   Take care that Analyzer Icon comes On (Green) **{2}**
   The main battery in the handle is charging although there is no indicator.
3. If Delta On, the Battery Status Screen appears
4. Place a spare battery in the auxiliary socket
   Battery Icon is On (Red - unless fully charged) **{3}**
5. Both batteries will charge; their real-time charge status is displayed.
6. When both batteries are fully charged, the Icons display Green. **{4}**



Cradle

Delta Docking Station Procedure for
Automatic Cal_Check

1. Ensure that the DDS has DC power cable installed
   See *page 44*
   The all Icon lights are Off **{1}**
2. With Delta On, place instrument in cradle.
   Take care that Analyzer Icon comes On (Green) **{2}**
   Battery Status screen is displayed.
3. Ensure that the Battery Status screen stays On.

NOTE: Do not exit this screen -->> the automatic Cal_Check function will not work.

Use the Delta Docking Station for Startup - Initial Cal Check


NOTICE!

This instrument produces ionizing radiation. It should only be used by trained technicians.

Select START if you are a certified user.

DDS w/Empty Cradle

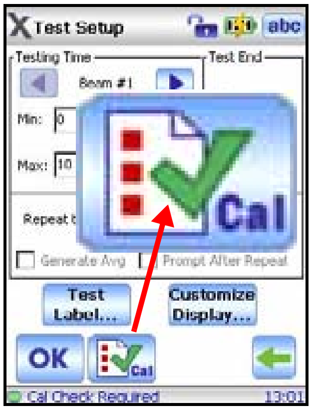
DDS w/Premium Delta in Cradle


Test-Alloy Plus

Cal Check Required 13:01

1. Place analyzer into the Delta Docking Station cradle.
   Ensure that the Delta indicator light is ON.
   This signifies that the instrument is properly seated in the cradle.
2. Press analyzer’s I/O switch (>1 second to turn it ON.)

DDS - Indicator Light
Delta is engaged in cradle

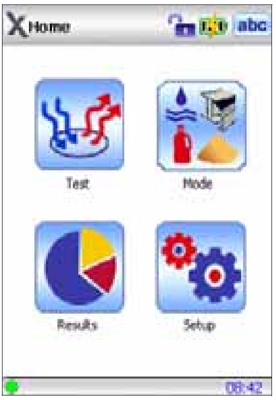

Test Setup

Testing Time: Beam #1, Min: 0, Max: 10

Cal Check Required 13:01

Radiation Safety **NOTICE** appears after a few seconds.

3. Read and respond to notice
   Tap **START** to acknowledge that you are a certified user.
   The UI begins its launch with the following messages:
   Initializing System
   Starting System
   Loading Files


Home

08:42

4. Unit displays a **Test** screen using the Mode last selected.
   4a. If the mode should be changed, go to **Home** screen.
   4b. Select the Mode button
   4c. Choose the desired Mode

5. Return to **Test** {now with your selected Mode}
   Note that message *Cal Check Required* is present.

6. Choose **Tools** icon:
   This launches **Test Setup** screen with Cal_Check button

7. Tap **Cal_Check**
   If necessary, unlock the **Trigger** with the icon at top of screen.
   Procedure begins immediately; it concludes in about 15 seconds.
8. Message *Cal Check - Passed* means you may begin testing.
   Message *Cal Check - Failed* will give error message, such as”! Wrong Count Rate”
   Re-try the procedure
   If unit fails repeatedly, contact InnovX service or your local distributor.

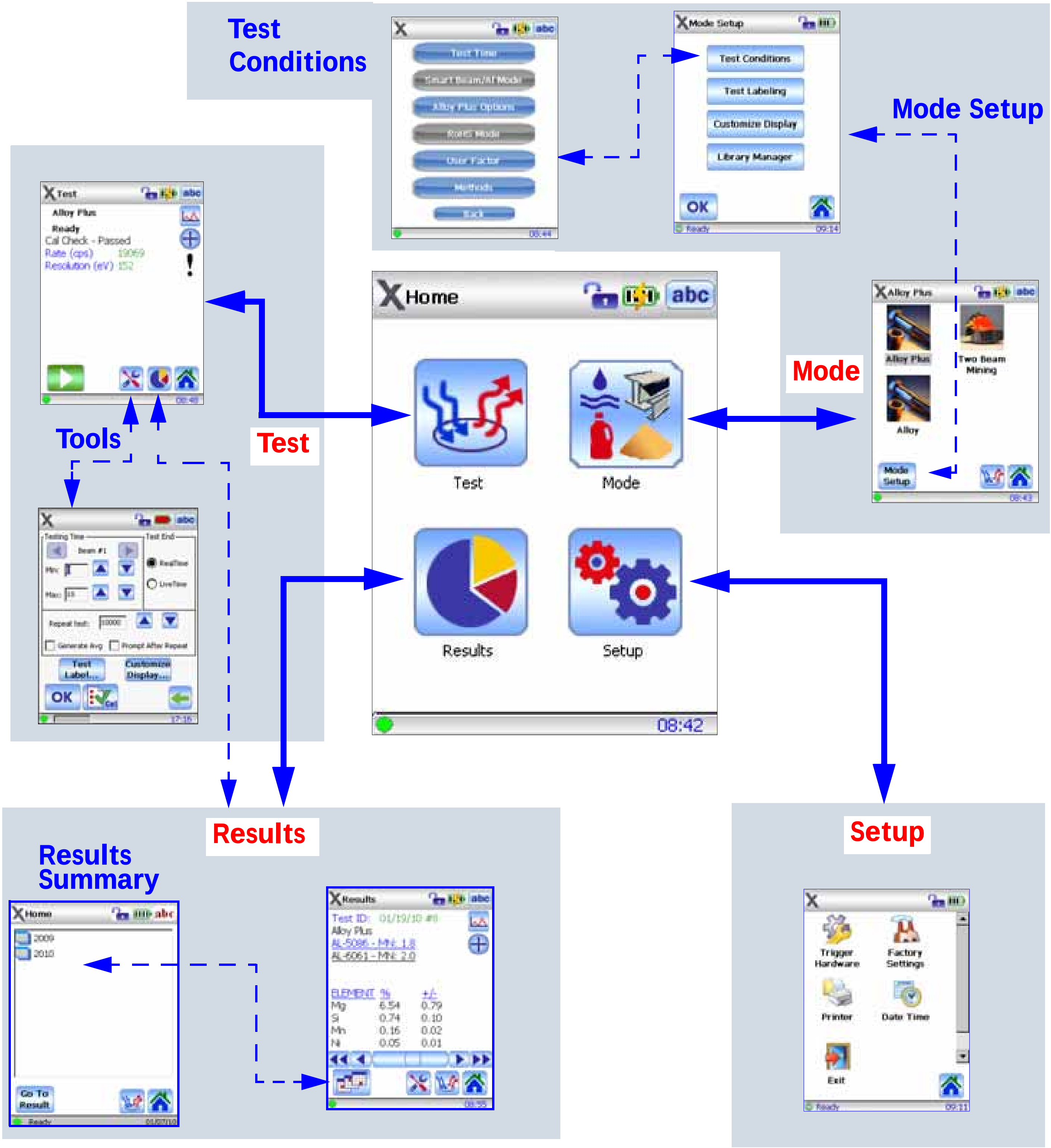

Results

Test ID: 01/12/10 #1
Cal Check - Passed
Rate (cps) 29118
Resolution (eV) 183

17:14

SNAPSHOT of Delta’s User Interface

The Delta’s user interface is introduced by the startup **Radiation Safety** and **Initialization** screens.
Main operations then revolve around the **Home** screen.



ELEMENT	%	+/-
Mg	6.54	0.79
Si	0.74	0.10
Mn	0.16	0.02
Ni	0.05	0.01

Typical Test Procedure

Background

Details of routine testing operations vary depending on the selected analysis mode. Some relevant modes for Delta XRF users are:

- Alloy Modes
  - —Alloy Plus
  - —Fast ID & Pass/Fail
  - —Precious Metals
- Mining Modes
  - —Two-Beam Mining
  - —Mining
  - —Car Catalyst
- Soil Modes
  - —Environmental
  - —Exploration
- Consumer Goods
  - —RoHS
  - —Consumer Products

For the test sequence (below) the instrument has:

- Mode selected (Soil 3 Beam), and
- Cal Check procedure successfully completed.

To conduct a typical test:

1. Remove the instrument from the Delta Docking Station. Place the the measurement window flush against the sampling area. Ensure the sampling area is covered by the window.

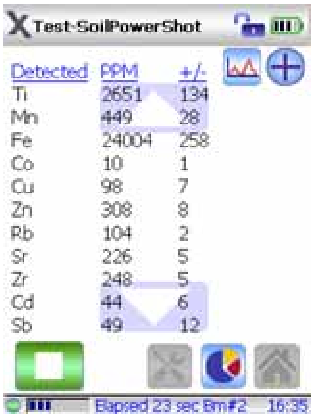
WARNING

Do not point the unit at yourself or any other person during operation. Do not test small samples in your hand. Place them on a surface for testing.
See *C2, Safety Information, Pages 29-31* for examples of safe and unsafe testing techniques.

2. Use one of these techniques to initiate the X-ray beam:
   a. Tap **Start Test (Green Arrow Icon)**, or
   b. Pull the trigger (toggles unit ON); can release the trigger during the test, or
   c. Pull-and-hold the trigger (deadman trigger function is enabled)
   This is a mandatory technique in Canada.

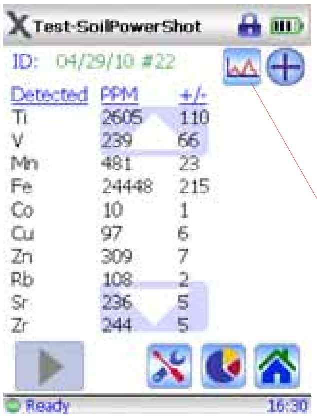
   Trigger options are configurable from:
   Setup > **Trigger Hardware** > **Trigger Settings**

The Test screens are as follow:



Detected	PPM	+/-
Ti	2651	134
Mn	449	28
Fe	24004	258
Co	10	1
Cu	98	7
Zn	308	8
Rb	104	2
Sr	226	5
Zr	248	5
Cd	44	6
Sb	49	12

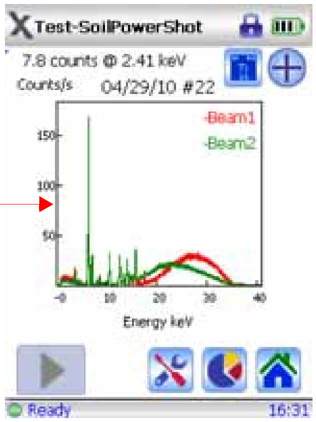
Test results with progress status bar



ID: 04/29/10 #22

Detected	PPM	+/-
Ti	2605	110
V	239	66
Mn	481	23
Fe	24448	215
Co	10	1
Cu	97	6
Zn	309	7
Rb	108	2
Sr	236	5
Zr	244	5

Test result complete; Elements are listed



Spectrum screen for this result (ID: 4/29/10 #22)

End of Day Operations

Save Results

When finishing testing for the day (or shift, or current session} InnovX recommends that test results be saved (e.g. exported) to a PC.

A necessary prerequisite is a DATA connection between the analyzer and PC.

This connection is made in one of two ways:

- Analyzer in DDS cradle — use the powered hub USB cable assembly (PN 103209 and PN 103210) from the DDS' rear Data port to a USB port of the PC
- Analyzer NOT in DDS cradle — use the mini USB B to USB A (PN 101310) cable from the analyzer's Data port to a USB port on the PC

The UI operational sequence is:

1. Navigate from **Home** > **Results** > **Calendar**
2. Select Year, Month, Day listing; it lists the total number of tests for the day
3. Select **Tools**, then **Results Setup**
4. Select the **Export** icon (button)
5. Choose the results to be exported
6. Name the export file (or accept default name)
7. Select Destination to save to
8. Tap the **Export** button

The file is exported.

GO TO

- See "*Delta SW User Interface Guide*" for the details (including options) of this sequence.

Ending Test Operations

When testing and exporting are complete, the user has the following options:

- Turn off Delta with I/O switch or UI (see Exit Options procedure below); store unit in a secure location
- Place Delta in Docking Station and use the "Automatic" option:
  - Leave Delta powered ON;
  - Ensure that DDS is On (Delta ICON is lit);
  - Unit initiates Cal_Check after being idle for five minutes, then every ten hours thereafter.

Exit Option Procedure from UI

Setup Screen

Exit Icon

User has **three** options:

Soft Reboot
Restart OS and restart IX app.

Power OFF
Turn analyzer off after confirmation.

Relaunch
Restart IX app.

Battery Issues

1 — Changing a Battery

To CHANGE the battery:

1. Hold the instrument by the handle, upside down, so the bottom of the instrument base is pointing upward with the nose pointing away from the operator.
2. Pull the rubber latch and lift cover.
3. Remove the existing battery using the tab. A new instrument will **not** have an installed battery.
4. Insert the charged battery into the analyzer with the battery connectors facing to the left. The battery slot is keyed so that the battery can be inserted only one way.

2 — Battery Status

To TEST a Li-ion battery's charge status:

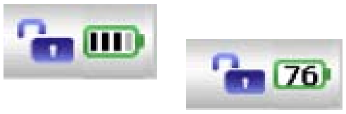
EXTERNAL battery test —

1. Push the white button on the battery.

   The green lamps indicate the percent of charge, from less than 25% to 100%.
2. If a battery has a charge of less than 25%, use the Delta Docking Station to establish a full charge. See *Page 45*.

INTERNAL MAIN battery test —

1. The battery icon from any UI screen (upper right side) shows an approximate value of charge.
2. Tap the battery icon and a more precise charge percentage is displayed as a number.

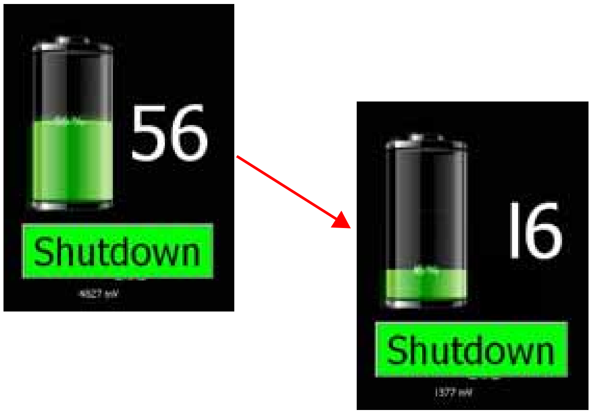


3 — HOT SWAP for Delta Battery

A battery HOT SWAP capability is a **standard feature** with the Delta analyzer. An operator can remove and replace a battery without having to shut down, restart, or Cal Check.

When the battery is removed:

- A "Shutdown" status display gives the percentage of internal charge remaining.
- If the internal charge reaches 0, you have to re-start the unit with the I/O switch, after inserting a fresh battery.
- If red X-ray indicator lights flash, the battery voltage is too low.



Cal_Check Information

Cal_Check Facts

Question: What is involved with the Cal_Check procedure?

Answer: The analyzer:

- Collects a spectrum on a known standard (Alloy 316 Stainless Steel)
- Compares a variety of parameters to values stored when the instrument was calibrated at the factory.
- When comparisons are within pre-set tolerances, the unit determines that it remains properly calibrated.

GENERAL FACTS INCLUDE:

- Cal_Check must be performed when the analyzer requests the procedure.
- The *Start* button and trigger are disabled until a successful Cal_Check is achieved.
- You can run a Cal_Check at any time during *InnovX* software operation, except during a test.
- When Cal_Check is in progress, the x-ray indicator light assembly blinks.This indicates that the X-ray tube is energized and the filter wheel is operational. In addition, a status bar appears on the UI display, showing the percentage completion for the measurement.
- The Cal_Check procedure takes about 15 seconds.

Cal_Check Procedures

There are two separate techniques:

- **In the test laboratory** - Use the DDS to initiate “on-demand” procedure. Described above in *“Use the DDS for Startup - Initial Cal Check”*:

Also have the “Automatic” option, as follows:

Leave Delta powered On and InnovX software running;

Ensure that DDS is On (Delta ICON is lit);

Unit initiates Cal_Check after being idle for five minutes, then every 10 hours thereafter.

- **In the field** - Use the Coupon {the procedure is described below)

1. Place the 316 stainless steel Cal_Check coupon on a flat surface.

   See *C2. Safety Information, Page 29* for safety measures that must be observed.
2. Position the analyzer’s measurement window flush over the coupon.
3. With the Test Setup screen invoked, tap the Cal Check icon. There are now two techniques to choose from:
   - Tap the “Start Test” icon, or
   - Pull the trigger (or pull-and-hold if using “Deadman Trigger”)
4. The procedure takes about fifteen seconds.

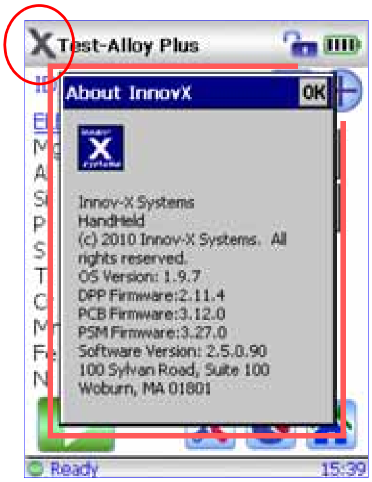
NOTE

Improperly positioning the window over the coupon can result in a failure.

5. When Cal_Check completes successfully, you may begin testing.
6. If Cal_Check fails, ensure that:
   - Coupon is positioned correctly.
   - X-ray indicator assembly is blinking during the procedure.
   - You have waited several seconds before starting the procedure.
7. If Cal_Check fails again,
   - Shut down the Delta software.
   - Shutdown and restart the analyzer.
   - Launch another attempt to Cal Check.

If Cal_Check fails repeatedly, contact Innov-X Systems Customer Service or your local distributor. Contact information is available at appendix *A6. Packing and Shipping*

TIPS - or - things you should know about the Delta



Innov-X Systems
HandHeld
(c) 2010 Innov-X Systems. All rights reserved.
OS Version: 1.9.7
DPP Firmware:2.11.4
PCB Firmware:3.12.0
PSM Firmware:3.27.0
Software Version: 2.5.0.90
100 Sylvan Road, Suite 100
Woburn, MA 01801

System Information

To call information “About InnovX” tap the **X** (InnovX icon) in upper left of UI screen. This provides various firmware and software versions that are installed on the analyzer.

UI Screen Note

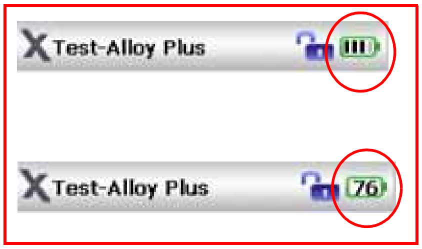
All User Interface screens have a time-out (power saving) feature that causes the screen to go blank after 45 seconds if the UI is not accessed or the unit is not moved.

However, the analyzer is still running.

Restore the screen by tapping it or by moving the instrument.

Battery Status Info #1

When you turn on the instrument and you may not be aware that the battery is low, the X-ray indicator (Red LEDs) flashes dimly and briefly. The unit will not turn ON. Swap out the battery.



Battery Status Info #2

The on-screen battery icon (in upper right corner of UI) shows “real-time” battery charge status in a **graphical** way.

Tap this icon to receive a **numeric** value for battery charge level.

Delta Docking Station to Delta Analyzer: Contact Status

Keep the rubber boot attached to instrument when inserting it into the DDS. This helps ensure that the DDS contact pins are engaged.

The DDS analyzer icon (rear left corner) should be ON.

If the rubber boot is not available, and the analyzer icon remains OFF, use a small piece of padding under the handle to ensure contact.

C5. Alloy Analysis Modes

Alloy analysis for the Delta family includes:

- Wide range of modes and calibrations
- Outstanding performance for a variety of materials

There are five Alloy modes/calibrations:

ALLOY Use with: **ALL Models**

ALLOY

Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, Hf,
Ta, Re, Pb, Bi, Zr, Nb, Mo, Ag, Sn, Sb

Fundamental Parameters Analysis for metal alloys.
Alloy library including 300+ grade specifications, common tramp limits, including full editing capabilities.

ALLOY Plus Use with: **Premier** and **Standard Only**

ALLOY PLUS

Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, Hf,
Ta, Re, Pb, Bi, Zr, Nb, Mo, Ag, Sn, Sb
PLUS Mg, Al, Si, P

Fundamental Parameters Analysis for metal alloys.
Optimized beam condition for extended light element performance.
Alloy library including 300+ grade specifications, common tramp limits, including full editing capabilities.

FastID Use with: **All** Models

Spectral signature matching for alloy grade & chemistry calculation.
Full library editing & alloy matching capabilities included.

Pass/Fail Use with: **All** Models

Spectral signature or **chemistry matching** for alloy grades.
Customer created library with min/max grade specifications.
Full library editing & alloy matching capabilities included.

Precious Metals Additions Use with: **All** Models

ADDS Ir, Pt, Au, Rh, and **Pd** to Analytical Analysis calibration suite.

Introduction to Alloy Analysis Modes

ALLOY

ALLOY PLUS

The Delta family of instruments currently presents six unique modes for alloy analysis. The core analytical analyzer modes/types are:

Alloy mode - **Classic** (PiN detector based) type

Alloy Plus mode - **Standard** (SDD detector based) type

- **Premium** (SDD detector based) type

All three analyzer types can support additional alloy-oriented modes, such as

FastID

Pass/Fail

Precious Metals (No added details)

Alloy analysis utilizes a Fundamental Parameters (FP) algorithm to determine elemental chemistry. This method calculates chemistry from the spectral data, without the requirement of stored fingerprints. The Analytical FP calibration is done at the factory, and requires no user set-up or recalibration. The software also searches an alloy grade library to produce a grade match based on the calculated chemistry. Analytical mode can provide a **grade ID** and **chemistry** in as little as one second, with increased precision for longer test times.

Alloy mode/Classic type supports Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, Hf, Ta, Re, Pb, Bi, Zr, Nb, Mo, Ag, Sn, Sb.

Alloy Plus mode /Standard type and Premium type supports light elements Mg, Al, Si, and P in addition to the core list of elements from the Alloy mode.

Standard and Premium units expand the Limits of Detection range permitting operators to analyze these light elements without a vacuum or helium purge requirement.

Both modes have a feature, Altitude Compensation, which automatically corrects calibrations based on barometric pressure.

Determination of Grade Identification:

Analytical modes utilize a Factory Grade Library consisting of a set of minimum and maximum values for each element in an alloy.

There is a SPECIFIC Alloy Factory Grade Library for EACH Delta model.

See appendix *A8. Alloy Grade Libraries* for a listing of the alloys that are contained in each Factory Grade Library.

Additionally, every analyzer is shipped with a "**Tramp**" library comprised of seven base alloys. These seven items with their min/max element values are increasingly valuable to fast and accurate sorting in Pass/Fail and FastID modes.

The libraries can be searched individually or together. All libraries, including each Factory Grade Library, can be edited by the user. However, InnovX strongly suggests that users NOT edit the Factory Grade Library. Instead, copy the Factory Grade Library to a USER library, then make any edits on it.

Match Number Concept

After calculating chemistry with the Fundamental Parameters algorithm, *Innov-X* compares the chemical composition values to grade tables stored in a grade library. The application calculates the value for a parameter called *Match Number*. This provides an indication of how close the measured alloy's chemistry is to library values.

- The *lower* the Match Number, the *better* the match.
- A Match Number of 0 is an *exact match*, meaning that the calculated chemistry for all elements falls within the grade table specifications.

GO TO

- See **"***Delta User Interface Guide"* (PN 103202) for a complete description of the *Innov-X* application's User Interface.
- See *A8. Alloy Grade Libraries* for listing of each model's "Factory Grade Library"
  - A "Spectral Fingerprint" library that would be used for "FastID" and "Pass/Fail" analysis is created by the customer.

Match Issues

There are three Match determination possibilities provided within the Analytical modes:

Exact Match

An unknown alloy is matched to one of the grades contained in the Grade Libraries, and a *Grade ID* appears on the *Results* screen. Often other grades are listed with their accompanying Match Numbers. The analyst has the opportunity to view their elemental chemistries and see how they differ from an exact match.

Multiple Matches

In some cases, several grades are shown as possible matches. This can signify one of two conditions:

- There was not enough statistical information to definitively separate two or more alloys. The actual identification of the unknown alloy is one of the grades listed. Often increasing the testing time makes it possible to separate the alloys.
- There was sufficient statistical information, but the test sample did not meet any of the existing specifications with enough precision to cause an exact match identification.

No Match

If no matches are found within the libraries, the words *NO MATCH* appear.

There are several causes for a NO MATCH result:

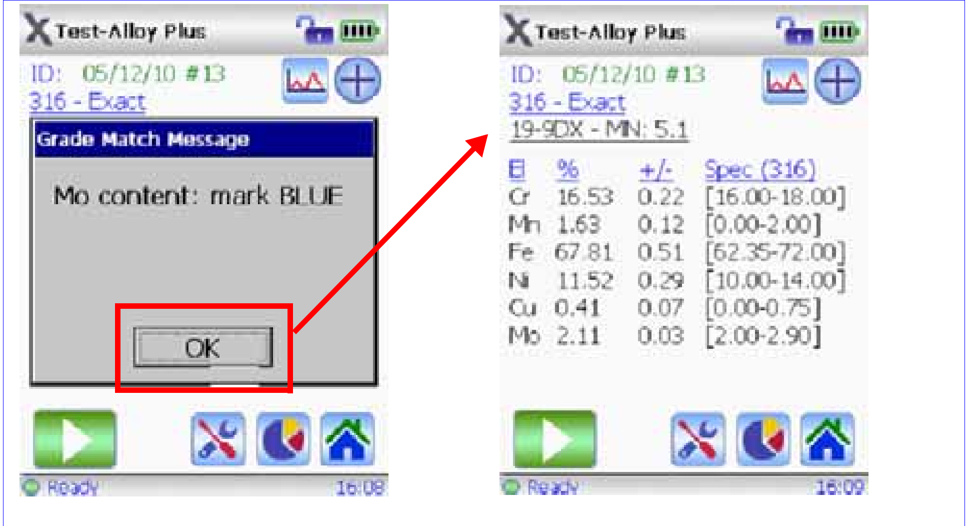
- The test sample does not meet any of the specifications in the Grade Library.
- The test sample is coated; Remove the coating by grinding, filing, or sanding and repeat the test.
- The testing time was too short.
  - Increase the testing time and measure the sample again.
- The Match Number is too low.
  - If possible, increase the Match Number

Scrap and Recycling Features

Delta analyzers in Alloy or Alloy Plus modes support many new features to specifically enhance scrap processing by maximizing speed and accuracy.

Grade Match Messaging (GMM)

User or Yard Manager can assign pop-up messages to specific alloy grades



ID: 05/12/10 #13
316 - Exact

Mo content: mark BLUE

ID: 05/12/10 #13
316 - Exact
19-9DX - MN: 5.1

El	%	+/-	Spec (316)
Cr	16.53	0.22	[16.00-18.00]
Mn	1.63	0.12	[0.00-2.00]
Fe	67.81	0.51	[62.35-72.00]
Ni	11.52	0.29	[10.00-14.00]
Cu	0.41	0.07	[0.00-0.75]
Mo	2.11	0.03	[2.00-2.90]

- Quick start for next test, or
  view the chemistry details with one click

Grade Match Messaging offers:

- Immediate sorting instructions
- Less operator training
- More efficiency and higher throughput

SmartSort

Automated sorting decisions that allow users to maximize speed and sorting accuracy. Some features include:

- Specific grades set up to automatically extend testing time.
- Maximize efficiency for speed testing by automatically extending test time for light elements (Mg, Al, Si, P, S)
  - Eliminate unnecessary long tests

Nominal Chemistry

Nominal Chemistry looks for ‘invisible’ elements, based on grade ID, including:

- Elements not tested under active beam, (like Al in Beam 1)

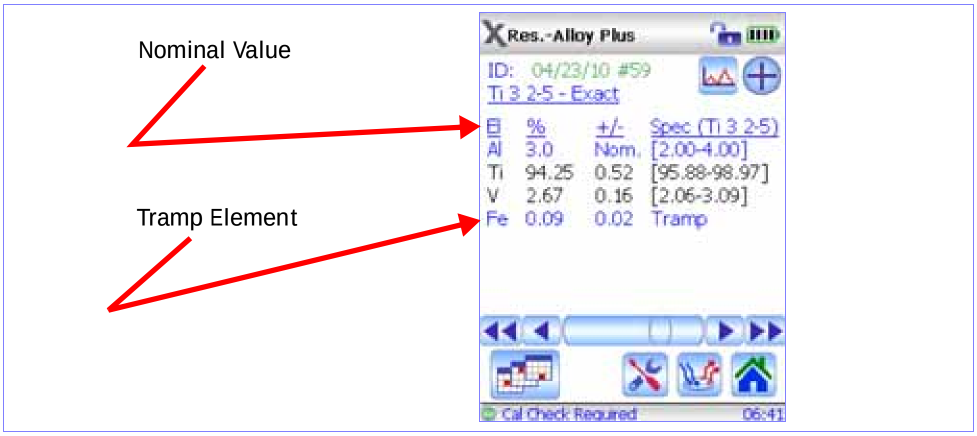
  — or —

- XRF invisible elements (like B or C)

Tramp Library

Analyzers with Alloy or Alloy Plus mode come pre-loaded with a tramp library based on industry standards.

- Operators may assign other “Tramp” elements with max tolerated concentration for individual elements in seven unique graded families.
- Analyzers can report tramp material (optionally) and simplify grade match by not counting small, expected amounts of tramp elements against the grade match.



ID: 04/23/10 #59

Ti 3 2-5 - Exact

El	%	+/-	Spec (Ti 3 2-5)
Al	3.0	Nom.	[2.00-4.00]
Ti	94.25	0.52	[95.88-98.97]
V	2.67	0.16	[2.06-3.09]
Fe	0.09	0.02	Tramp

Cal Check Required 06:41

See appendix *A8. Alloy Grade Libraries* for a discussion of the Tramp Library concept, including:

- How the InnovX Tramp Library works
- Practical advantages of the Tramp element approach
- List of seven Tramp Base Alloys

Test Sample Considerations

Coated or Painted Samples

XRF is a surface analysis technique, where X-rays penetrate a very short distance into most alloy samples. Therefore, the analyzer detects what is on the surface of an alloy, rather than what comprises the bulk of the material. If a material has been coated, plated, painted, or has had some sort of surface treatment, such as heat treating, it may be misidentified.

For example, a steel piece painted grey may show high concentrations of titanium from the paint, and may be misidentified as a titanium alloy. In another example, large amounts of metal dust or turnings on a surface may be detected by the analyzer.

To ensure proper identification of coated materials, grind an area slightly larger than the analyzing window to remove the coating. It is important to select the correct grinding material so as to not interfere with the analysis.

Do not use Silica for a Silicon analysis.

It may not be necessary to completely clean and polish all materials, however, remove obvious metal dust.

Mixed Samples, Heterogeneous Materials

Often finished metal pieces may consist of more than one type of metal. In addition, you may wish to measure mixed turnings, or an assortment of small pieces. In these cases, remember that the analyzer measures the entire area covered by the analyzing window and reports an average chemistry. For turnings, this is useful, as the analyzer provides an average composition. However, if two or more pieces of metal cover the window, the results is just an average reading, and may tell very little about the composition of one piece or the other.

When shooting metal pieces, or welds, ensure that **only** the metal of interest is covering the analyzing window.

Small and Irregularly Shaped Samples

To measure samples smaller than the analyzing window:

- Increase the testing time.

— and —

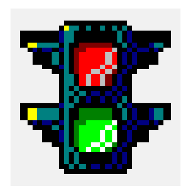
- Maximize the material in contact with the window.

The precision of analysis for small parts measurements is reduced, as the signal from smaller samples is less than for samples that completely cover the window. If possible, analyze the largest, flattest side of an irregularly shaped object.

GO TO

- See *A4. Typical Test Procedure* for description of a Test sequence.
- See **“***Delta User Interface Guide”* (PN 103202) for a complete description of the *Innov-X* application’s User Interface.

Introduction to FastID Mode (All Models)



FastID mode is designed to quickly identify an alloy. It uses an empirical calibration method known as a “type” calibration. It is most useful where the number of alloys to test is small and well known.

FastID is best suited for Positive Material Identification (PMI) and QA/QC applications.

For example, where alloy producers or fabricators handle materials that may be very similar or where maximum user simplicity is a primary concern.

This mode offers:

- Simplified results (grade name only or less information on tramp elements).
- A narrow, customized grade library base upon stored spectral fingerprint reference standards.
- **Full chemical analysis based on reference standard assays.**
- Results which are the best combination of SPEED and ACCURACY.
  - A Grade and Chemistry result in as little as one to two seconds.
- User selectable match criteria settings.
- Expansion of up to 500 additional alloy grades and assays (alloy chemistries) — password protected.
- Multiple independent grade libraries. You choose to search one or more libraries.
- All libraries are editable

How FastID works:

Prerequisite: The operator creates a “custom FastID fingerprint’ library by testing an array of reference standards. This list spans the number of alloys for which he is interested.

1. Delta’s XRF process allows a test sample to create a spectral fingerprint.
2. Analyzer compares this spectral fingerprint to entries from library of many certified spectra, the “custom FastID fingerprint” library.
3. Analyzer finds the best spectral match to the sample spectra: thus identifying and reporting the matching alloy grade.
4. If concentration data has been entered for the standards, the instrument then calculates the sample’s **chemistry**.

   The reported chemistry data are an extrapolation from standard intensity data stored in the customer -generated fingerprint library.

   The user gets a real time grade match and a precise report of the chemical composition of the sample.

NOTE

— Because FastID mode performs a spectral match to a library of reference standards, it is important that before testing, a “likely” stored reference standard be in the customer-created FastID fingerprint library.

Introduction to Pass/Fail Mode (All Models)

Pass/Fail mode is designed for high-throughput alloy sorting and quality control.

Mode Features

- All test samples are sorted by comparison to an operator-selected reference standard.
- Results are displayed as a *PASS* or a *FAIL*, depending on whether they match the reference standard.
- Pass/Fail criteria may be based on:
  - “quality of fit” to the selected spectral fingerprint

    — or —

  - elemental chemistry.
- Pass/Fail ranges may be implemented for one or more elements.
- This mode offers a full range of options from the simple sorting of mixed loads in a recycling facility to QC on specific element(s) of the most complex superalloys.

Pass/Fail mode has two options: *Fingerprint and Chemistry*:

1. Fingerprint Option

Select this method when the goal is to determine whether or not test samples are a **specific grade**.

Fingerprint Pass/Fail and FastID use the same method to determine a match.

Data from analyzed samples are compared to the reference standard fingerprint.

If the differences between the fingerprints are small enough, the sample is judged to be of the same grade as the reference sample.

This method requires:

Only that the library contains a valid fingerprint for the reference standard.

2. Chemistry Option

Select this method to determine whether the chemistries for specific elements fall **within specified min/max grade** specifications.

Chemistry pass/fail process is:

1. Analyzer uses the fingerprint method to determine whether the sample matches the reference sample.
If it does not, it automatically fails.

2. If Step 1 has a match, the alloy chemistry is calculated from assays stored for the standard fingerprint.

3. The calculated chemistry for each element is compared to the values stored in a *Grade Table*.

In order for a sample to pass, all the chemistries must be within “n” standard deviations of the min and max values specified in the grade table.
Number “n” is specified by the user.

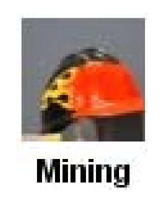
This method requires three items:

(1) a valid fingerprint, (2) assays for that fingerprint, and (3) Min/Max values saved in the library.

C6. Mining Modes

There are three Mining modes

MINING Use with: **ALL models**



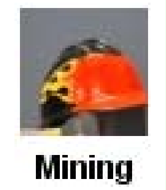
Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, As, Pb,
Bi, Zr, Mo, Ag, Cd, Sn, Sb

(elements may be customized on request)

Fundamental Parameter based calibration for **ore grading and percent-level** analysis of **process bulk** samples.

Suitable for measurement of percentage level analyte concentrations, 0.5% and greater.

2 BEAM MINING Use with: **Premier** and **Standard** Only



Mg, Al, Si, P, S, Cl, K, Ca,
Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, As, Pb,
Bi, Zr, Mo, Ag, Cd, Sn, Sb

(elements may be customized on request)

Mining mode optimized for **SDD based systems to enhance SPEED and LOD for light elements**

CAR Catalyst Use with: **All** Models

Mode ICON
T.B.A.

Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, Hf,
Ta, Re, Pb, Bi, Zr, Nb, Mo, Ag, Sn, Sb
PLUS Rh, Pt, Pd

Accurate analysis of **bulk recycled catalyst** materials

The Mining modes/types are:

- **Mining** mode - **Classic** (PiN detector based) type
- **2 Beam Mining** mode - **Standard** (SDD detector based) type
- **Beam Mining** mode - **Premium** (SDD detector based) type
- **Car Catalyst** mode - **All** types

These modes utilize a Fundamental Parameters algorithm which automatically corrects for inter-element results.

The units can analyze:

- *in situ* (directly on the ground),
- prepared soil samples (in sample cups)
- bagged samples

Best Practices

Check Standards

Measure a check standard after each Cal Check, and periodically throughout the day. This confirms that data continues to be as accurate as possible.

The standards provided with Delta instruments are contained in special XRF sample cups. These cups have film windows (through which the soil can be viewed and analyzed) on one side, and solid caps on the other side.

Sample Presentation

in situ testing

In situ testing is performed by pointing the analyzer at the ground. Clear any grass or large rocks away and hold the analyzer with the probe head front flush to the ground.

Since dirt can accumulate on the analyzer window, wipe the window clean after each analysis. Ensure the window is not ripped or punctured.

Bagged or prepared sample testing

Analyze prepared samples in a sample cup, through its Mylar window. Place the instrument's measurement window directly over the sample cup with the Mylar side up.

Preparation considerations include:

- Avoid measuring very thin samples, as this can affect results. Prepare samples cups to contain at least 15 mm of packed samples.
- When analyzing bagged samples, ensure that sufficient sample material exists in the bag to completely cover the window with a sample thickness of a minimum of 15 mm.
- When using bags, cheaper bags (having thinner plastic walls) are better than more expensive ones (which have thicker plastic walls).

Optional Accessories

Accessories that can assist in Mining mode testing are:

- A-035: Soil Foot
- 990055: Soil Extension Pole
- A-020-D: Workstation - portable, fully shielded, closed beam test stand for bench-top or remote controlled testing.
- Trimble Xplorer Package

Typical Test Procedure

GO TO

See *“A4. Typical Test Procedure”* for description of a Delta Test sequence..

Mining Mode Options

Test length in Mining Mode is **user defined**.

GO TO

Refer to *“Delta User Interface Guide, User Factors”* for procedure to modify User Factors..

Factors

Mining modes allow you to create your own set of **factors**, focusing on particular elements of interest or correcting for matrix effects.

You can make several different *Factor* tables, allowing analysis of a variety of samples.

Setting Mining User Factors

Example:

A group of samples covering the full concentration range for each element of interest are identified. Each sample is homogenized and split. A portion of each sample is sent to an outside lab for analysis. The other portion is analyzed with the analyzer. For best results ensure that the samples are very well homogenized, and characterized, so the correlation is quite good.

Procedure:

Plot the data. Innov-X data must be on the X-axis, lab values on the y-axis.

CAUTION

ENSURE that you use this order: Innov-X data on X-axis and lab data on the Y-axis.

Determine the linear best fit with both the slope and intercept for each element.

The slope and intercepts for these graphs are entered directly into the analyzer. In many cases it is sufficient to enter just a correction for the slope as the intercept is almost zero. In others, enter the slope and intercept.

You can enter multiple sets of user factors for different applications, or different ore bodies. A group of factors is given a name, and then the factors are entered. The factor set can then be selected by name.

NOTES

C7. Soil Modes

The Delta family currently supports two soil modes, **Soil** and **3 Beam Soil**. Each mode has a possibility of two default element suites, **Environmental** and **Exploration**.
Note that both calibration packages cannot reside on one instrument.:

SOIL Environmental

Use with: **All** Models

K, Ca, S, P, Cl, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Hg, As, Pb, Se, Rb, Sr, Zr, Mo, Ag, Cd, Sn, Sb, Ba

(elements may be customize on request)

Compton Normalization algorithm designed for achieving lowest Limit of Detection (LOD) possible for **SOIL** and **BULK** samples.

PowerShot and SmartShot 3-beam modes included.

SOIL Exploration

Use with: **All** Models

K, Ca, S, P, Cl, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, Hg, As, Pb, Bi, Se, Th, Rb, U, Sr, Zr, Mo, Ag, Cd, Sn, Sb

(elements may be customized on request)

Compton Normalization algorithm designed for achieving lowest Limit of Detection (LOD) possible for exploration samples. PowerShot and SmartShot 3-beam modes included.

Soil Mode Beam Selection

SmartShot Beam Mode:

Uses a single incident bean setting (Transition Metals) otimized to deliver ultra fast results with solid LOD performance across the periodic table. SmartShot offers excellent sensitivity in the fastest testing time possible.

PowerShot Beam Mode:

Offers a fully optimized, multi-beam analysis method that provides exceptional LODs for all elements analyzed - heavy metals, transition metals, and light elements. PowerShot can be used to analyze the full element range, or to focus in on a particular element of interest, such as Cr, Cd, Ni, or Cu. Any or all of the following beams conditions may be selected:

- Heavy Elements
- Transition Metals
- LEAP (Light Elements)

Use this procedure to configure beam selections:

From the Mode Setup screen select **Test Conditions**.

Select the **LEAP** option

○ SmartShot
● Customized Powershot(s)

Select Desired Powershot(s)

☑ Heavy Elements
☑ Transition Metals
☑ LEAP

(Multiple beams may be selected)

Configure one or more **Powershot(s)**. Note that multiple beams may be chosen.

Press **Save** to return to soil testing.

Best Practices

Check Standards

Measure a check standard after each standardization, and periodically throughout the day, for a minimum of one minute. Elemental concentrations for elements of interest, in the range expected at the site, plus or minus the error on the reading, should be within 20 percent of the standard value. *A2.Soil Testing* describes recommended quality assurance considerations in detail.

The standards provided with the analyzer are contained in XRF sample cups. These containers have a film window (through which the soil can be viewed) on one side, and a solid cap on the other side. Always measure samples through the film window.

Sample Preparation

Preparation considerations include:

- Avoid measuring very thin samples, as this can affect results. Prepare samples cups to contain at least 0.5”(usually 4-8 grams) of packed samples.
- When analyzing bagged samples, ensure that sufficient sample material exists in the bag to create a a sample thickness of a minimum of 15 mm for a spot size that is larger than the analyzer’s measurement window.
- When using bags, cheaper bags (having thinner plastic walls) are better than more expensive ones (which have thicker plastic walls).

C8. Consumer Goods Analysis Modes

There are two consumer goods modes:

RoHS

RoHS regulated elements- **Cr, Hg, As, Pb, Br, Cd**,
PLUS Cl, Ti, Fe, Co, Ni, Cu, Zn, Sn, Sb, Ba

Analysis software for measurement of restricted elements in electronics and consumer goods. Auto-compensations built in for metal, polymer, and mixed matrices.

Consumer Products

Analysis software designed for CPSIA & Prop 65 testing. **Pb** content displayed as **Pass/Fail** based on regulated limits.

Additional elements Cl, Ti, Cr, Fe, Co, Ni, Cu, Zn, Hg, As, Br, Cd, Sn, Sb, Ba also reported.

Introduction to RoHS Mode

Toxic metals in consumer electronics are the focus of EU regulations that have worldwide ramifications. These new directives currently include:

- *Restriction of Hazardous Substances* (**RoHS**)
  - Designates maximum allowable levels of Pb, Cd, Cr^{6+}, Hg and certain Br-containing flame retardants (PBB and PBDE) in new electrical and electronic equipment sold into the EU.

The limits for RoHS elements are:

- <0. 1% Pb, Cr6+, Hg, Br (as flame retardants, PBB and PBDE)
- <0.01% Cd

The Innov-X analyzer is a screening tool for RoHS Compliance. It is used to:

- Directly analyze the amount of toxic metals in electronics,
- Identify quickly whether a plastic is made of or contains:
  - PVC
  - A brominated flame retardant.

XRF measures *total elemental composition*, regardless of speciation of the element. Therefore, it reports

- Total chromium including the concentration of hexavalent chromium plus any other forms of Cr.
- Total bromine, however cannot distinguish the type of brominated flame retardant present in analyzed materials.

In order for XRF to be quantitative, samples must be:

- Homogeneous
- Have a certain minimum sample thickness
  - Five (5) mm for polymers and light alloys
  - Fifteen (15) mm for liquid samples
  - One (1) mm for other alloys

If samples are heterogeneous, too thin, or too small, only qualitative screening is possible.

The IEC-ACEA (International Electro-technical Commission – Advisory Committee on Environmental Aspects) recommends XRF screening.

Test Overview

The Delta analyzer controlled by *InnovXPC* application software (in RoHS mode) automatically executes a test sequence to determine:

- Whether a sample is an **alloy**, **polymer**, or **mixed**.
  - “Mixed” indicates heterogeneous samples consisting of both polymer and alloy, such as wires or circuit boards.
- Whether each RoHS element **passes**, **fails**, or is **inconclusive** when compared to a set of stored criteria.
  - These criteria are either those recommended by the IEC, or ones added by the user.

The sequence begins with the instrument utilizing tube settings appropriate for analyzing a polymer sample. The following logic applies:

- If the sample is determined to be a polymer or mixed, the test continues, and a calibration based on a polymer matrix is used.
- If the sample is found to be a metal alloy, the analyzer switches to a secondary test, using an alloy matrix calibration, in order to determine correct alloy concentrations.

Check Standards

Innov-X Systems recommends that a check standard be measured after each Cal Check procedure, and periodically throughout the day.

Two certified standards are provided for verification.

- At least one standard should be measured for a minimum of two minutes.
- Concentrations for target elements (plus or minus the error on the reading) should be within 20% of the standard value.
- Standards provided are contained in XRF sample cups with a Mylar window (through which the plastic pellets can be viewed) on one side, and a solid cap on the other side.
- Samples should be measured in the sample cup, through the Mylar window.

Sample Presentation

Since many pieces of plastic analyzed for ROHS compliance are very small, take care to measure them in a safe and accurate manner. See the IEC-ACEA recommendations for minimum thickness of test samples.

IEC Quantitative Screening Requirements

RoHS requirements are derived from the *"Directive 2002/95/EC of the European Parliament and of the Council of the European Union on the restriction of the use of certain hazardous substances in electrical and electronic equipment."*

Dated 27 January 2003.

Important Current Issues

- At this User Manual's release date (May, 2010), the IEC requirements (including limits and exemptions) have **not been formally accepted.**
  A timetable for acceptance has not been established.
- Users must be aware that the information in Figure 1 concerning RoHS screening limits has been extracted from **proposed/draft** IEC-ACEA documentation**.**
- **Innov-X strongly advises users to have their own compliance departments determine the current status of the requirements that they must meet.**

Elemental Range/Limits for RoHS Compliance

	Polymer Materials				
—RoHS— Elements	**P**ASS	**Lower Limit**	**Incon-clusive**	**Upper Limit**	FAIL
Cd	P	≤(70-3s)	< X <	(130 +3s)≤	F
Pb	P	≤(700-3s)	< X <	(1300+3s)≤	F
Hg	P	≤(700-3s)	< X <	(1300+3s)≤	F
Br	P	≤(300-3s)<	X		
Cr	P	≤(700-3s)<	X		
	Metallic Materials				
Cd	P	≤(70-3s)	< X <	(130 +3s)≤	F
Pb	P	≤(700-3s)	< X <	(1300+3s)≤	F
Hg	P	≤(700-3s)	< X <	(1300+3s)≤	F
Br			N/A		
Cr	P	≤(700-3s)<	X		
	Electronics				
Cd	P	LOD	< X <	(150 +3s)≤	F
Pb	P	≤(500-3s)	< X <	(1500+3s)≤	F
Hg	P	≤(500-3s)	< X <	(1500+3s)≤	F
Br	P	≤(250-3s)<	X		
Cr	P	≤(500-3s)<	X		

Figure 1: Proposed Screening Limits for RoHS Elements

Grade Definitions for Screening

Grade	Proposed Screening Criteria
PASS	Results for ALL elements are lower than the lower limits shown in Figure 1.
FAIL	Result for ANY element higher than the higher limits shown in Figure 1.
INCONCLUSIVE	Result of the quantitative analysis, for any of the elements Hg, Pb, or Cd, is in the region defined as intermediate, OR if the result of the elements BR and Cr is higher than the higher limits shown in Figure 1, the analysis is inconclusive. Additional investigation must be performed.

GO TO

- See *A4. Typical Test Procedure* for description of a Test sequence.
- See **“***Delta User Interface Guide” *(PN 103202) for a complete description of the *Innov-X* application’s User Interface.

Introduction to Consumer Products Mode

Background

This mode is dedicated to testing items for Lead (**Pb**) content.

The result output is **Pass/Fail** based on the regulated limits that are specified in:

- **CPSIA** (the Consumer Products Safety Improvement Act of 2008)
- **Prop 65** - refers to California Proposition 65 enacted in 1986

Additional elements that may be reported are:
Cl, Ti, Cr, Fe, Co, Ni, Cu, Zn, Hg, As, Br, Cd, Sn, Sb, Ba

Regulatory limits vary with the governing body, state-to-state, and country-to-country. European Union nations generally use the RoHS limits and testing practices.

The regulatory limits for Pb are:

- CSPIA: 300ppm currently, but going to 100ppm
- RoHS: see Table 1.0 on Page 70

GO TO

- See *A4. Typical Test Procedure* for description of a Test sequence.
- See **“***Delta User Interface Guide”* (PN 103202) for a complete description of the *Innov-X* application’s User Interface.

A1. Overview: X-Ray Fluorescence (XRF) Spectrometry

Basic Theory

Although most commonly known for diagnostic applications in the medical field, x-rays are the basis of many powerful analytical measurement techniques, including X-ray Fluorescence (XRF) Spectrometry.

XRF Spectrometry determines the elemental composition of a material. This method identifies elements in a substance and quantifies the amount present of those elements. An element is defined by its characteristic X-ray emission wavelength (λ) or energy (E). The amount of an element present is determined by measuring the intensity of its characteristic line.

All atoms have a fixed number of electrons (negatively charged particles) arranged in orbitals around their nucleus. The number of electrons in a given atom is equal to the number of protons (positively charged particles) in the nucleus. In the classical Periodic Table of Elements, the Atomic Number is specified by the number of protons. Each Atomic Number is assigned an elemental name, such as Iron (Fe), with Atomic Number 26.

XRF Spectrometry typically utilizes activity in the first three electron orbitals, the K, L, and M lines, where K is closest to the nucleus. Each electron orbital corresponds to a specific and different energy level for a given element.

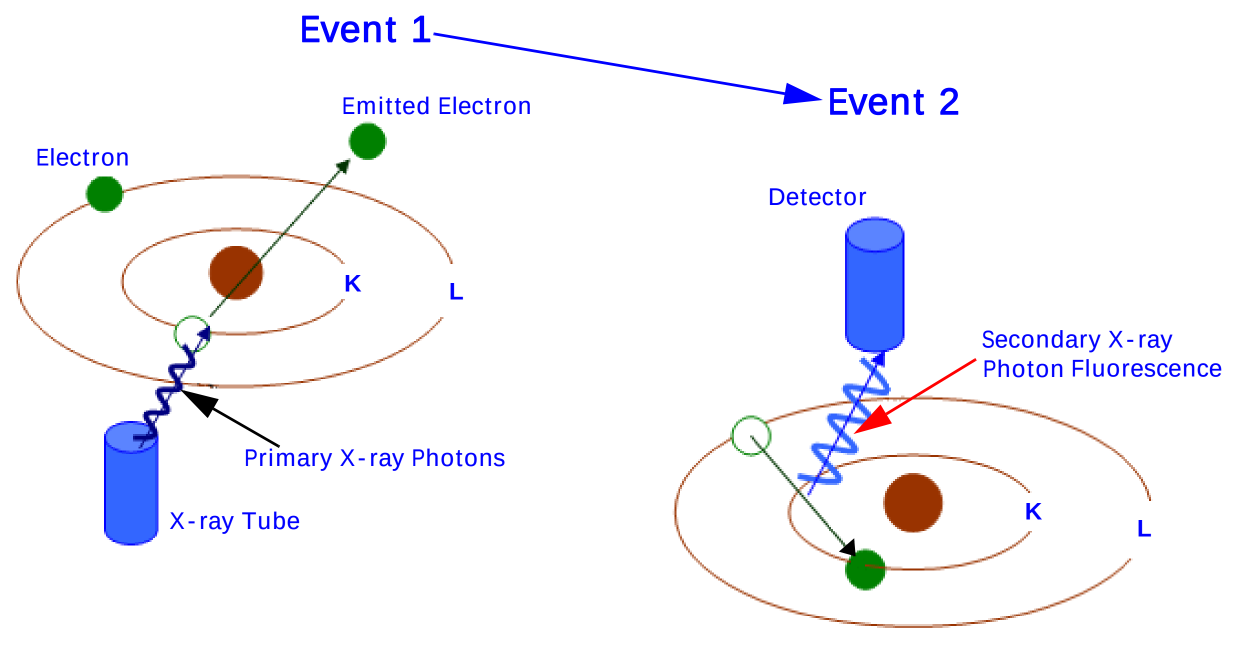
In XRF Spectrometry, high-energy primary X-ray photons are emitted from a source (X-ray tube or *radioisotope*) and strike the sample. The primary photons from the X-ray source have enough energy to knock electrons out of the innermost, K or L, orbitals. When this occurs, the atoms become unstable ions. Electrons seek stability; therefore, an electron from an outer orbital, L or M, moves into the newly vacant space at the inner orbital. As the electron from the outer orbital moves into the inner orbital space, it emits an energy known as a secondary X-ray photon.

This phenomenon is called **fluorescence**.

The secondary X-ray produced is characteristic of a specific element.

The energy (**E**) of the emitted fluorescent X-ray photon is determined by the difference in energies between the initial and final orbitals of the individual transitions.

This is described by the formula $\mathbf{E=hc/}\lambda$ where **h** is Planck's constant; **c** is the velocity of light; and λ is the characteristic wavelength of the photon.

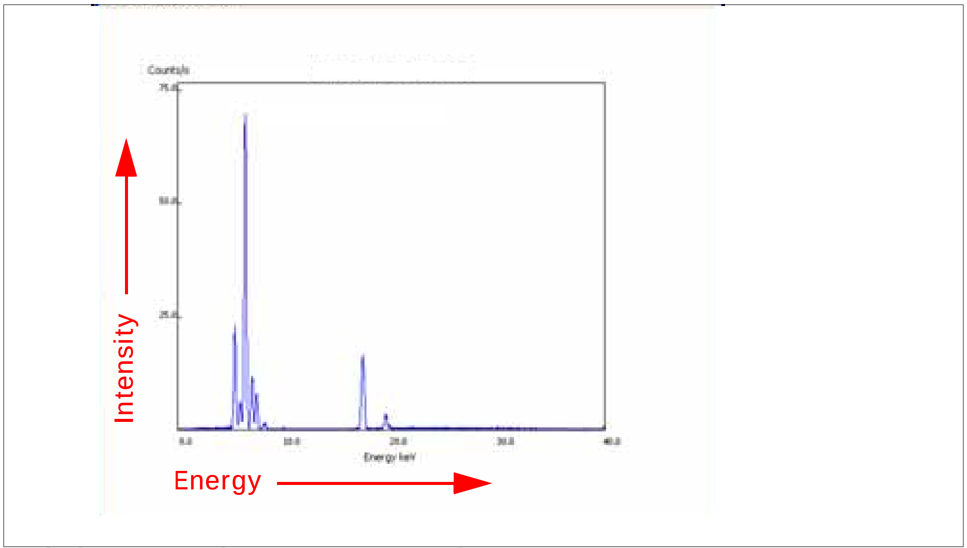


Creating a Secondary X-ray - Photon Fluorescence

Wavelengths are inversely proportional to the energies; they are characteristic for each element.

For example, the Ka energy for Iron (Fe) is about 6.4keV. The number of element-specific characteristic X-rays produced in a sample over a given period of time, or the intensity, is measured. This determines the quantity of a given element in that sample.

Typical spectra for EDXRF Spectrometry appear as a plot of **Energy (E)** versus the **Intensity (I)**.



Typical Spectrum Plot: Energy vs. Intensity

History

Timeline for XRF Spectrometry

- Wilhelm Roentgen discovered X-rays in 1895.
- Henry Moseley first published methods for identifying and quantifying elements using XRF in 1913.
- XRF research and development continued, especially during WWII.
  - Critical developments in the aircraft, automotive, steel, and other metals industries increased the need to identify alloys *quickly* and *reliably*.
- The first commercial XRF Spectrometers became available in the early 1950's. These systems were based on **Wavelength Dispersive (WD) XRF** technology.
  - The characteristic **wavelength** of an element was measured **one element at a time**.
  - WDXRF systems were useful for elemental analyses, however, the equipment had the following properties:
    - Large size
    - High initial cost
    - Required highly skilled operators to use and maintain them.
- In the late 1960's, **Energy Dispersive (ED) XRF** technology emerged as a viable commercial choice:
  - EDXRF measured the characteristic **energy** of an element.
  - Improvements in solid state detectors offered better energy resolution of the signal.
  - Had potential to collect and display information on **all** of the elements in a sample at the **same time**.
- Many of the early EDXRF systems used radioisotopes for excitation. They had the following properties:
  - Required changing sources to determine all the elements of interest.
  - Did not easily resolve multiple elements in a single analytical run.
- The current state-of-the-art in EDXRF is the result of
  - Advancements in technology (particularly X-ray tubes, solid-state components, electronics, computers, software)
  - Application of the technology by instrument manufacturers, research scientists, engineers, and industrial users.
- Now a mature technology, XRF Spectrometry is routinely used for R&D, QC, production support, and regulatory compliance.

Elemental Analysis

Investigators involved with elemental analysis generally have two working instrument techniques — *Wet Chemistry* and *XRF Spectrometry*. They are compared operationally as follows.

Wet Chemistry

Important considerations are:

- Instrument techniques are *time-consuming*.
    - Often takes twenty minutes to several hours for specimen preparation and analysis.
- Specimen is *destroyed*.
- Often necessary to employ *concentrated acids* or other *hazardous materials*.
- Requires *disposal* of waste streams generated during the analytical process.
- Relatively *high cost* per sample.

However, wet chemistry instrument techniques are necessary if the primary measurement requirement involves elemental concentrations in the PPB (or lower) range

XRF Spectrometry

Important considerations are:

- Easily and quickly identifies and quantifies elements over a wide dynamic concentration range, from PPM levels up to virtually 100% by weight.
- Does *not destroy* the sample.
- Overall sample turnaround time is *fast*.
    - Requires little, if any, specimen preparation.
    - Often results are available within seconds, minutes for some details.
- Relatively *low cost* per sample

Interferences

All elemental analysis techniques experience chemical and physical interferences. They must be corrected or compensated for in order to achieve adequate analytical results.

Wet Chemistry Issues

Most suffer from interferences that are corrected only by extensive and complex specimen preparation techniques.

XRF Spectrometry Issues

The primary interference is from other specific elements in a substance that can influence (matrix effects) the analysis of the target element(s) of interest.

However, this interference style is well known and documented.

Both types of analyzer techniques benefit from (a) instrumentation advancements, and (b) mathematical corrections in the system's software.

In certain cases, the *geometry* of the sample can effect XRF analysis.

- This is compensated for by:
    - Grinding or polishing the sample
    - Pressing a pellet
    - Making glass beads

Quantitative analysis

XRF Spectrometry supporting quantitative analysis typically employs one of two software applications:

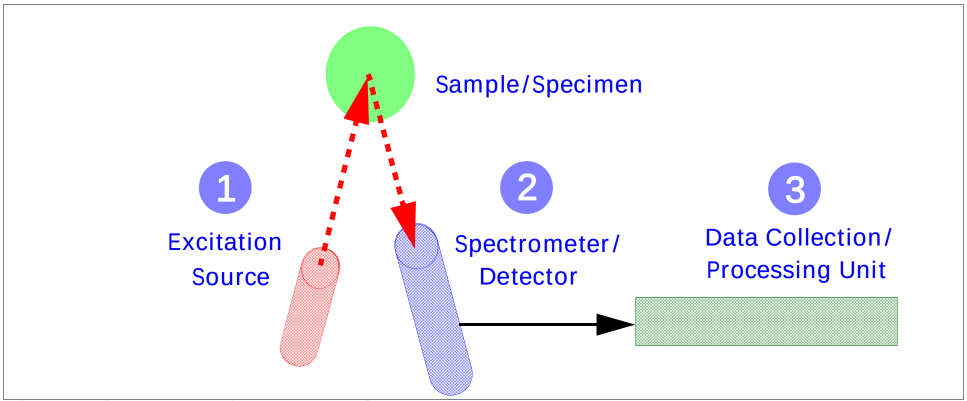
- **Empirical Methods**
  Uses calibration curves derived from standards similar in property to the target unknown sample.
- **Fundamental Parameters (FP)**

  FP is frequently preferred because it allows elemental analysis to be performed *without* standards or calibration curves.
  The analyst can use the system immediately.

  Modern computers support this *no-standard* mathematical analysis, FP, accompanied by stored libraries of known materials. These systems quickly determine not only the elemental composition of an unknown material, but even identify the unknown material itself.

EDXRF Spectrometers

An EDXRF instrument typically has three major subsystems:



Three Subsystems of EDXRF Analyzer

EDXRF analyzers are mechanically very simple; there are *no moving parts* in the excitation and detection subsystems. However, a bench-top analyzer can have moving parts.

When compared to WDXRF systems, EDXRF systems exhibit the following attributes:

- Ease of use
- Rapid analysis time
- Lower initial purchase price
- Substantially lower long-term maintenance costs

EDXRF analysis equipment is useful for many applications, including:

- Environmental analysis
- RoHS/WEEE compliance
- Scrap alloy sorting
- Forensic science
- Archaeometry

NOTES

A2. Soil Testing

This appendix explains usage of all of the company's hand-held portable analyzers with the *Soil* or *3 Beam Soil* mode option installed.

This document offers instructions/procedures and regulations, as well as useful reference material, regarding:

- Portable XRF equipment usage in accordance with accepted methods.
- Basic overview of the technique of x-ray fluorescence (XRF).
- Appropriate data quality assurance protocols.
- Sample preparation steps for operators analyzing prepared soil samples.
- Tables of certified values for selected standards.

If LEAP mode is enabled, refer to configuration help in *PN 103202*.

Section 1: Commonly Accepted Methods for Field Portable XRF

A commonly accepted method is shown: *Field Portable XRF Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment*.

Features of this method are:

- It is a field screening method, for analysis of *in-situ* or bagged samples.
- The method provides basic quality assurance methods, including calibration verification, determination of instrument precision, accuracy and limit of detection.
- The method recognizes that some XRF instruments do not require site-specific calibrations by the operator, that is, the factory calibration provides appropriate data quality.
- The method recommends that a minimum of 5-10% of samples tested by XRF be confirmed by an outside laboratory, using a total-digestion EPA analytical reference method.

The purpose of this method is *NOT* to replace laboratory analysis.

There are two primary sources of error in assessing a site for metal concentration: *Analytical error* and *Sampling error.*

ANALYTICAL ERROR

The error in the analysis of any one sample by whatever technique is used, for example XRF, ICP, or AA.

SAMPLING ERROR

This arises when **too few** samples are collected and tested.

> In this case an incomplete picture of the extent of metals contamination may be obtained. Although any one sample may be analyzed with very high analytical accuracy, measuring too few samples may result in contamination plumes being mis-judged in size, or depth into the soil. In extreme cases contamination can be missed entirely.

Methods have been developed to reduce Sampling Errors by **increasing** the number of samples measured. In general, a large number of screening-level measurements provide a better characterization of contamination than a small number of measurements produced by sample removal and analytical analysis. A large number of in-situ samples provide detailed data on contamination profiles, depth (provided surface soil is moved aside), and approximate contamination levels. Portable XRF can provide results with a high degree of analytical accuracy on any given sample.

Section 2: Overview of Field Usage:

Field portable XRF is generally used in three ways to test for metals in soil:

IN-SITU SOIL TESTING:

The XRF is placed directly onto the ground for soil testing. Operators remove any plant growth and foreign objects so that the analyzer probe is flush to the soil.

BAGGED SOIL SAMPLE TESTING:

A soil sample is collected in a thin plastic bag (i.e. a *Baggie*) and testing occurs directly through the Baggie. Except for a few elements – namely Cr, V and Ba – testing through the thin plastic bag has little effect on the test result. However, results for Cr, V and Ba will be lower by 20-30%.

PREPARED SOIL SAMPLE TESTING:

Prepared sample testing assures the operator of the maximum possible accuracy. Prepared sample tests require a sample to be collected, dried if necessary, sieved and ground into a powder. The prepared sample is then placed into a baggie or XRF cup for analysis.

Sample prep procedures are provided on Section 8: Sample Prep Procedures and Testing Protocols on page 130.

ALL analytical methods require a *uniform, homogenous* sample for the best results. **XRF is no different!**

The methods generally used, namely In-situ and bagged sample testing, are considered *field-screening methods*. Although a field-screening method, in-situ testing is a valuable technique because it generates a great deal of data very quickly. Prepared soil samples generally offer the best accuracy, albeit with several minutes of sample preparation required per sample.

Subsection 2-A: Data Quality Objectives

The objective of testing is generally to determine the mixture of in-situ versus prepared sample testing. It is important to understand your data quality objectives (DQO) in order to determine the appropriate mix of field screening and prepared sample testing.

In-situ testing usually provides only *screening-level data quality.*

This is because analytical testing always requires a uniform, homogeneous sample matrix. A laboratory achieves this by digesting the sample into a hot acid before analysis. Testing directly on the ground does not ensure that uniformity is met. Preparing a sample provides a uniform sample and likely better analytical data quality, although several minutes of testing time is required.

Most portable XRF operators use a mixture of in-situ and prepared sample testing. The exact mixture of in-situ and prepared sample testing depends upon the goals of the soil testing. The examples below serve as guidelines.

Example 1: Initial site investigation to provide detailed contamination data with efficient use of laboratory analysis costs.

PROBLEM:

The site needs to be assessed for metals contamination. Little information is available about what metals are present, likely contamination levels or geographic profile of contamination.

The goal of testing is to determine what metals are present at what levels, both in area and in depth into soil. Additionally, testing will locate possible contamination plumes and/or possible sources of contamination.

RECOMMENDED TESTING PLAN:

This example uses predominately in-situ testing. The analyst will perform in-situ testing, and gather samples into plastic bags for XRF analysis. A testing grid should be established in two or three dimensions, every several feet. XRF tests can be taken at each location or bagged samples can be collected from each location for later analysis. The in-situ data for each element analyzed may be plotted in a 2-dimensional grid (X, Y coordinates versus elemental concentration) to profile a site. These concentration profiles are ideal for showing contamination patterns, boundaries and plumes. Combining this data with historical use data from the site often allows the operator to deduce sources of contamination. Obtaining this level of geographic data with purely laboratory analysis would produce excessive analytical costs.

Prepared sample analysis should also be done to confirm the regions where in-situ data indicates low or non-detected levels of metal contaminant. There is little need to prepare areas where in-situ testing indicates high concentration levels.

Innov-X recommends this procedure:

For locations where in-situ tests indicate low or non-detected concentrations, calculate the total number of in-situ tests, collect 5% of this number of tests from the various locations. Prepare these samples according to instructions on “Section 8: Sample Prep Procedures and Testing Protocols on page 130.” Use these prepared samples to confirm the findings of the in-situ testing. Send a subset of these prepared samples to a laboratory for confirmatory results.

COST JUSTIFICATION:

To adequately characterize a site may require 100-200 samples/acre to be sure the contaminated areas are firmly established. This work may be done with in-situ testing to generate laboratory savings of $5,000 - $10,000/acre depending upon the number of elements being analyzed. The cost reduction in off-site analysis often justifies the price of the XRF.

Example 2: Monitor remediation efforts and assure site meets clearance levels before contractors leave the site.

GOAL:

Minimize remediation costs by only treating contaminated soil, and obtain immediate verification that various site locations meet clearance objectives.

RECOMMENDED TESTING PLAN:

This type of project uses a lot of both in-situ and prepared sample testing. Use in-situ testing to thoroughly delineate contamination regions in both area and depth. To determine depth profiles, test surface soil, remove at least 1-2’, and retest. Repeat this step as necessary to profile contamination depth to guide remediation activities (XRF is a surface technique and only analyzes the first few mm of soil sample). As part of clearance, collect several samples from *cleared* area. Prepare samples according to *“Section 8: Sample Prep Procedures and Testing Protocols”* on page 92. Test with portable XRF.

If XRF indicates that concentration levels are:

- In excess of clearance requirements, then continue remediation efforts.
- Below clearance requirements, then discontinue remediation efforts, and send a subset of the samples to an analytical laboratory to confirm results. Most operators safely assume that the cleanup requirements have been met for the elements in question, but await final analysis from the laboratory.

If XRF lists concentration levels as non-detected, but the detection level reported exceeds clearance requirements, send samples to a laboratory for final results.

Cost Justification: In-situ results are used to guide remediation efforts, in order to obtain maximum efficiency. Efficiency is produced because contamination boundaries are firmly established, thus avoiding remediation efforts with *clean* soil. Prepared sample testing is used to assure that clearance requirements are met on-site in near real-time (pending laboratory confirmation). Costs savings are generated by avoiding clearance failures. The contractors can leave the site earlier and will not be called back to the site for additional cleanup.

IMPORTANT NOTE:

Never clear a site based solely on in-situ testing. Always use well-prepared samples to make a clearance decision.

Example 3: Minimize volume of hazardous waste for treatment or disposal.

GOAL:

For some cleanup projects, the cost of soil disposal in a hazardous waste landfill is much greater than disposal in a standard landfill. Testing soil samples with XRF may minimize the amount of *clean* soil that is inadvertently shipped to a hazardous-waste landfill.

RECOMMENDED TESTING PLAN:

This example is almost entirely based on prepared sample testing. Representative samples are removed from the soil being hauled to landfill. Obtaining an accurate analysis of the samples is crucial for making a hazardous versus non-hazardous determination. For this reason, prepared sample testing is strongly recommended.

IMPORTANT NOTE:

These types of samples are subject to Toxicity Characteristic Leaching Procedures (TCLP) for the landfill determination. In general, 20 times the XRF result should be less than the allowable limit for the metal in question. Please contact Innov-X Systems for more details on testing samples versus TCLP regulatory requirements.

Section 3: Quality Assurance

Quality assurance is detailed for both the proper use of the analyzer and for verifying the data quality of in-situ testing. All operators should perform the QC procedure, regardless of their data quality objectives. There must be strict requirements about quality assurance. Additionally, Innov-X recommends that operators verify the data quality of in-situ test results, if they are using in-situ data to guide their reporting or remediation decisions. Procedures are listed below:

Proper verification of instrument operation

Quality assurance here consists of testing known standards to verify calibration, as well as testing blank standards to determine limits of detection and to check for sample cross-contamination or instrument contamination. We recommend a detailed procedure, which is provided here in abbreviated form.

Components of instrument QC:

- An energy calibration check sample at least twice daily
- An instrument blank for every 20 environmental samples
- A method blank for every 20 *prepared* samples
- A calibration verification check sample for every 20 samples
- A precision sample at least one per day
- A confirmatory sample for every 10 environmental samples

Energy Calibration Check: The Innov-X analyzer performs this automatically; this is the purpose of the standardization check when the analyzer is started. The software does not allow the analyzer to be used if the standardization is not completed.

Instrument Blank: The operator should use the SiO_2 (silicon dioxide) blank provided with the analyzer. The purpose of this test is to verify there is no contamination on the analyzer window or other component that is *seen* by the x-rays. We recommend an instrument blank at least once per day, preferably every 20 samples. For either in-situ or prepared-sample testing, the operator should just test the SiO_2 blank to be sure there are no reported contaminant metals.

Method Blank: The purpose of the method blank is to verify that cross-contamination is not introduced into samples during sample preparation. We recommend following the sample preparation procedures with clean SiO_2 once very 20 prepared samples. This QC step is not required if the operator is not preparing samples.

Calibration Verification: Innov-X provides standard reference samples for calibration check by operator. The operator should perform a two minute test on a standard. The difference between the XRF result for an element and the value of the standard should be 20% or less. Calibration Verification should be performed upon instrument startup and periodically during testing.

NOTE

Innov-X recommends a calibration check every 4 hours. Some users make a calibration check every 20 samples. Reference standards are generally applicable for Pb, As, Cr, Cu, Zn. Innov-X provides additional reference standards for Priority Pollutant metals including Cd, Se, Ag, Hg, Ag, Ba, Sn, Sb, and Ni.

Precision Verification: It is good practice to make a minimum of one precision sample run per day by conducting from 7 to 10 replicate measurements of the sample. The precision is assessed by calculating a relative standard deviation (RSD) of the replicate measurements for the analyte. The RSD values should be less than 20 percent for most analytes, except chromium, for which the value should be less than 30 percent.

Confirmatory Sample: It is recommended that one confirmatory sample is run for every 10 samples collected. It is good practice to have confirmatory samples collected from the same sample material that is analyzed on site, but are sent to an off-site laboratory for formal analysis. The purpose of a confirmatory sample is to judge the accuracy of the data obtained by analysis on site and to allow corrections, if necessary."

Important Notes about confirmatory samples:

Innov-X always recommends that customers compare prepared-sample results to laboratory results. To do this, collect and prepare a sample following the protocols shown on *"Section 8: Sample Prep Procedures and Testing Protocols"* on page 92. Take a subsample and submit to the laboratory for analysis. The single largest error in XRF analysis is lack of sample preparation. For the best comparison, always use prepared samples.

Determining data quality of in-situ testing:

For operators relying extensively on in-situ testing, it is important to determine the data quality of this testing at a given site. *This protocol is not intended for every sample, but rather for a small percentage of samples considered representative of the site.* If the operator can demonstrate that quantitative data is achieved with little or no sample preparation, then the site characterization will be completed much more quickly but correctly.

For example, an operator may be able to demonstrate that the XRF result changes considerably when samples are passed through a 2 mm sieve, but that XRF results do NOT change appreciably upon finer sieving. In this case, the operator can conclude that good XRF data is achievable with only 2 mm sieving. Sieving only to this level requires far less time than a more robust sample preparation.

A protocol to determine the *appropriate level of sample preparation* is the following:

1. Delineate a region of soil approximately 4" x 4".
2. Perform several in-situ tests in this area, or collect the top (approximately) quarter inch of soil from this region, bag the soil, test through the bag. In either case, average the results.
3. If you did not bag the in-situ test sample, collect the top (approximately) quarter inch of soil from this region and sieve through the 2 mm sieve provided. Otherwise sieve the bagged sample used for the in-situ test. Thoroughly mix the sieved sample, and place some of the sieved material into an XRF cup, and perform a test of this sample.
4. If the results of this prepared sample differ by:
    - Less than 20% with the average in-situ result, this indicates the soil in this region is reasonably homogeneous. The data quality in this case is probably at the semi-quantitative level, rather than just screening data.
    - More than 20%, this indicates the soil is not very homogeneous, and there are serious particle size effects affecting your in-situ measurements.

      In this case, sieve the sample through the ~250 m sieve. Mix this sample and place a sub-sample into an XRF cup for testing. If this result differs from the previous by less than 20% then this indicates that at a minimum the 2 mm sieving is necessary to achieve higher data quality.

      If this result differs by more than 20% from the sample sieved through 2 mm, then particle size effects are still affecting the XRF result. In this case samples should be sieved through 125 µm to assure data quality at the quantitative level.

Section 4: Calibration for Innov-X Portable XRF

The Innov-X analyzer can run *three* different calibration methods, described below.

COMPTON NORMALIZATION:

In nearly all cases, customers use the Compton Normalization method. This method (recognized in EPA 6200) offers speed, ease of use, and generally good accuracy for concentration ranges from the ppm level up to 2-3% concentrations. As most field-testing is seeking to remediate or locate environmental contaminants, the upper limit of the calibration (2-3%) is generally not a limitation.

FUNDAMENTAL PARAMETERS (FP):

If customers do require a calibration up to 100% concentration (i.e. a pure element), then Innov-X recommends they also include the Fundamental Parameters (FP) software module with the analyzer. The FP module may be added at time of purchase or as an upgrade at any later date.

NOTE

In general, customers do not need to calibrate Innov-X analyzers for soil testing. The analyzer is delivered with a factory calibration, generally based upon the Compton Normalization (CN) method. The CN method has been proven over the past several years to provide a robust calibration generally independent of site-specific soil matrix chemistry.

All customers should follow the QC procedure described in Section 3, which includes a check of the calibration.

EMPIRICAL CALIBRATION:

In this case, customers run standards to generate calibration curves for various elements in specific soil matrices. With a well-prepared sample, the empirical method generally yields the most accurate result. In our experience, the accuracy gains going *from* Compton Normalization *to* Empirical Mode are small and not worth the extra effort in setting up calibration curves.

The empirical calibration module is an optional software package, available for an upgrade fee at the time of purchase, or as an upgrade at any later date.

CAUTION

The *greatest source of error* for in-field XRF analysis of soil is *lack of adequate sample preparation*, thus there is little gained in developing a sophisticated empirical calibration if the operator does not grind and homogenize the all measured samples.

Calibration Requirements:

The concentration of an element in a soil sample is well-described by the formula:

$$w_i = \frac{k_i}{M(Z,i)} I_i$$

where:

k_i = calibration constant for element *i*

ω_i = concentration of element *i* – the quantity being measured

I_i = measured x-ray intensity from element *i*

M(Z,I) = Soil matrix value

The factory calibration determines the value of the calibration constants k_i for each element, and a typical value M(Z,I). The calibration method – either CN, fundamental parameters, or empirical – performs the necessary corrections to the value M(Z,I) that are important for the site-specific soil chemistry. The XRF analyzer uses the measured intensity of each element’s fluorescence from the sample, and the calibration data, to produce elemental concentrations.

COMPTON NORMALIZATION CALIBRATION:

The Compton Normalization method calibration consists of the analysis of a single, well-characterized standard, such as an SRM or SSCS. The standard data are normalized to the Compton peak. The Compton peak is produced from incoherent backscattering of X-ray radiation from the excitation source and is present in the spectrum of every sample. The matrix affects the way in which source radiation is scattered off the samples. This scatter is directly related to the intensity of the Compton peak. For that reason, normalizing to the Compton peak can reduce problems with matrix effects that vary among samples. Compton normalization is similar to the use of internal standards in analysis for organic analytes.

FUNDAMENTAL PARAMETERS CALIBRATION:

The fundamental parameters (FP) calibration is a *standardless* calibration. Rather than establishing a unit's calibration curve by measuring its response to standards that contain analytes of known concentrations, FP calibration relies on the known physics of the spectrometer's response to pure elements to set the calibration. Built-in mathematical algorithms are used to adjust the calibration for analysis of soil samples and to compensate for the effects of the soil matrix. The FP calibration is performed by the manufacturer, but the analyst can adjust the calibration curves (slope and y-intercept) on the bases of results of analyses of check samples, such as SRMs which are analyzed in the field.

EMPIRICAL CALIBRATION:

The empirical calibration method requires that a number of site-specific calibration standards (SSCS) are used to establish calibration parameters. The instrument response to known analytes is measured and used to create calibration curves. Empirical calibration is effective because the samples used closely match the sample matrix. SSCSs are well-prepared samples collected from the site of interest in which the concentrations of analytes have been determined by inductively coupled plasma (ICP), atomic absorption (AA), or other methods.

The standards should contain all the analytes of interest and interfering analytes. Manufacturers recommend that 10 to 20 calibration samples be used to generate a calibration curve. The empirical method is the least desirable calibration method as it requires that new standards and curves are generated for each site that is analyzed.

Section 5: Effects of Moisture on XRF Results

Sample moisture has two effects on XRF results:

- It alters the soil chemistry, since water is another chemical compound that comprises the soil matrix.
- Moisture impedes the ability to properly prepare samples.

There is a further testing consideration:

- Laboratory results are provided on a *dry weight* basis.

EFFECT ON SOIL CHEMISTRY:

While the presence of significant moisture does impact the soil chemistry, modern XRF analyzers all perform automatic corrections for variations in soil chemistry from site to site. Indeed, such variations are expected, and that is the reason analyzers use Compton Normalization or fundamental parameters, in order to correct for moisture content changes as well as other differences in soil geochemistry.

It is known that moisture content above 20 percent may cause problems, since moisture alters the soil matrix for which the FPXRF has been calibrated. However, the Compton Normalization or fundamental parameters methods are implemented in order to automatically correct results for changes to the soil matrix. Thus, we believe that soil moisture is not a significant effect on accuracy due to effects of soil matrix, except for the *dilution* effect that can cause discrepancies with laboratory results which is described below.

SAMPLE PREPARATION ISSUES:

The inability to adequately prepare a wet sample is, we believe, the single biggest contributor to errors when testing wet samples. It is very difficult to grind or sieve a wet sample. The highest quality XRF results are generally obtained from prepared samples.

CAUTION

If the operator is unwilling to dry the sample to prepare it, comparisons to the laboratory may yield poorer correlation since the samples are not homogeneous.

Laboratory Tests on Dry-Weigh Basis:

Laboratories always dry samples prior to analysis. They report percent weight content based upon a dry sample basis. Portable XRF may often be used to analyze wet samples in the field, and results are thus reported that include the moisture content. Thus, with all other factors the same, the laboratory will report results higher than portable XRF. The results are higher by the amount of moisture content in the sample. For example, laboratory results will be 10% higher compared to XRF results, if the sample contained 10% by weight water when it was tested with XRF. Recall, this applies to samples where other possible sources of error are the same or negligible.

Section 6: Comparing XRF Results to Laboratory Results

Innov-X strongly recommends that operators compare prepared sample results to laboratory results. This is because prepared-sample results yield the best possible accuracy with portable XRF. Moreover, the most common source of error is due to non-uniform samples. No analytical technique, including the XRF technique, can properly account for non-uniform sample types.

To perform a comparison between XRF results and laboratory:

1. Collect a sample and prepare it according to the sample preparation guide given in *"Section 8: Sample Prep Procedures and Testing Protocols"* on *page 90*.
2. Take a sub-sample (5-10 grams) of the fully-prepared sample, place it into an XRF cup and perform at least a one-minute test on that sample.
3. Send the same sample to the laboratory for wet chemistry analysis.
4. Require the laboratory to use a *total-digestion method*. If the laboratory does not, they may not extract all of the elemental metal from the sample. In this case, the lab result will be lower than the XRF result.   Incomplete sample digestion is one of the *most common* sources of laboratory error, thus it is very important to request a total digestion method.

Example of Error: The operator collects a bag of sample, performs XRF analysis on one part of the bag, and sends the bag, or part of the bag of sample to a laboratory for analysis. The laboratory reports a very different value than the operator obtained with the XRF.

Problem:

Since the sample is very non-homogeneous, the operator did not obtain a result that was representative of the entire bag of sample. The lab analyzed a different part of the sample and obtained a very different result due to the non-uniformity of the sample. The solution to this problem is, at a minimum, to test several locations in the bag of sample and report the average value. Also note the differences between the tests, as this is indicative of the non-uniformity of the sample. The operator should send entire bag of sample to the lab, and instruct the lab to prepare the sample before removing the sub-sample for lab analysis.

Best Practice:

The operator should homogenize and prepare the entire bag of sample, and then collect a sub-sample for XRF testing. After testing, the *same sample* should be sent to the lab.

Section 7: Common Interferences

Interference occurs when the spectral peak from one element overlaps either partially or completely with the spectral peak of another.

Case 1 Conditions

If the instrument is calibrated for both elements, one causing the interference and one being interfered with, it is generally capable of correctly handling the interference. In this instance, the element being interfered with may be measured with a poorer detection limit or poorer precision, but the analytical results should still be acceptable for field-portable XRF.

Case 2 Conditions

If the XRF is not calibrated for the element causing the interference, then the instrument may report the presence of elements not in the sample, or greatly elevated concentrations of elements in or not in the sample.

Example CASE 1: Lead and arsenic

Lead and arsenic. Most XRFs are calibrated for lead and arsenic. Lead interferes with arsenic (not vice-versa though). The net effect is a worsened detection limit for arsenic, and poorer precision. The XRF handles the correction automatically, but the precision is affected. The loss of precision is also reported by the XRF.

(Refer to Innov-X Applications Sheet: *In-field Analysis of Lead and Arsenic in Soil Using Portable XRF* which is now available as *Arsenic and Lead in Soil.PDF* for more detail).

Example CASE 2: Bromine

Bromine in the sample, but the XRF is not calibrated for bromine. Bromine, as a fire retardant, is being seen more and more in soil and other sample types. For this reason, Innov-X analyzers include Br in the calibration data. If Br is not calibrated, but is present in the sample, the analyzer will report highly elevated levels of Pb, Hg and As. The levels will depend upon the concentration of Br in the sample.

Interferences between elements can be broadly categorized into two types:

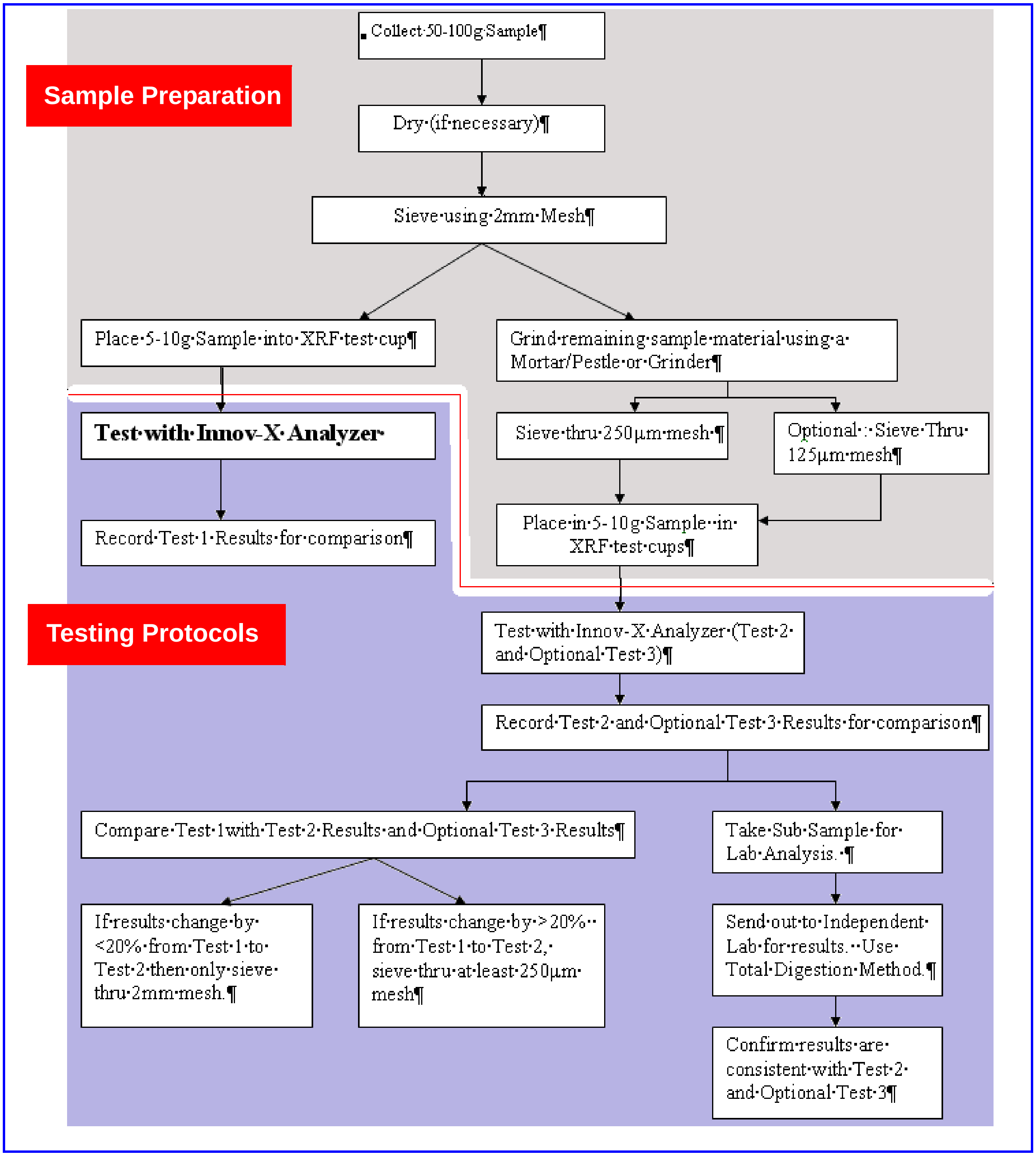
Z, Z-1, Z+1 interferences

Occurs when high levels of an element of atomic number Z are present. This can cause elevated levels of elements with atomic number Z-1 or Z+1. Generally, portable XRFs have good correction methods, so this interference only causes problems with very high levels of the element in question. Example: High concentrations of Fe (Z=26) in excess of 10% may cause elevated levels of Mn or Co (Z=25 or Z=27 respectively).

K/L interferences

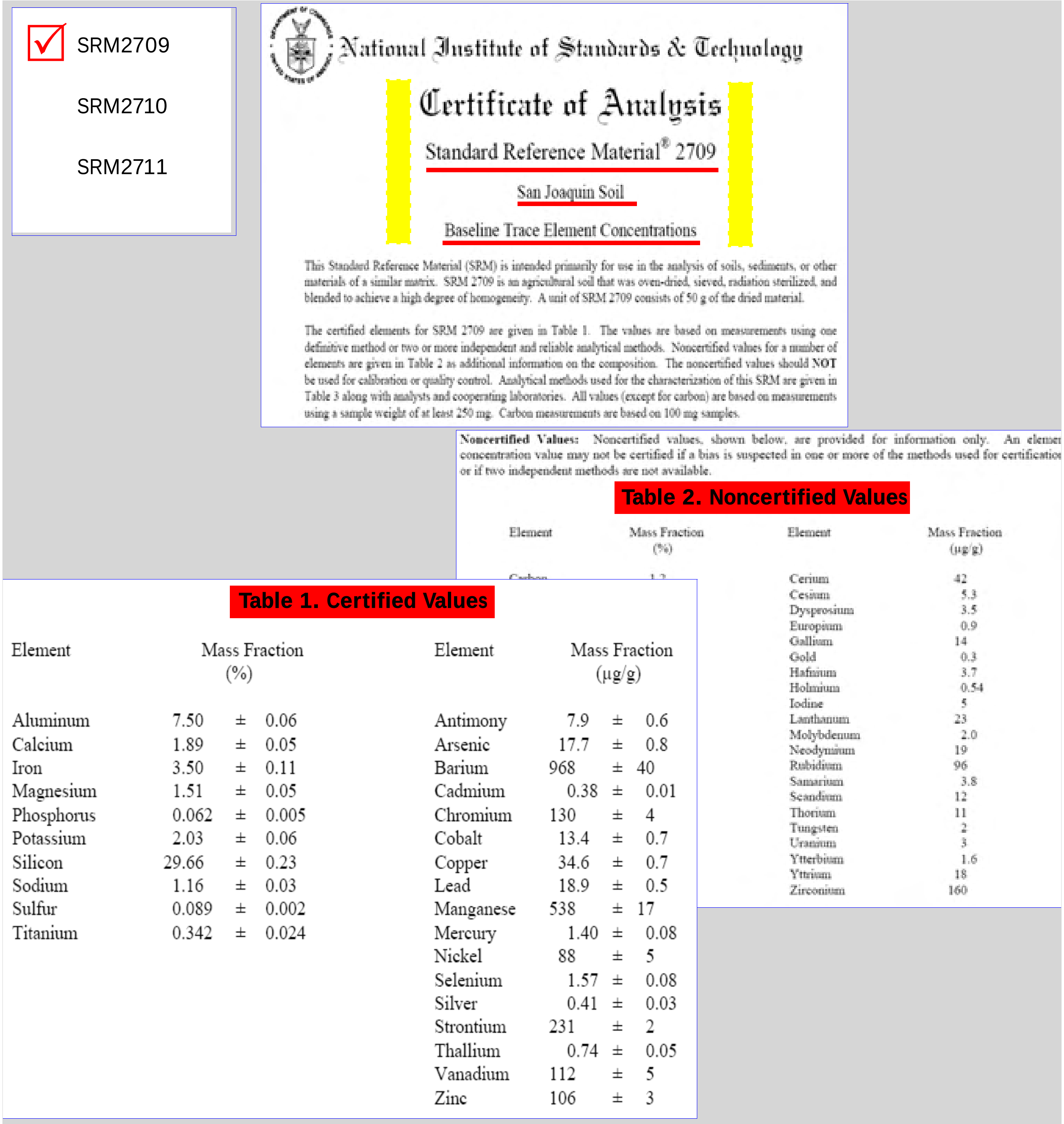
Occurs when the L-shell line of one element overlaps with the K-shell spectral line of another element. The most common example is the lead/arsenic interference where the L-alpha line of lead is in nearly the exact same location as the K-alpha line of arsenic.

Section 8: Sample Prep Procedures and Testing Protocols



Section 9: NIST Certificates of Analysis

Innov-X systems provides three NIST standards (subject to change with availability). Each standard’s certified values are given in Table 1 and Non-certified values are in Table 2 in the graphics below.



☑ SRM2709

SRM2710

SRM2711

National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 2709

San Joaquin Soil

Baseline Trace Element Concentrations

This Standard Reference Material (SRM) is intended primarily for use in the analysis of soils, sediments, or other materials of a similar matrix. SRM 2709 is an agricultural soil that was oven-dried, sieved, radiation sterilized, and blended to achieve a high degree of homogeneity. A unit of SRM 2709 consists of 50 g of the dried material.

The certified elements for SRM 2709 are given in Table 1. The values are based on measurements using one definitive method or two or more independent and reliable analytical methods. Noncertified values for a number of elements are given in Table 2 as additional information on the composition. The noncertified values should **NOT** be used for calibration or quality control. Analytical methods used for the characterization of this SRM are given in Table 3 along with analysts and cooperating laboratories. All values (except for carbon) are based on measurements using a sample weight of at least 250 mg. Carbon measurements are based on 100 mg samples.

Noncertified Values: Noncertified values, shown below, are provided for information only. An elemen concentration value may not be certified if a bias is suspected in one or more of the methods used for certificatio or if two independent methods are not available.

Table 2. Noncertified Values

Element	Mass Fraction (%)	Element	Mass Fraction (µg/g)
Carbon	1.2	Cerium	42
		Cesium	5.3
		Dysprosium	3.5
		Europium	0.9
		Gallium	14
		Gold	0.3
		Hafnium	3.7
		Holmium	0.54
		Iodine	5
		Lanthanum	23
		Molybdenum	2.0
		Neodymium	19
		Rubidium	96
		Samarium	3.8
		Scandium	12
		Thorium	11
		Tungsten	2
		Uranium	3
		Ytterbium	1.6
		Yttrium	18
		Zirconium	160

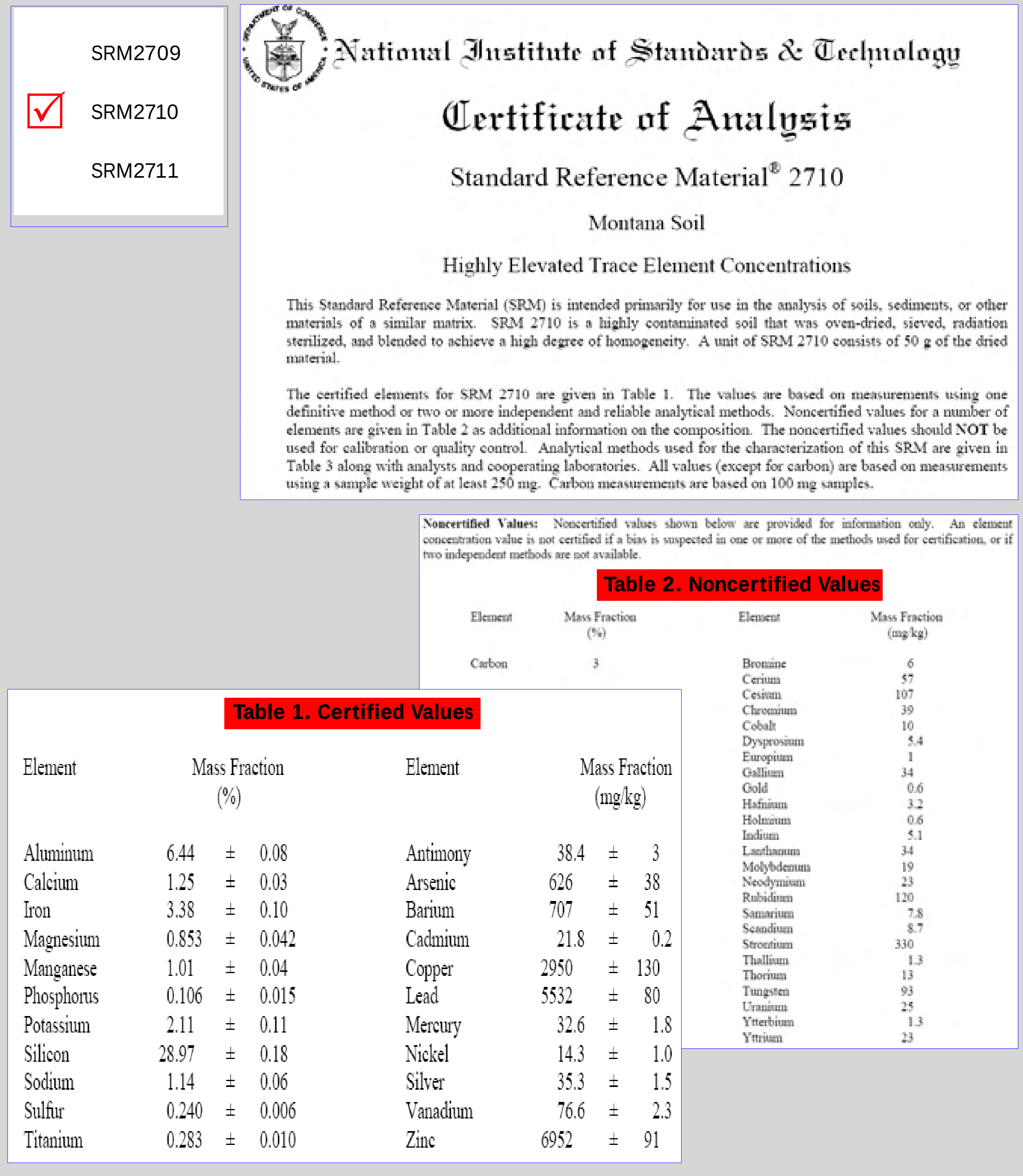
Table 1. Certified Values

Element	Mass Fraction (%)			Element	Mass Fraction (µg/g)		
Aluminum	7.50	±	0.06	Antimony	7.9	±	0.6
Calcium	1.89	±	0.05	Arsenic	17.7	±	0.8
Iron	3.50	±	0.11	Barium	968	±	40
Magnesium	1.51	±	0.05	Cadmium	0.38	±	0.01
Phosphorus	0.062	±	0.005	Chromium	130	±	4
Potassium	2.03	±	0.06	Cobalt	13.4	±	0.7
Silicon	29.66	±	0.23	Copper	34.6	±	0.7
Sodium	1.16	±	0.03	Lead	18.9	±	0.5
Sulfur	0.089	±	0.002	Manganese	538	±	17
Titanium	0.342	±	0.024	Mercury	1.40	±	0.08
				Nickel	88	±	5
				Selenium	1.57	±	0.08
				Silver	0.41	±	0.03
				Strontium	231	±	2
				Thallium	0.74	±	0.05
				Vanadium	112	±	5
				Zinc	106	±	3

SRM2709

☑ SRM2710

SRM2711



National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 2710

Montana Soil

Highly Elevated Trace Element Concentrations

This Standard Reference Material (SRM) is intended primarily for use in the analysis of soils, sediments, or other materials of a similar matrix. SRM 2710 is a highly contaminated soil that was oven-dried, sieved, radiation sterilized, and blended to achieve a high degree of homogeneity. A unit of SRM 2710 consists of 50 g of the dried material.

The certified elements for SRM 2710 are given in Table 1. The values are based on measurements using one definitive method or two or more independent and reliable analytical methods. Noncertified values for a number of elements are given in Table 2 as additional information on the composition. The noncertified values should **NOT** be used for calibration or quality control. Analytical methods used for the characterization of this SRM are given in Table 3 along with analysts and cooperating laboratories. All values (except for carbon) are based on measurements using a sample weight of at least 250 mg. Carbon measurements are based on 100 mg samples.

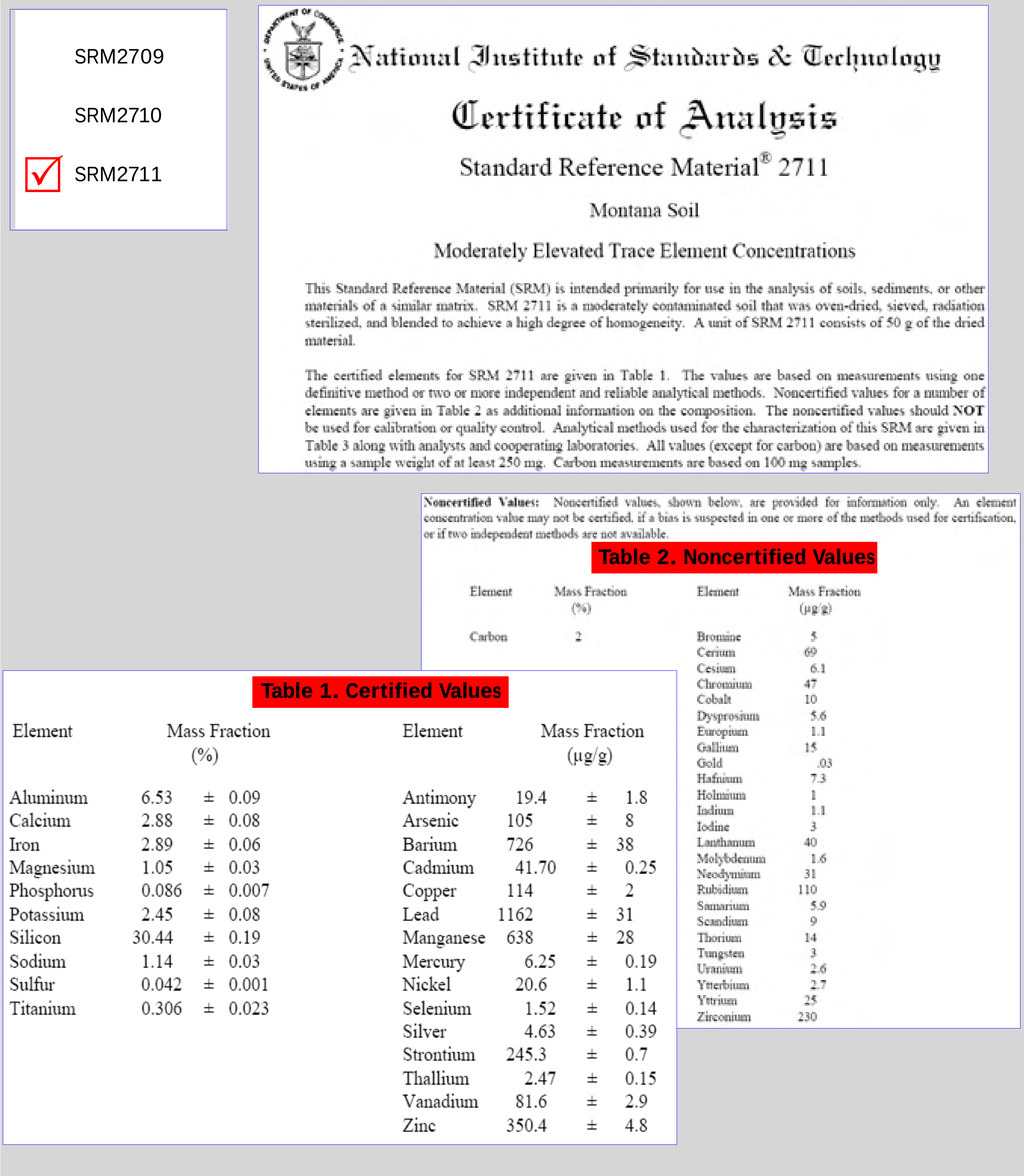
Noncertified Values: Noncertified values shown below are provided for information only. An element concentration value is not certified if a bias is suspected in one or more of the methods used for certification, or if two independent methods are not available.

Table 2. Noncertified Values

Element	Mass Fraction (%)	Element	Mass Fraction (mg/kg)
Carbon	3	Bromine	6
		Cerium	57
		Cesium	107
		Chromium	39
		Cobalt	10
		Dysprosium	5.4
		Europium	1
		Gallium	34
		Gold	0.6
		Hafnium	3.2
		Holmium	0.6
		Indium	5.1
		Lanthanum	34
		Molybdenum	19
		Neodymium	23
		Rubidium	120
		Samarium	7.8
		Scandium	8.7
		Strontium	330
		Thallium	1.3
		Thorium	13
		Tungsten	93
		Uranium	25
		Ytterbium	1.3
		Yttrium	23

Table 1. Certified Values

Element	Mass Fraction (%)	Element	Mass Fraction (mg/kg)
Aluminum	6.44 ± 0.08	Antimony	38.4 ± 3
Calcium	1.25 ± 0.03	Arsenic	626 ± 38
Iron	3.38 ± 0.10	Barium	707 ± 51
Magnesium	0.853 ± 0.042	Cadmium	21.8 ± 0.2
Manganese	1.01 ± 0.04	Copper	2950 ± 130
Phosphorus	0.106 ± 0.015	Lead	5532 ± 80
Potassium	2.11 ± 0.11	Mercury	32.6 ± 1.8
Silicon	28.97 ± 0.18	Nickel	14.3 ± 1.0
Sodium	1.14 ± 0.06	Silver	35.3 ± 1.5
Sulfur	0.240 ± 0.006	Vanadium	76.6 ± 2.3
Titanium	0.283 ± 0.010	Zinc	6952 ± 91



SRM2709

SRM2710

☑ SRM2711

National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 2711

Montana Soil

Moderately Elevated Trace Element Concentrations

This Standard Reference Material (SRM) is intended primarily for use in the analysis of soils, sediments, or other materials of a similar matrix. SRM 2711 is a moderately contaminated soil that was oven-dried, sieved, radiation sterilized, and blended to achieve a high degree of homogeneity. A unit of SRM 2711 consists of 50 g of the dried material.

The certified elements for SRM 2711 are given in Table 1. The values are based on measurements using one definitive method or two or more independent and reliable analytical methods. Noncertified values for a number of elements are given in Table 2 as additional information on the composition. The noncertified values should **NOT** be used for calibration or quality control. Analytical methods used for the characterization of this SRM are given in Table 3 along with analysts and cooperating laboratories. All values (except for carbon) are based on measurements using a sample weight of at least 250 mg. Carbon measurements are based on 100 mg samples.

Noncertified Values: Noncertified values, shown below, are provided for information only. An element concentration value may not be certified, if a bias is suspected in one or more of the methods used for certification, or if two independent methods are not available.

Table 2. Noncertified Values

Element	Mass Fraction (%)	Element	Mass Fraction (µg/g)
Carbon	2	Bromine	5
		Cerium	69
		Cesium	6.1
		Chromium	47
		Cobalt	10
		Dysprosium	5.6
		Europium	1.1
		Gallium	15
		Gold	.03
		Hafnium	7.3
		Holmium	1
		Indium	1.1
		Iodine	3
		Lanthanum	40
		Molybdenum	1.6
		Neodymium	31
		Rubidium	110
		Samarium	5.9
		Scandium	9
		Thorium	14
		Tungsten	3
		Uranium	2.6
		Ytterbium	2.7
		Yttrium	25
		Zirconium	230

Table 1. Certified Values

Element	Mass Fraction (%)			Element	Mass Fraction (µg/g)		
Aluminum	6.53	±	0.09	Antimony	19.4	±	1.8
Calcium	2.88	±	0.08	Arsenic	105	±	8
Iron	2.89	±	0.06	Barium	726	±	38
Magnesium	1.05	±	0.03	Cadmium	41.70	±	0.25
Phosphorus	0.086	±	0.007	Copper	114	±	2
Potassium	2.45	±	0.08	Lead	1162	±	31
Silicon	30.44	±	0.19	Manganese	638	±	28
Sodium	1.14	±	0.03	Mercury	6.25	±	0.19
Sulfur	0.042	±	0.001	Nickel	20.6	±	1.1
Titanium	0.306	±	0.023	Selenium	1.52	±	0.14
				Silver	4.63	±	0.39
				Strontium	245.3	±	0.7
				Thallium	2.47	±	0.15
				Vanadium	81.6	±	2.9
				Zinc	350.4	±	4.8

NOTES

A3. Specifications

Handheld Analyzer	Description
Weight	3.35 lbs. (Base wt.), 3.70 lbs. (1.6 kg) with battery
Excitation Source	4 Watt X-ray tube - Au, Ag, Rh, or Ta anode (application optimized), 8-40 keV, 5 - 200 µA, eight filter positions
Detector	Various: Si PIN diode or Si Drift detector, thermo-electrically cooled, high resolution
Power	Removable Li-ion batteries, or AC power unit
Battery Life	Battery life varies depending on usage patterns
Display	Color “transflective” touchscreen (800 x 600) with 16-bit LCD interface)
Cal Check Coupon	316 Stainless Steel Alloy -- see also Docking Station
Power Requirements for AC Adapter	110-220 VAC, 50-60 Hz, 600 W max (P/N 100043)
Pressure Correction	Built-in barometer for automatic altitude correction
Operating Environment	Temperature: -10°C to 45°C Humidity: 10 to 90% Relative Humidity, non-condensing Altitude Rating: 2000 meters
Operating System	Windows Embedded CE®
Application Software	Innov-X Systems’ proprietary Data Acquisition and Processing package.
USB Interface	USB 2.0

Operating specifications ar
posted as **nominal**.

Docking Station	Description
Dimensions	L=14.0 in x W=8.75 in x H=4.75 in (H w/ spare battery = 6.5 in); Wt = 3.25 lbs.
Power Requirement	AC adapter standard: 110-220 VAC, 50-60 Hz, 600 W max
Cal Check Cup	Automatically performs Cal Check on inserted instrument
Battery Charging	Charges battery in unit; can simultaneously charge spare battery in separate socket

Accessories	Description
AC Battery Charger	P/N 120253
TestStand/Workstation	A-020-D - portable equipment stand making a fully shielded closed beam system. Uses Delta PC Software.
Soil Foot	A-035
Soil Extension Pole	P/N 990055
Trimble Xploration Package (P6000FDC)	**XPLORER FIELD DATA COLLECTION BUNDLE** **Trimble Nomad 800G-LC** - Ruggedized 800Mhz Field Computer with integrated GPS, Wi-Fi, Bluetooth, Camera, 16Gb Memory, SD Card Slot Options: Barcode Scanner, Cell Phone Interface, Fully DGPS compatible running Windows Mobile 6.0 OS.

Trimble Xploration Package (P6000TFG)	**XPLORER TOTAL FIELD GEOCHEM BUNDLE** Includes all features supplied with **Field Data Collection Package** and: **Soil Extension Pole** - Ergonomic extension pole facilitating soil analysis by a standing (and walking) operator. **Soil Foot** - Attaches to nose of DELTA analyzer balancing analyzer on ground for hands-free, extended in-situ testing. **ioGAS** - ioAnalytics GeoChemical Analysis Software Suite, an advanced spatial data analysis package for visualization, interrogation & validation of geochemical data for mineral exploration, mining, & environmental industries.

A4. Typical Delta Test Sequence

Innov-X Delta User Interface

Operators manage their measurement, analysis, and results activities from the *Innov-X* UI when in ANY of the Alloy modes/calibrations. This Appendix presents:

- Typical Sample Test Procedure, and
- Prerequisites for testing necessary for various modes

GO TO

The operational features of the *Home, Mode, Setup, Test, and Results* screens are explained in *"Delta User Interface Guide" (PN 103202)*
In this document, **"***Delta User Manual***,"** see *C4, Operations, Page 47* for a SNAP-SHOT of the UI.

Typical Sample Test Procedure

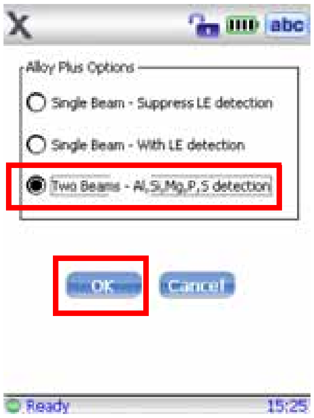
This sample procedure features the **Alloy Plus** mode.

Other modes follow a similar sequence, however, the **Test Condition** screens are generally unique to each testing situation.

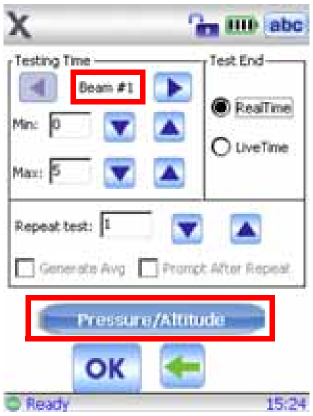
Use these steps:

1. From the **Home** screen, tap **Mode** icon
2. From **Mode** screen, tap the **Alloy Plus** icon
3. Select **Mode Setup** button

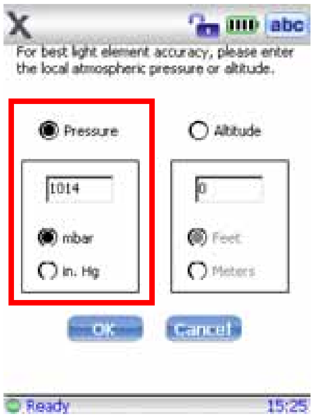
4. Select **Test Conditions**, then **Test Time**
5. Ensure that the **Testing Time** and other parameters are properly selected



○ Single Beam - Suppress LE detection
○ Single Beam - With LE detection
● Two Beams - Al,Si,Mg,P,S detection



Beam #1
Min: 0
Max: 5
● RealTime
○ LiveTime
Repeat test: 1
☐ Generate Avg
☐ Prompt After Repeat



For best light element accuracy, please enter the local atmospheric pressure or altitude.

● Pressure
1014
● mbar
○ in. Hg

○ Altitude
0
● Feet
○ Meters

6. Press OK button, the Back, then OK again
7. Return to Home screen, select **Test** to call the *Test-Alloy Plus* screen

Testing Tips for Certain Modes

Alloy:

- Place the analyzer's window on/over the test specimen, cover the window completely.
- Remember the Safety information (*C2, Pages 29-31*) to ensure your own personal safety.
- Take care not to damage the window film, such as when testing "metal turnings" or hot surfaces.

Soil or Mining:

- Place the analyzer's measurement window directly over the sample cup with the film side up.
- Specify the altitude or atmospheric pressure to gain increased accuracy for light elements.
- Confirm that the Testing Time and other parameters are properly selected
- Take care not to damage the window film, such as when testing uneven surfaces

RoHS:

- In order for XRF testing to be *quantitative*, samples must be:
  - Homogeneous
  - Have a certain minimum sample thickness
    - Five (5) mm for polymers and light alloys
    - Fifteen (15) mm for liquid samples
    - One (1) mm for other alloys
- If samples are heterogeneous, too thin, or too small, only *qualitative* screening is possible.

8. Start a new test by using one of these methods:
   a. Tap **Start** button on the UI (toggles Delta to X-ray ON state)
   — or —
   b. Pull the trigger (toggles instrument to X-ray ON state)
   — or —
   c. Pull-and-hold the trigger when the "Deadman Trigger" is active.

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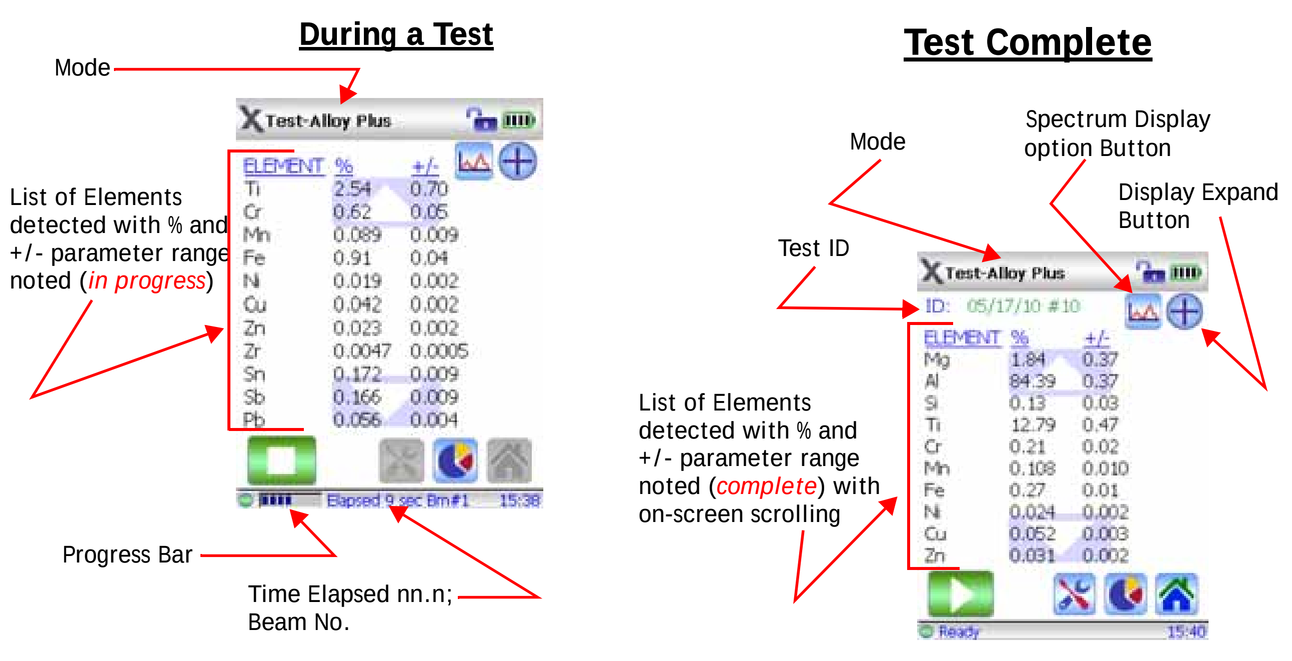


During a Test

List of Elements detected with % and +/- parameter range noted (*in progress*)

Time Elapsed nn.n; Beam No.

Test-Alloy Plus

ELEMENT	%	+/-
Ti	2.54	0.70
Cr	0.62	0.05
Mn	0.089	0.009
Fe	0.91	0.04
Ni	0.019	0.002
Cu	0.042	0.002
Zn	0.023	0.002
Zr	0.0047	0.0005
Sn	0.172	0.009
Sb	0.166	0.009
Pb	0.056	0.004

Elapsed 9 sec Bm#1 15:38

Test Complete

List of Elements detected with % and +/- parameter range noted (*complete*) with on-screen scrolling

Test-Alloy Plus

ID: 05/17/10 #10

ELEMENT	%	+/-
Mg	1.84	0.37
Al	84.39	0.37
Si	0.13	0.03
Ti	12.79	0.47
Cr	0.21	0.02
Mn	0.108	0.010
Fe	0.27	0.01
Ni	0.024	0.002
Cu	0.052	0.003
Zn	0.031	0.002

Ready 15:40

Best Practices for Testing

Alloy Mode

Prior to a test session, analysts should have an understanding of *Innov-X*'s implementation of:

- **Grade Libraries** -> populated by alloy Grades -> their chemistry characterized by Grade Tables.
  See *Grade Libraries* for library management procedures.
- **Match Issues** including the concept and use of Match Numbers.
  See *Match Issues*

Prior to initiating testing with the analyzer software, **ensure** that the following tasks are complete:

1. Analyzer does not require a Cal Check procedure.
2. The analyzer's measurement window is properly positioned in front of or over the test sample.
3. The *Match Cutoff* and *nSigma* parameters are configured.

Mining and Soil Modes

Check Standards

- Measure a **check standard** after each Cal Check, and periodically throughout the day. Test for a recommended minimum of one minute.
- Concentrations for elements of interest, in the range expected, plus or minus the error on the reading, should be within 20 percent of the standard value.
- *A2.Soil Testing* describes recommended quality assurance details.

- The standards provided with the analyzer are contained in XRF sample cups. These containers have a window (through which the soil can be viewed) on one side, and a solid cap on the other side.

Always measure samples through the window.

Sample Presentation

IN SITU TESTING

In situ testing is performed by pointing the analyzer at the ground. Clear any grass or large rocks away and hold the analyzer with the probe head front flush to the ground.

Since dirt can accumulate on the analyzer window, gently wipe the window clean after each analysis. Ensure the window is not ripped or punctured.

BAGGED OR PREPARED SAMPLE TESTING

Analyze prepared samples in a sample cup, through its window. Place the instrument's measurement window directly over the sample cup with the film side up.

Preparation considerations include:

- Avoid measuring very thin samples, as this can affect results. Prepare samples cups to contain at least 15 (usually 4-8 grams) mm of packed samples.
- When analyzing bagged samples, ensure that sufficient sample material exists in the bag to create a a sample thickness of a minimum of 15 mm for a spot size that is larger than the analyzer's measurement window.
- When using bags, cheaper bags (having thinner plastic walls) are better than more expensive ones (which have thicker plastic walls).

Consumer Mode

RoHS Best Practices

Check Standards

Innov-X Systems recommends that a check standard be measured after each Cal Check procedure, and periodically throughout the day.

Two certified standards are provided for verification.

- At least one standard should be measured for a minimum of two minutes.
- Concentrations for target elements (plus or minus the error on the reading) should be within 20% of the standard value.
- Standards provided are contained in XRF sample cups with a window (through which the plastic pellets can be viewed) on one side, and a solid cap on the other side.
- Samples should be measured in the sample cup, through the window.

Sample Presentation

Since many pieces of plastic analyzed for ROHS compliance are very small, take care to measure them in a safe and accurate manner.

See the IEC-ACEA recommendation for minimum thickness of test samples as shown in Chapter *C.8*.

A5. User Maintenance

5.1 Alternative Techniques for Powering or Charging the Delta

5.1.1. AC Power Adapter Kit

The kit is an **optional** accessory.

It is supplied with a 10 foot AC power cord, a switching AC adapter, and a Battery Module. This kit eliminates the Li-ion battery requirement, however the user is constrained by the length of the AC power cord.

The procedure for using the AC adapter is shown below.

WARNING

Ensure that each AC supply circuit has adequate power load capability and is provided from a grounded AC receptacle.

TO SETUP THE ADAPTER:

1. Plug the three-prong male plug into the receptacle.

2. Insert the three-prong female plug into the male receptacle on the *Switching AC Adaptor* brick.

3. Slide the Battery Eliminator unit into the analyzer with the contacts to the left. It is keyed to only go in oriented this way.

4. The user now has no limit to instrument power; not restricted by battery charge level. The range of action is constrained by the length of the power cord.

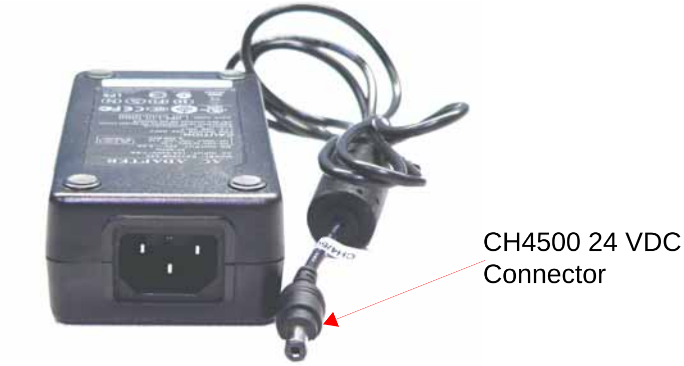
5.1.2. Li ion Battery Charger Assembly

This section describes the procedure for charging the Li-ion batteries when the Delta Docking Station is NOT available. It features a single socket standalone battery charger (P/N 120253) The unit takes about two hours to completely charge a battery. Status of the battery's charge is shown by two lights on the power adaptor.

To charge the battery:

1. Plug the three-prong male plug into the Modes receptacle.

2. Plug the three-prong female plug into the male receptacle on the *AC Adaptor* brick.

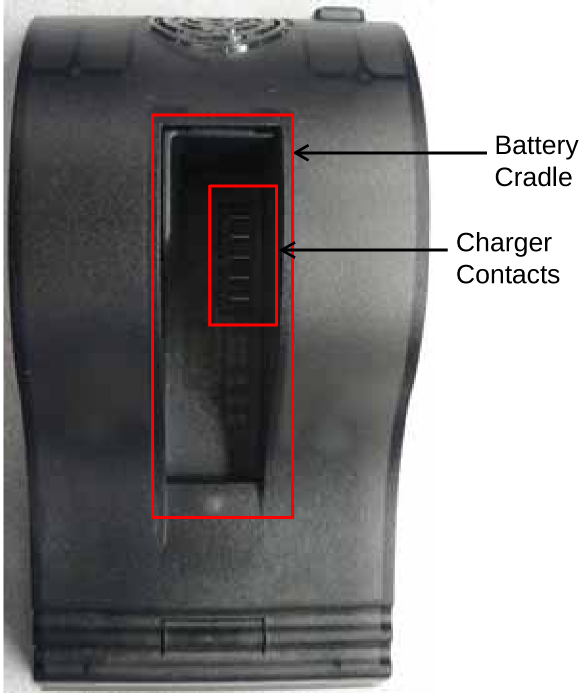


3. Plug the connector labeled *CH4500 24 VDC* into the connector labeled *SWC* on the back of the charger.

4. Insert the Li-ion battery into the charger with the contacts facing right.

CAUTION

Forcing the battery in with the contacts oriented improperly will injure the contacts and destroy the battery.



Battery Charger Status Lights

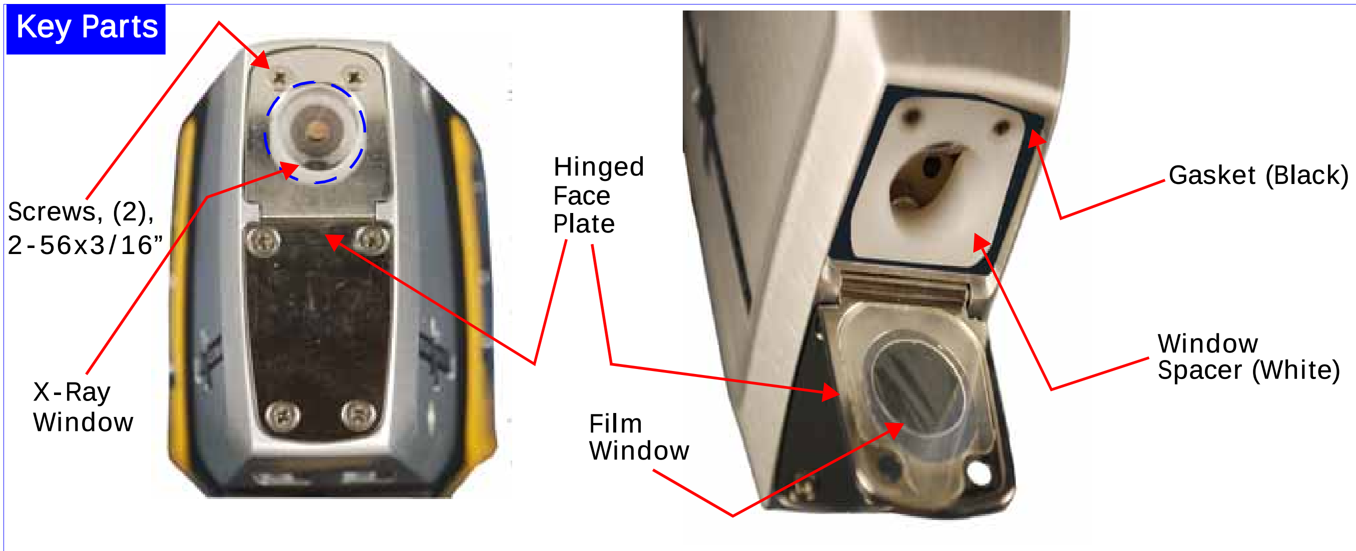
Left Light (Green only)	Right Light (Red only)	Status 
On - Flashing	Off	Battery is charging
On - Solid	Off	Battery is charged
Off	On - Solid	Error. Remove battery and replace on charger. If the error persists, call Innov-X Systems Technical support.
Off	Off	No battery is on charger

5.2 — Window Replacement for “Hinged Plate” Analyzers

How to Replace the Window on a Delta Analyzer (All Models)

Tools: *Required* - Small Phillips Head Screwdriver
Recommended - Tweezers or Needle nose pliers; Can of compressed air
As needed: - Lint-free wipes or swabs

Key Parts



Remove Old Window

Use these guidelines:

- During this entire removal process, keep dust or foreign material out of the instrument.
- Ensure that the instrument is powered off.
- Take care to have clean hands.
- Orient the instrument with the nose pointing up.
- Review the **TIPS** section on next page **before** opening the hinged plate.
- Use Phillips head screwdriver to remove the two screws.
  - Carefully set aside the screws.
- Swing the hinged face plate out to expose the film window.
- Remove the old window.
- Observe the white plastic window spacer and the black rubber gasket
- Remove any dirt or foreign material from the gasket with compressed air
- Take EXTREME CARE to not harm any internal components

CAUTION Avoid expensive internal damage, DO NOT INSERT anything (fingers or tools) into the instrument.

Replacement Window Details

- Windows assemblies are made from either **Prolene, Mylar,** or **Kapton** film.
    - Users must specify the proper material to match their original application and calibration.
- The selected film is adhered to **one** side of a polyester backing plate; this creates a “front” and “back” surface
    - “Back” surface is completely covered with film.
    - “Front” surface shows a circular ridge where the film only is present, showing through the center hole of backing plate. This front surface also has a part type designator.
- Ensure that the “back” surface faces up when installing a new window (See below).

PRO 6
Prolene

MYL 25
Mylar

KAP 8
Kapton

P/N: -->> 102999 103000 103173 (Hi-Temp)
103115 (Classic Standard)

Install Replacement

Follow these steps:

- Remove new window assembly from shipping envelope.
- Handle it by edges or use tweezers.
- Apply canned compressed air to clear any contaminants from the surfaces.
- Place window assembly on the hinged plate with **film back surface facing up**.
    - Center it to avoid the screw holes.
- Carefully rotate the hinged plate up to secure the window assembly.
- Insert the two screws; tighten only to “snug”.
    - Don’t over-tighten them or strip the threads.

TIPS

- Do not touch the film in the center opening (on either side).
- When using the screwdriver, keep a finger or thumb between the tool and the X-ray window. This prevents accidentally sticking the tool through the film and causing internal damage.
- The cost for replacement windows is quite low. Users are encouraged to change them frequently in order to obtain optimum test results.
- When not operating an instrument, experienced users routinely keep it the Delta Docking Station cradle.
    - This keeps the window clean, and
    - Prevents accidental damage to the window film, and
    - Takes advantage of the battery charging and Cal Checking procedure that the DDS offers.

NOTES

A6. Packing and Shipping

If the instrument is not returned in the protective case, it can be damaged during shipping. Innov-X Systems reserves the right to void the warranty on instruments that are damaged during return shipping that are sent <u>without</u> the protective case.

Prior to returning a unit, contact Customer Service at the appropriate depot:

— United States —

- Phone: 1-781-938-5005
- Fax: 1-781-938-0128
- Email:
  Service@Innov-Xsys.com

- Mail & Shipping Address:
  Innov-X Systems, Inc.
  100 Sylvan Road
  Woburn, MA 01801

— Canada —

- Phone: 1-778-960-6279
- Fax: 1-604-568-2474
- Toll Free Fax:
  1-888-873-6598
- Email:
  service@innovx.ca

- Mail & Shipping Address:
  Innov-X Canada
  1201 West Georgia, Ste. 2
  Vancouver BC
  Canada V6E 3J5

— Europe —

- Phone:
  +31 (0)73 62 72 590
- Fax: +31 (0)73 62 72 599
- Email:
  info@innovx-europe.com

- Mail & Shipping Address:
  Innov-X Systems, Inc.
  Kasteleinenkampweg 9R
  5222 AX 's-Hertogenbosch
  The Netherlands

— Australia —

- Phone: 02 9577 9500
- Fax: 02 9519 1850
- Email:
  service@innovx.com

- Mail & Shipping Address:
  Innov-X Systems Australia
  PTY LTD
  Suite 6, Level 3
  215 Euston Road
  Alexandria NSW 2015
  Australia

Or call your local distributor.

Ensure that you receive the required RMA number.

Follow these instructions to return your XRF Analyzer:

1. Pack the analyzer in the black protective case in which it arrived, using the original packing materials.
2. Include the RMA in the case and reference the RMA number in your shipping documents.
3. Close the protective case and either:
   - Secure it with plastic zip ties,
     — or —
   - Pack the protective case within another box.

Regulations for Shipping Products with Lithium Ion Batteries

The United States and many other countries have instituted regulations that require shippers to use a special Caution label referring to a Lithium Ion Battery.

- Label must be prominently displayed on the outer shipping container of any product that contains a Lithium Ion battery.
- Shipper may copy the label shown below to facilitate making the warning label. Use a color copier if possible.

CAUTION!

IF DAMAGED

LITHIUM ION BATTERY

DO NOT LOAD OR TRANSPORT
PACKAGE IF DAMAGED

For more information, call

L435P LABELMASTER® (800) 621-5808 www.labelmaster.com

A7. Legal Information

This section provides copies of the following:

- Delta Analyzer Limited Warranty including:
    - Limitation of Liability
    - Warranty Period, Returns, and Repairs
    - Instructions for Contacting Innov-X
- End User Software License Agreement including:
    - Use, Restrictions, and Termination of Software
    - Governmental End User Conditions
    - Limited Warranty and Limitation of Liability

Innov-X Delta Analyzer Limited Warranty

General Terms

EXCEPT AS EXPRESSLY SET FORTH IN THIS LIMITED WARRANTY, INNOV-X SYSTEMS, INC. (INNOV-X) MAKES NO OTHER WARRANTIES OR CONDITIONS, EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. INNOV-X EXPRESSLY DISCLAIMS ALL WARRANTIES AND CONDITIONS NOT STATED IN THIS LIMITED WARRANTY. ANY IMPLIED WARRANTIES THAT MAY BE IMPOSED BY LAW ARE LIMITED IN DURATION TO THE LIMITED WARRANTY PERIOD.

This Limited Warranty applies to Innov-X analyzers sold or leased from Innov-X, its affiliates, authorized resellers, or country distributors (collectively referred to in this Limited Warranty as “Innov-X.”

Innov-X warrants that the analyzer and all its internal and external components that you have purchased are free from defects in materials or workmanship under normal use during the Limited Warranty Period. The Limited Warranty Period starts on the date of shipment by Innov-X. You may be required to provide proof of purchase or lease as a condition of receiving warranty service. You are entitled to warranty service according to the terms and conditions of this document if a repair to your Innov-X analyzer is required within the Limited Warranty Period.

During the Limited Warranty Period, Innov-X will repair or replace the defective component parts. All component parts removed under this Limited Warranty become the property of Innov-X. In the unlikely event that your Innov-X analyzer has a recurring failure, Innov-X, at its discretion, may elect to provide you with a replacement unit of Innov-X’s choosing that is at least equivalent to your Innov-X analyzer. This is your exclusive remedy for defective products. The repaired or replacement analyzer is warranted for the remainder of the limited Warranty Period.

YOU SHOULD MAKE PERIODIC BACKUP COPIES OF THE DATA STORED ON THE ANALYZER’S SYSTEM COMPUTER AS A PRECAUTION AGAINST POSSIBLE FAILURES, ALTERATION, OR LOSS OF THE DATA. BEFORE RETURNING ANY UNIT FOR SERVICE, BE SURE TO BACK UP DATA AND REMOVE ANY CONFIDENTIAL, PROPRIETARY, OR PERSONAL INFORMATION. INNOV-X IS NOT RESPONSIBLE FOR DAMAGE TO OR LOSS OF ANY PROGRAMS, OR DATA. INNOV-X IS NOT RESPONSIBLE FOR THE RESTORATION OR REINSTALLATION OF ANY PROGRAMS OR DATA OTHER THAN SOFTWARE INSTALLED BY INNOV-X WHEN THE ANALYZER IS MANUFACTURED.

Innov-X does not warrant that the operation of this analyzer will be uninterrupted or error-free. Innov-X is not responsible for damage that occurs as a result of your failure to follow the instructions that came with the Innov-X analyzer.

This Limited Warranty does not apply to expendable parts. This Limited Warranty does not extend to any analyzer from which the serial number has been removed or that has been damaged or rendered defective (a) as a result of accident, misuse, abuse, or other external causes; (b) by operation outside the usage parameters stated in user documentation that shipped with the product; (c) by modification or service by anyone other than (i) Innov-X, or (ii) an Innov-X authorized service provider; (d) installation of software not approved by Innov-X.

These terms and conditions constitute the complete and exclusive warranty agreement between you and Innov-X regarding the Innov-X analyzer you have purchased or leased. These terms and conditions supersede any prior agreements or representations --- including representations made in Innov-X sales literature or advice given to you by Innov-X or any agent or employee of Innov-X --- that may have been made in connection with your purchase or lease of the Innov-X analyzer. No change to the conditions of this Limited Warranty is valid unless it is made in writing and signed by an authorized representative of Innov-X.

Limitation of Liability

IF YOUR INNOV-X ANALYZER FAILS TO WORK AS WARRANTED ABOVE, YOUR SOLE AND EXCLUSIVE REMEDY SHALL BE REPAIR OR REPLACEMENT. INNOV-X'S MAXIMUM LIABILITY UNDER THIS LIMITED WARRANTY IS EXPRESSLY LIMITED TO THE LESSER OF THE PRICE YOU HAVE PAID FOR THE ANALYZER OR THE COST OF REPAIR OR REPLACEMENT OF ANY COMPONENTS THAT MALFUNCTION IN CONDITION OF NORMAL USE.

INNOV-X IS NOT LIABLE FOR ANY DAMAGE CAUSED BY THE PRODUCT OR THE FAILURE OF THE PRODUCT TO PERFORM INCLUDING ANY LOST PROFITS OR SAVINGS OR SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES. INNOV-X IS NOT LIABLE FOR ANY CLAIM MADE BY A THIRD PARTY OR MADE BY YOU FOR A THIRD PARTY.

THIS LIMITATION OF LIABILITY APPLIES WHETHER DAMAGES ARE SOUGHT, OR A CLAIM MADE, UNDER THIS LIMITED WARRANTY OR AS A TORT CLAIM (INCLUDING NEGLIGENCE AND STRICT PRODUCT LIABILITY), A CONTRACT CLAIM, OR ANY OTHER CLAIM. THIS LIMITATION OF LIABILITY CANNOT BE WAIVED OR AMENDED BY ANY PERSON. THIS LIMITATION OF LIABILITY WILL BE EFFECTIVE EVEN IF YOU HAVE ADVISED INNOV-X OR AN AUTHORIZED REPRESENTATIVE OF INNOV-X OF THE POSSIBILITY OF ANY SUCH DAMAGES.

Software

This Limited Warranty does not warrant software products. The Innov-X software installed on the analyzer’s system computer is covered by the Innov-X End User Software License Agreement.

Warranty Period

The warranty period for an Innov-X Delta Analyzer is two years. This warranty does not extend to expendable parts. Extended warranties are available from Innov-X.

Warranty Returns

A Return Material Authorization (RMA) Number must be obtained from the INNOV-X Service Department before any items can be shipped to the factory. Returned goods will not be accepted without an RMA Number. Customer will bear all shipping charges for warranty repairs. All goods returned to the factory for warranty repair should be properly packed to avoid damage and clearly marked with the RMA Number.

Warranty Repairs

Warranty repairs will be done either at the customer's site or at the INNOV-X plant, at our option. All service rendered by INNOV-X will be performed in a professional manner by qualified personnel.

Contacting Innov-X

Be sure to have the following information available before you call Innov-X:

- Analyzer serial number, model name, and model number
- Applicable error messages
- Description of problem
- Detailed questions

Methods of Contact

— United States —

- Phone: 1-781-938-5005
- Fax: 1-781-938-0128
- Email: Service@Innov-Xsys.com

- Mail & Shipping Address:
  Innov-X Systems, Inc.
  100 Sylvan Road
  Woburn, MA 01801

— Canada —

- Phone: 1-778-960-6279
- Fax: 1-604-568-2474
- Toll Free FAX: 1-888-873-6598
- Email: service@innovx.ca

- Mail & Shipping Address:
  Innov-X Canada
  1201 West Georgia, Ste. 2
  Vancouver BC
  Canada V6E 3J5

— Europe —

- Phone: +31 (0)73-62 72 590
- Fax: +31 (0)73-62 72 599
- Email: info@innovx-europe.com

- Mail & Shipping Address:
  Innov-X Systems, Inc.
  Kasteleinenkampweg 9R
  5222 AX 's-Hertogenbosch
  The Netherlands

— Australia —

- Phone: 02 9577 9500
- Fax: 02 9519 1850
- Email: service@innovx.com

- Mail & Shipping Address:
  Innov-X Systems Australia
  PTY LTD
  215 Euston Road, # 6 / L3
  Alexandria, NSW, 2015
  Australia

Or call your local distributor.

End User Software License Agreement

THIS END USER SOFTWARE LICENSE AGREEMENT IS FOR THE SOFTWARE USED TO OPERATE THE INNOV-X SYSTEMS' Delta™ XRF ANALYZER AND LIMITED PRODUCT WARRANTY

NOTICE TO USER:

PLEASE READ THIS DOCUMENT CAREFULLY. THIS IS THE CONTRACT BETWEEN YOU AND INNOV-X SYSTEMS, INC. (INNOV-X), REGARDING THE OPERATING SOFTWARE FOR YOUR INNOV-X Delta™ XRF ANALYZER INSTRUMENT.

THIS LICENSE COVERS THE INNOV-X SOFWARE INSTALLED ON THE DELTA™ XRF ANALYZER'S SYSTEM COMPUTER AND THE INNOV-X SOFTWARE OR FIRMWARE INSTALLED ON THE COMPUTER CHIPS WITHIN YOUR ANALYZER ENCLOSURE. THIS AGREEMENT CONTAINS WARRANTY AND LIABILITY DISCLAIMERS AND LIMITATIONS. YOUR INSTALLATION AND USE OF THE INNOV-X SOFTWARE IS SUBJECT TO THE TERMS AND CONDITIONS CONTAINED IN THIS END USER SOFTWARE LICENSE AGREEMENT. THIS LICENSE DOES NOT COVER THE OPERATING SYSTEM SOFTWARE AND OTHER SOFTWARE THAT MAY BE INCLUDED.

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5. You may not modify, sell, rent, transfer (except temporarily in the event of a computer malfunction), resell for profit, or distribute this license or the Software, or create derivative works based on the Software, or any part thereof or any interest therein. Notwithstanding the foregoing, you may transfer this Software to a purchaser of the specific Innov-X Analyzer in or for which this Software is installed in connection with any sale of such Analyzer, provided that the transferee agrees to be bound by and to comply with the provisions of this Agreement. A re-licensing fee may be charged for any such replacement software.

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You may terminate this Agreement by discontinuing use of the Software, removing all copies from the system computer' hard drive and returning the Software and Documentation, and all copies thereof, to Innov-X Systems, Inc. Innov-X Systems, Inc. may terminate this Agreement if you fail to comply with all of its terms, in which case you agree to discontinue using the Software, remove all copies from the system computer and storage media, and return all copies of the Documentation thereof, to Innov-X Systems, Inc.

WARNING: Although it is theoretically possible for you to write software to operate the Innov-X analyzer, you are required to return the software as a result of failing to comply with the terms of this license, it is likely that the Analyzer purchased with the software covered by this License will not work properly. In addition, any remaining term under the warranty on the Analyzer will be voided.

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Limited warranty and Limitation of remedies

Limited Warranty

Innov-X Systems, Inc. warrants that for a period of ninety days from the beginning of the applicable warranty period (as described below), or for the designated warranty period if a different warranty period is designed as the warranty period for the Software in the current version of an instrument operating manual or catalog or in a specific written warranty including with and covering the Software, the Software will function substantially in accordance with the functions and features described in the Documentation delivered with the Software when properly installed.

The above warranties do not apply to defects resulting from misuse, neglect, or accident, including without limitation: operation outside of the Innov-X analyzer or use specifications, or not in conformance with the instructions for any instrument system, software, or accessories; improper or inadequate maintenance by the user; installation of software or interfacing, or use in combination with software or products not supplied or authorized by Innov-X Systems, Inc.; and modification or repair of the analyzer not authorized by Innov-X Systems, Inc.

Warranty Period Commencement Date.

The applicable warranty period for software begins on the earlier of the date of installation or three (3) months from the date of shipment for software installed by Innov-X Systems, Inc.' personnel. For software installed by the purchaser or anyone other than Innov-X Systems, Inc., the warranty period begins on the date the software is delivered to you. The applicable warranty period for media begins on the date the media is delivered to the purchaser.

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IN NO EVENT SHALL INNOV-X SYSTEMS, INC. OR ITS SUPPLIERS BE RESPONSIBLE OR LIABLE, WHETHER IN CONTRACT, TORT, WARRANTY OR UNDER ANY STATUTE (INCLUDING WITHOUT LIMITATION ANY TRADE PRACTICE, UNFAIR COMPETITION OR OTHER STATUTE OF SIMILAR IMPORT) OR ON ANY OTHER BASIS FOR SPECIAL, INDIRECT, INCIDENTAL, MULTIPLE, PUNITIVE, OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE POSSESSION OR USE OF, OR THE INABILITY TO USE, THE SOFTWARE OR DOCUMENTATION, EVEN IF INNOV-X SYSTEMS, INC. IS ADVISED IN ADVANCE OF THE POSSIBILITY OF SUCH DAMAGES, INCLUDING WITHOUT LIMITATION DAMAGES ARISING FROM OR RELATED TO LOSS OF USE, LOSS OF DATA, DOWNTIME, OR FOR LOSS OF REVENUE, PROFITS, GOODWILL OR BUSINESS OR OTHER FINANCIAL LOSS. IN ANY CASE, THE ENTIRE LIABILITY OF INNOV-X SYSTEMS, INC.' AND ITS SUPPLIERS UNDER THIS LICENSE, OR ARISING OUT OF THE USE OF THE SOFTWARE, SHALL NOT EXCEED IN THE AGGREGATE THE PURCHASE PRICE OF THE PRODUCT.

SOME STATES, COUNTRIES OR JURISDICTIONS LIMIT THE SCOPE OF OR PRECLUDE LIMITATIONS OR EXCLUSION OF REMEDIES OR DAMAGES, OR OF LIABILITY, SUCH AS LIABILITY FOR GROSS NEGLIGENCE OR WILLFUL MISCONDUCT, AS OR TO THE EXTENT SET FORTH ABOVE, OR DO NOT ALLOW IMPLIED WARRANTIES TO BE EXCLUDED. IN SUCH STATES, COUNTRIES OR JURISDICTIONS, THE LIMITATION OR EXCLUSION OF WARRANTIES, REMEDIES, DAMAGES OR LIABILITY SET FORTH ABOVE MAY NOT APPLY TO YOU. HOWEVER, ALTHOUGH THEY SHALL NOT APPLY TO THE EXTENT PROHIBITED BY LAW, THEY SHALL APPLY TO THE FULLEST EXTENT PERMITTED BY LAW. YOU MAY ALSO HAVE OTHER RIGHTS THAT VARY BY STATE, COUNTRY OR OTHER JURISDICTION.

General

This Agreement shall be governed by laws of the State of Massachusetts, exclusive of its conflict of laws provisions. This Agreement shall not be governed by the United Nations Convention on Contracts for the International Sale of Goods. This Agreement contains the complete agreement between the parties with respect to the subject matter hereof, and supersedes all prior or contemporaneous agreements or understandings, whether oral or written. If any provision of this Agreement is held by a court of competent jurisdiction to be contrary to law that provision will be enforced to the maximum extent permissible and the remaining provisions of this Agreement will remain in full force and effect. The controlling language of this Agreement, and any proceedings relating to this Agreement, shall be English. You agree to bear any and all costs of translation, if necessary. The headings to the sections of this Agreement are used for convenience only and shall have no substantive meaning. All questions concerning this Agreement shall be directed to Innov-X Systems, Inc., 100 Sylvan Road, Suite 500, Woburn, MA 01801 USA. Tel: 1-781-938-5005 Fax: 1-781-938-0128

A8. Alloy Grade Libraries

Every Delta unit is supplied with four libraries:

1. “Factory” Library unique to every Model
    - See following pages for tables showing Model/Factory grade names
2. Tramp Library
3. User Library #1 (user may store more than 500 grade names)
4. User Library # 2 (user may store more than 500 grade names)

Libraries are editable. However, InnovX does not recommend that users edit the “Factory” grade library.

Tramp Library

Every analyzer is shipped with a “Tramp” library comprised of seven base alloys. The “Tramp” library supports other grade libraries.

Users can set Tramp Limits, element by element, alloy base by alloy base, to meet their specific requirements.

A single click can select/deselect (globally) the Tramp feature.

How the Tramp Library works:

1. Tramp Grades are matched to alloy bases rather than specific grades.
    — Each sample is determined to be one of seven possible base alloys - see list below
    — Analyzer applies the Tramp Grade/base specific tramp limits from the matching Tramp Grade;
2. These “Tramp Limits” or “alloy base specific” limits are applied when an element is detected in a specific grade.
    — But, the nearest grade match has no specification for that element,
    — And, the concentration of the sample is less than the max limit specified by the matching Tramp Grade.
3. When conditions of #2 are met, the element is reported on the User Interface screen.
    - In **blue**;
    - Is labeled as a **“Tramp”** material in the grade comparison table;
    - But the grade match is not penalized.

PRACTICAL ADVANTAGES of this “tramp element” approach:

- Faster sorting,
- Fewer ambiguous or incorrect matches,
- Improved grade library integrity,
- Prominent labeling of tramp elements.

TRAMP Library Base Alloys

_AlAlloyBase
Common Tramp Elements: Pb, Bi, Sn, Fe, Cu, Zn

_CoAlloyBase
Common Tramp Elements: Al, Ti, V, Cu, Nb, Ta, Zr

_CuAlloyBase
Common Tramp Elements: S, As, Ag, Sb, Sn; not as common Pb, Co, Ni

_FeAlloyBase
Common Tramp Elements: V, Co, Cu, Ni, As - sometimes Si, W, Nb

_GenericAlloyBase
Common Tramp Elements: V, Co, Cu, Ni, As - sometimes Si, W, Nb

_NiAlloyBase
Common Tramp Elements: V, Co, W, Zr, Nb - sometimes Ta, Mo, Cr, Cu

_TiAlloyBase
Common Tramp Elements: Fe is common, Cu & Si show up at low levels.

Factory Grade Library {Table A9.1-Classic}

Aluminums-C

- 2007
- 2011
- 2018
- 2117
- 2618
- 4032
- 5454
- 6040
- 6061
- 6070
- 6253
- 6262
- 7005
- 7016
- 7019
- 7039
- 7050
- 7072
- 7075
- 7104
- 1100-plus
- 2024-plus
- 2098-2195
- 2219-2519
- 3003 or 4 or 5
- 355-2
- 5052-plus
- 5086-plus
- 6063-plus
- 7049-149-249

Cobalt Alloys - C

- Alloy 686
- AlnicoVIII
- Cobalt
- Elgiloy
- F75
- FSX-414
- Haynes188
- Haynes36
- HS-1
- HS-12
- HS-19
- HS-21
- HS25-L605
- HS-31
- HS-4
- HS-6B
- Jetalloy
- MarM302
- MarM509
- MarM905
- MP35N
- MPN159
- Star J
- Ultimet

Specialty Grades- C

- 60Sn-40Pb
- 63Sn-37Pb
- 96-4
- AZ31B
- AZ91A or C
- SAC 300
- SAC 305
- SAC 400
- SAC 405
- 97-3
- Ag
- Au
- Bi
- Cb 103
- CP Ta
- Cr
- Densalloy
- Hf
- Mn
- Mo
- Nb
- Ni
- Pb
- Pd
- Re
- Sb
- Se
- Sn
- TungCarb C
- TungCarb S
- V
- W
- Zn
- Zr
- Zr 2 or 4
- Zr 702
- Zr 704
- Zr 705

Copper Alloys -C

- C 110
- C 172
- C 194
- C 210
- C 220
- C 260
- C 270
- C 310
- C 314
- C 330
- C 332
- C 340
- C 342
- C 360
- C 377
- C 425
- C 443
- C 464
- C 482
- C 485
- C 510
- C 524
- C 534
- C 544
- C 623
- C 630
- C 655
- C 667
- C 673
- C 675
- C 706
- C 710
- C 715
- C 745
- C 752
- C 814
- C 836
- C 857
- C 864
- C 867
- C 868
- C 875
- C 8932
- C 903
- C 922
- C 932
- C 937
- C 955
- C194HiCu
- C197HiCu
- Elec Cu
- Muntz
- NarloyZ
- SeBiLOYI
- SeBiLOYII
- SeBiLOYIII

Low Alloy Steels-C

- 3310
- 4130
- 4140
- 4340
- 8620
- 9310
- 12L14
- A10
- Carb 1-2 Moly
- Carbon Steel
- 20Mo4

Chrome-Moly Steels -C

- 1 1-4 Cr
- 2 1-4 Cr
- 5 Cr
- 9 Cr
- P91

Nickel Alloys - C

- B 1900
- B-1900 Hf
- C-1023
- GMR235
- GTD222
- Hast BC1
- HastB
- HastB2
- HastB3
- HastC2000
- HastC22
- HastC276
- HastC4
- HastF
- HastG
- HastG2
- HastG3
- HastG30
- HastN
- HastR
- HastS
- HastW
- HastX
- Haynes230
- HR160
- HyMu80
- I-102I-49
- I-600
- I-601
- I-617
- I-625
- I-690
- I-700
- I-702
- I-706
- I-713
- I-718
- I-720
- I-722
- I-725
- I-738
- I-750
- I-792
- I-800
- I-801
- I-825
- I-901
- I-903
- I-907-909
- I-939
- IN100Mar
- M002
- MarM200
- MarM246
- MarM247
- MarM421
- Monel400
- Monel411
- MonelK500
- MuMetal
- Ni 200
- NichromeV
- Nim101
- Nim263
- Nimonic75
- Nimonic80A
- Nimonic90
- PWA1480
- PWA1484
- RA333
- Rene125
- Rene142
- Rene220
- Rene41
- Rene77
- Rene80
- Rene95
- Supertherm
- Udimet500
- Udimet520
- Udimet700
- Waspaloy

Factory Grade Library {Table A9.2-Classic}

Stainless Grades - C

- 201
- 203
- 304
- 309
- 310
- 316
- 317
- 321
- 329
- 330
- 347
- 422
- 430
- 431
- 434
- 440
- 441
- 446
- 2003
- 2101
- 2507
- 13-8 Mo
- 15-5 PH
- 15Mn7Cr
- 17-4 PH
- 17-7 PH
- 19-9DL
- 19-9DX
- 20Cb3
- 20Mo6
- 21-6-9
- 25-4-4
- 254SMO
- 26-1
- 29-4
- 29-4-2
- 29-4C
- 302HQ
- 410 Cb
- 410-16-20
- 904L
- A-286
- AL6XN
- Alloy42
- AlnicoII
- AlnicoIII
- AlnicoV
- AMS350
- AMS355
- CD4MCU
- Custom450
- Custom455
- Duplex2205
- E-bite
- Ferallium255
- GreekAscoloy
- H12
- H13
- Haynes556
- Incoloy840
- Invar 36
- Kovar
- M152
- Maraging350
- MaragingC200
- MaragingC250
- MaragingC300
- N-155
- Ni-hard#1
- Ni-hard#4
- Ni-Span902
- Nitronic40
- Nitronic50
- Nitronic60
- RA330
- RA85H
- Zeron100

Ti Grades - C

- Cp Ti
- Cp Ti Pd
- Ti 12
- Ti 17
- Ti 3 2-5
- Ti 6-22-22
- Ti 6-2-4-2
- Ti 6-2-4-6
- Ti 6-4
- Ti 6-6-2
- Ti 8
- Ti 8-1-1
- Ti10-2-3
- Ti15-3-3-3
- Ti3-11-13
- Ti5 - 2-5
- Ti6-2-1-1
- TiBetaC

Tool Steels- C

- A2
- A6
- A7
- D2 or D4
- D7
- H-11
- M1
- M2
- M4
- M42
- O1
- O2
- O6
- O7
- S1
- S5
- S6
- S7
- T1

Factory Grade Library {Table A9.3-Standard}

Aluminums-S

319
333
380
383
384
2007
2011
2018
2024
2117
2618
3004
4032
5042
5052
5083
5086
5154
5454
6040
6061
6070
6253
6262
7005
7016
7019
7039
7050
7072
7075
7104
1100-plus
2014-17 std
2024-plus
2098-2195
2219-2519
3003 or 4 or 5
3003 or 5
355-2
356-57-std
5052-plus
5056-82
5086-plus
6063-plus
7049-149-249

Cobalt Alloys - S

Alloy 686
AlnicoVIII
Cobalt
Elgiloy
F75
FSX-414
Haynes188
Haynes36
HS-1
HS-12
HS-19
HS-21
HS25-L605
HS-31
HS-4
HS-6B
Jetalloy
MarM302
MarM509
MarM905
MP35N
MPN159
Star J
Ultimet

Low Alloy Steels-S

3310
4130
4140
4340
8620
9310
12L14
A10
Carb 1-2
Moly
Carbon Steel
P20
135 N

Specialty Grades- S

60Sn-40Pb
63Sn-37Pb
96-4
AZ31B
AZ91A or C
SAC 300
SAC 305
SAC 400
SAC 405
97-3
Ag
Au
Bi
Cb 103
CP Ta
Cr
Densalloy
Hf
Mn
Mo
Nb
Ni
Pb
Pd
Re
Sb
Se
Sn
TungCarb C
TungCarb S
V
W
Zn
Zr
Zr 2 or 4
Zr 702
Zr 704
Zr 705

Chrome-Moly Steels -S

1 1-4 Cr
2 1-4 Cr
5 Cr
9 Cr
P91

Copper Alloys -S

C 110
C 172
C 194
C 210
C 220
C 260
C 270
C 310
C 314
C 330
C 332
C 340
C 342
C 360
C 377
C 425
C 443
C 464
C 482
C 485

C 510
C 524
C 534
C 544
C 623
C 630
C 655
C 667
C 673
C 675
C 706
C 710
C 715
C 745
C 752
C 814
C 836
C 857

C 864
C 867
C 868
C 875
C 8932
C 903
C 922
C 932
C 937
C 955
C194HiCu
C197HiCu
Elec Cu
Muntz
NarloyZ
SeBiLOYI
SeBiLOYII
SeBiLOYIII

Nickel Alloys - S

20Mo4
B 1900
B-1900 Hf
C-1023
Colmonoy 6
GMR235
GTD222
Hast BC1
HastB
HastB2
HastB3
HastC2000
HastC22
HastC276
HastC4
HastF
HastG
HastG2
HastG3
HastG30
HastN
HastR
HastS
HastW
HastX
Haynes214
Haynes230
HR160
HyMu80

I-102
I-49
I-600
I-601
I-602
I-617
I-625
I-690
I-700
I-702
I-706
I-713
I-718
I-720
I-722
I-725
I-738
I-750
I-792
I-800
I-801
I-825
I-901
I-903
I-907-909
I-939
IN100
MarM002
MarM200
MarM246

MarM247
MarM421
Monel400
Monel411
MonelK500
MuMetal
Ni 200
NichromeV
Nim101
Nim263
Nimonic75
Nimonic80A
Nimonic90
PWA1480
PWA1484
RA333
Rene125
Rene142
Rene220
Rene41
Rene77
Rene80
Rene95
Supertherm
Udimet500
Udimet520
Udimet700
Waspaloy

Factory Grade Library {Table A9.4-Standard}

Stainless Grades - S

201
203
303
304
309
310
316
317
321
329
330
347
410
416
420
422
430
431
434
440
441
446
2003
2101
2205
2205
2507
13-8 Mo
15-5 PH
15Mn7Cr

17-4 PH
17-7 PH
19-9DL
19-9DX
20Cb3
20Mo6

21-6-9
25-4-4
254SMO
26-1
29-4
29-4-2
29-4C
302HQ
410 Cb
410-16-20
904L
A-286
AL6XN
Alloy42
AlnicoII
AlnicoIII
AlnicoV
AMS350
AMS355
CD4MCU
Custom450
Custom455
E-bite
Ferallium255
GreekAscoloy

H12
H13
Haynes556
Incoloy840
Invar 36
Kovar
M152
Maraging350
MaragingC200
MaragingC250
MaragingC300

N-155
Ni-hard#1
Ni-hard#4
Ni-Span902
Nitronic40
Nitronic50
Nitronic60
RA330
RA85H
Zeron100

Ti Grades - S

Cp Ti
Cp Ti Pd
Ti 12
Ti 17
Ti 3 2-5
Ti 6-22-22
Ti 6-2-4-2
Ti 6-2-4-6
Ti 6-4
Ti 6-6-2
Ti 8
Ti 8-1-1
Ti10-2-3
Ti15-3-3-3
Ti3-11-13
Ti5 - 2-5
Ti6-2-1-1
TiBetaC

Tool Steels- S

A2
A6
A7
D2 or D4
D7
H-11
M1
M2
M4
M42
O1
O2
O6
O7
S1
S5
S6
S7
T1

Factory Grade Library {Table A9.5-Premium}

Aluminums-P

319
333
356
357
380
383
384
1100
2007
2011
2018
2024
2117
2618
3002
3003
3004
3005
3105
4032
5005
5042
5052
5083
5086
5154
5454
5657
6040
6061
6063
6070
6253
6262
7005
7016
7019
7039
7050
7072
7075
7104
1100-plus
2014-17
2024-plus
2098-2195
2219-2519
3003 or 4 or 5
355-2
5052-plus
5056-82
5086-plus
6063-plus
7049-149-249

Cobalt Alloys - P

Alloy 686
AlnicoVIII
Cobalt
Elgiloy
F75
FSX-414
Haynes188
Haynes36
HS-1
HS-12
HS-19
HS-21
HS25-L605
HS-31
HS-4
HS-6B
Jetalloy
MarM302
MarM509
MarM905
MP35N
MPN159
Star J
Ultimet

Low Alloy Steels-P

3310
4130
4140
4340
8620
9310
12L14
A10
Carb 1-2
Moly
Carbon Steel
P20
135 N

Specialty Grades- P

60Sn-40Pb
63Sn-37Pb
96-4
AZ31B
AZ91A or C
SAC 300
SAC 305
SAC 400
SAC 405
97-3
Ag
Au
Bi
Cb 103
CP Ta
Cr
Densalloy
Hf
Mn
Mo
Nb
Ni
Pb
Pd
Re
Sb
Se
Sn
TungCarb C
TungCarb S
V
W
Zn
Zr
Zr 2 or 4
Zr 702
Zr 704
Zr 705

Chrome-Moly Steels -P

1 1-4 Cr
2 1-4 Cr
5 Cr
9 Cr
P91

Copper Alloys -P

C 110
C 172
C 194
C 210
C 220
C 240
C 260
C 270
C 310
C 314
C 330
C 332
C 340
C 342
C 360
C 377
C 425
C 443
C 464
C 482
C 485
C 510
C 524
C 534
C 544
C 623
C 630
C 642
C 655
C 667
C 673
C 675
C 687
C 706
C 710
C 715
C 745
C 752
C 814
C 836
C 857
C 861
C 863
C 864
C 867
C 868
C 875
C 8932
C 903
C 922
C 932
C 937
C 954
C 955
C194HiCu
C197HiCu
Elec Cu
Muntz
NarloyZ
SeBiLOYI
SeBiLOYII
SeBiLOYIII

Nickel Alloys - P

20Mo4
B 1900
B-1900 Hf
C-1023
Colmonoy 6
GMR235
GTD222
Hast BC1
HastB
HastB2
HastB3
HastC2000
HastC22
HastC276
HastC4
HastF
HastG
HastG2
HastG3
HastG30
HastN
HastR
HastS
HastW
HastX
Haynes214
Haynes230
HR160
HyMu80
I-102
I-49
I-600
I-601
I-602
I-617
I-625
I-690
I-700
I-702
I-706
I-713
I-718
I-720
I-722
I-725
I-738
I-750
I-792
I-800
I-801
I-825
I-901
I-903
I-907-909
I-939
IN100
MarM002
MarM200
MarM246
MarM247
MarM421
Monel400
Monel411
MonelK500
MuMetal
Ni 200
NichromeV
Nim101
Nim263
Nimonic75
Nimonic80A
Nimonic90
PWA1480
PWA1484
RA333
Rene125
Rene142
Rene220
Rene41
Rene77
Rene80
Rene95
Supertherm
Udimet500
Udimet520
Udimet700
Waspaloy

Factory Grade Library {Table A9.6-Premium}

Stainless Grades - P

201
203
303
304
309
310
316
317
321
329
330
347
410
416
420
422
430
431
434
440
441
446
2003
2101
2205
2205
2507
13-8 Mo
15-5 PH
15Mn7Cr

17-4 PH
17-7 PH
19-9DL
19-9DX
20Cb3
20Mo6
21-6-9
25-4-4
254SMO
26-1
29-4
29-4-2
29-4C
302HQ
410 Cb
410-16-20
904L
A-286
AL6XN
Alloy42
AlnicoII
AlnicoIII
AlnicoV
AMS350
AMS355
CD4MCU
Custom450
Custom455
E-bite
Ferallium255
GreekAscoloy

H12
H13
Haynes556
Incoloy840
Invar 36
Kovar
M152
Maraging350
MaragingC200
MaragingC250
MaragingC300
N-155
Ni-hard#1
Ni-hard#4
Ni-Span902
Nitronic40
Nitronic50
Nitronic60
RA330
RA85H
Zeron100

Ti Grades - P

Cp Ti
Cp Ti Pd
Ti 12
Ti 17
Ti 3 2-5
Ti 6-22-22
Ti 6-2-4-2
Ti 6-2-4-6
Ti 6-4
Ti 6-6-2
Ti 8
Ti 8-1-1
Ti10-2-3
Ti15-3-3-3
Ti3-11-13
Ti5 - 2-5
Ti6-2-1-1
TiBetaC

Tool Steels- P

A2
A6
A7
D2 or D4
D7
H-11
M1
M2
M4
M42
O1
O2
O6
O7
S1
S5
S6
S7
T1

GO TO

- See **"***Delta User Interface Guide"* (PN 103202) for a complete description for using Alloy modes' new capabilities such as:
    - Grade Match Messaging,
    - SmartSorting,
    - Nominal Chemistry, and
    - Tramp Library management.

OLYMPUS

Your Vision, Our Future

HANDHELD XRF ANALYZERS

Limits of Detection

Low-Density Sample Types — (soils, powders, liquids)

⬜	Not Measured	🟧	<1 %	▨	<0.5 %	🟥	<200 ppm
🟪	<50 ppm	🟦	<20 ppm	🟨	<10 ppm	🟩	<5 ppm

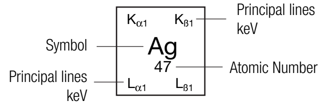
H 1 ⬜	IIA											IIIA	IVA	VA	VIA	VIIA	He 2 ⬜
0.05 Li 3 ⬜	0.11 Be 4 ⬜											0.18 B 5 ⬜	0.28 C 6 ⬜	0.39 N 7 ⬜	0.52 O 8 ⬜	0.68 F 9 ⬜	0.85 Ne 10 ⬜
1.04 1.07 Na 11 ⬜	1.25 1.3 Mg 12 🟧	IIIB	IVB	VB	VIB	VIIB		Group VIII		IB	IIB	1.49 1.56 Al 13 🟧	1.74 1.84 Si 14 🟧	2.01 2.14 P 15 ▨	2.31 2.46 S 16 🟥	2.62 2.82 Cl 17 🟥	2.96 3.19 Ar 18 ⬜
3.31 3.59 K 19 🟪	3.69 4.01 Ca 20 0.34 0.34 🟪	4.09 4.46 Sc 21 0.4 0.4 🟪	4.51 4.93 Ti 22 0.45 0.46 🟨	4.95 5.43 V 23 0.51 0.52 🟨	5.41 5.95 Cr 24 0.57 0.58 🟨	5.9 6.49 Mn 25 0.64 0.65 🟨	6.4 7.06 Fe 26 0.71 0.72 🟨	6.93 7.65 Co 27 0.78 0.79 🟨	7.48 8.26 Ni 28 0.85 0.87 🟨	8.05 8.91 Cu 29 0.93 0.95 🟨	8.64 9.57 Zn 30 1.01 1.03 🟩	9.25 10.26 Ga 31 1.1 1.12 🟩	9.89 10.98 Ge 32 1.19 1.22 🟩	10.54 11.73 As 33 1.28 1.32 🟩	11.22 12.5 Se 34 1.38 1.42 🟩	11.92 13.29 Br 35 1.48 1.53 🟩	12.65 14.11 Kr 36 1.59 1.64 ⬜
13.4 14.96 Rb 37 1.69 1.75 🟩	14.17 15.84 Sr 38 1.81 1.87 🟩	14.96 16.74 Y 39 1.92 2 🟩	15.78 17.67 Zr 40 2.04 2.12 🟩	16.62 18.62 Nb 41 2.17 2.26 🟩	17.48 19.61 Mo 42 2.29 2.39 🟩	18.37 20.62 Tc 43 2.42 2.54 🟩	19.28 21.66 Ru 44 2.56 2.68 🟩	20.22 22.72 Rh 45 2.83 🟨	21.18 23.82 Pd 46 2.84 2.99 🟨	22.16 24.94 Ag 47 2.98 3.15 🟨	23.17 26.1 Cd 48 3.13 3.32 🟨	24.21 27.28 In 49 3.29 3.49 🟨	25.27 28.49 Sn 50 3.44 3.66 🟦	26.36 29.73 Sb 51 3.6 3.84 🟦	27.47 31 Te 52 3.77 4.03 🟦	28.61 32.29 I 53 3.94 4.22 🟦	29.78 33.62 Xe 54 4.11 4.42 ⬜
30.97 34.99 Cs 55 4.29 4.62 🟦	32.19 36.38 Ba 56 4.47 4.83 🟦		55.79 63.23 Hf 72 7.9 9.02 🟨	57.53 65.22 Ta 73 8.15 9.34 🟨	59.32 67.24 W 74 8.4 9.67 🟨	61.14 69.31 Re 75 8.65 10.01 🟨	63 71.41 Os 76 8.91 10.36 🟨	64.9 73.56 Ir 77 9.18 10.71 🟨	66.83 75.75 Pt 78 9.44 11.07 🟨	68.8 77.98 Au 79 9.71 11.44 🟨	70.82 80.25 Hg 80 9.99 11.82 🟩	72.87 82.58 Tl 81 10.27 12.21 🟩	74.97 84.94 Pb 82 10.55 12.61 🟩	77.11 87.34 Bi 83 10.84 13.02 🟩	79.29 89.8 Po 84 11.13 13.45 🟩	81.52 92.3 At 85 11.43 13.88 🟩	83.78 94.87 Rn 86 11.73 14.32 ⬜
86.1 97.47 Fr 87 12.03 14.77 🟩	88.47 100.13 Ra 88 12.34 15.24 🟩																

Lanthanides 57-71	33.44 37.8 La 57 4.65 5.04 🟦	34.72 39.26 Ce 58 4.84 5.26 🟦	36.03 40.75 Pr 59 5.03 5.49 🟦	37.36 42.27 Nd 60 5.23 5.72 🟦	38.72 43.83 Pm 61 5.43 5.96 🟦	40.12 45.41 Sm 62 5.64 6.21 🟦	41.54 47.04 Eu 63 5.85 6.46 🟦	43 48.7 Gd 64 6.06 6.71 🟦	44.48 50.38 Tb 65 6.27 6.98 🟦	46 52.12 Dy 66 6.5 7.25 🟦	47.55 53.88 Ho 67 6.72 7.53 🟦	49.13 55.68 Er 68 6.95 7.81 🟦	50.74 57.52 Tm 69 7.18 8.1 🟦	52.39 59.37 Yb 70 7.42 8.4 🟦	54.07 61.28 Lu 71 7.66 8.71 🟦
Actinides 89-103	90.88 102.85 Ac 89 12.65 15.71 🟩	93.35 105.61 Th 90 12.97 16.2 🟩	95.87 108.43 Pa 91 13.29 16.7 🟩	98.44 111.3 U 92 13.61 17.22 🟩	101.00 114.18 Np 93 13.95 17.74 🟩	103.65 117.15 Pu 94 14.28 18.28 🟩	106.35 120.16 Am 95 14.62 18.83 ⬜	109.10 123.24 Cm 96 14.96 19.39 ⬜	111.90 126.36 Bk 97 15.31 19.97 ⬜	114.75 129.54 Cf 98 15.66 20.56 ⬜	117.65 132.78 Es 99 16.02 21.17 ⬜	120.60 136.08 Fm 100 16.38 21.79 ⬜	Md 101 ⬜	No 102 ⬜	Lr 103 ⬜

Alloy Analysis:

Elements detected: Magnesium (Mg, Z=12) through Sulfur (S, Z=16) and Titanium (Ti, Z=22) through Plutonium (Pu, Z=94).

Please see separate Alloy Analysis LOD Specifications.



Detection limits are a function of testing time, sample matrix and presence of interfering elements.
Detection limits are estimates based on 1-2 minutes test times and detection confidence of 3σ (99.7% confidence).
Interference-free detection limits are intended as guidelines: please contact Olympus Innov-X to discuss your specific application.

PHOTON ENERGIES, IN ELECTRON VOLTS, OF PRINCIPAL K- AND L-SHELL EMISSION LINES

Element	Symbol	Atomic #	$K_{\alpha1}$	$K_{\beta1}$	$L_{\alpha1}$	$L_{\beta1}$
Actinium	Ac	89	90.88	102.85	12.65	15.71
Aluminum	Al	13	1.49	1.56	0	0
Antimony	Sb	51	26.36	29.73	3.6	3.84
Argon	Ar	18	2.96	3.19	0	0
Arsenic	As	33	10.54	11.73	1.28	1.32
Astatine	At	85	81.52	92.3	11.43	13.88
Barium	Ba	56	32.19	36.38	4.47	4.83
Beryllium	Be	4	0.11	0	0	0
Bismuth	Bi	83	77.11	87.34	10.84	13.02
Boron	B	5	0.18	0	0	0
Bromine	Br	35	11.92	13.29	1.48	1.53
Cadmium	Cd	48	23.17	26.1	3.13	3.32
Calcium	Ca	20	3.69	4.01	0.34	0.34
Carbon	C	6	0.28	0	0	0
Cerium	Ce	58	34.72	39.26	4.84	5.26
Cesium	Cs	55	30.97	34.99	4.29	4.62
Chlorine	Cl	17	2.62	2.82	0	0
Chromium	Cr	24	5.41	5.95	0.57	0.58
Cobalt	Co	27	6.93	7.65	0.78	0.79
Copper	Cu	29	8.05	8.91	0.93	0.95
Dysprosium	Dy	66	46	52.12	6.5	7.25
Erbium	Er	68	49.13	55.68	6.95	7.81
Europium	Eu	63	41.54	47.04	5.85	6.46
Fluorine	F	9	0.68	0	0	0
Francium	Fr	87	86.1	97.47	12.03	14.77
Gadolinium	Gd	64	43	48.7	6.06	6.71
Gallium	Ga	31	9.25	10.26	1.1	1.12
Germanium	Ge	32	9.89	10.98	1.19	1.22
Gold	Au	79	68.8	77.98	9.71	11.44
Hafnium	Hf	72	55.79	63.23	7.9	9.02
Holmium	Ho	67	47.55	53.88	6.72	7.53
Indium	In	49	24.21	27.28	3.29	3.49
Iodine	I	53	28.61	32.29	3.94	4.22
Iridium	Ir	77	64.9	73.56	9.18	10.71
Iron	Fe	26	6.4	7.06	0.71	0.72
Krypton	Kr	36	12.65	14.11	1.59	1.64
Lanthanum	La	57	33.44	37.8	4.65	5.04
Lead	Pb	82	74.97	84.94	10.55	12.61
Lithium	Li	3	0.05	0	0	0
Lutetium	Lu	71	54.07	61.28	7.66	8.71
Magnesium	Mg	12	1.25	1.3	0	0
Manganese	Mn	25	5.9	6.49	0.64	0.65
Mercury	Hg	80	70.82	80.25	9.99	11.82
Molybdenum	Mo	42	17.48	19.61	2.29	2.39
Neodymium	Nd	60	37.36	42.27	5.23	5.72
Neon	Ne	10	0.85	0	0	0
Nickel	Ni	28	7.48	8.26	0.85	0.87
Niobium	Nb	41	16.62	18.62	2.17	2.26
Nitrogen	N	7	0.39	0	0	0
Osmium	Os	76	63	71.41	8.91	10.36
Oxygen	O	8	0.52	0	0	0
Palladium	Pd	46	21.18	23.82	2.84	2.99
Phosphorus	P	15	2.01	2.14	0	0
Platinum	Pt	78	66.83	75.75	9.44	11.07
Polonium	Po	84	79.29	89.8	11.13	13.45
Potassium	K	19	3.31	3.59	0	0
Praseodymium	Pr	59	36.03	40.75	5.03	5.49
Promethium	Pm	61	38.72	43.83	5.43	5.96
Protactinium	Pa	91	95.87	108.43	13.29	16.7
Radium	Ra	88	88.47	100.13	12.34	15.24
Radon	Rn	86	83.78	94.87	11.73	14.32
Rhenium	Re	75	61.14	69.31	8.65	10.01
Rhodium	Rh	45	20.22	22.72	2.7	2.83
Rubidium	Rb	37	13.4	14.96	1.69	1.75
Ruthenium	Ru	44	19.28	21.66	2.56	2.68
Samarium	Sm	62	40.12	45.41	5.64	6.21
Scandium	Sc	21	4.09	4.46	0.4	0.4
Selenium	Se	34	11.22	12.5	1.38	1.42
Silicon	Si	14	1.74	1.84	0	0
Silver	Ag	47	22.16	24.94	2.98	3.15
Sodium	Na	11	1.04	1.07	0	0
Strontium	Sr	38	14.17	15.84	1.81	1.87
Sulfur	S	16	2.31	2.46	0	0
Tantalum	Ta	73	57.53	65.22	8.15	9.34
Technetium	Tc	43	18.37	20.62	2.42	2.54
Tellurium	Te	52	27.47	31	3.77	4.03
Terbium	Tb	65	44.48	50.38	6.27	6.98
Thallium	Tl	81	72.87	82.58	10.27	12.21
Thorium	Th	90	93.35	105.61	12.97	16.2
Thulium	Tm	69	50.74	57.52	7.18	8.1
Tin	Sn	50	25.27	28.49	3.44	3.66
Titanium	Ti	22	4.51	4.93	0.45	0.46
Tungsten	W	74	59.32	67.24	8.4	9.67
Uranium	U	92	98.44	111.3	13.61	17.22
Vanadium	V	23	4.95	5.43	0.51	0.52
Xenon	Xe	54	29.78	33.62	4.11	4.42
Ytterbium	Yb	70	52.39	59.37	7.42	8.4
Yttrium	Y	39	14.96	16.74	1.92	2
Zinc	Zn	30	8.64	9.57	1.01	1.03
Zirconium	Zr	40	15.78	17.67	2.04	2.12

Appendix H

Data Quality Forms

Level A/B Assessment Checklist

1. General Information

Site:
Project:
Client:
Sample Matrix:

2. Screening Result

Meets Level A:
Meets Level B:
Unusable:

I. Level A - Must be fully documented.	**Yes**	**No**	**Comments**
1. Sampling date	Yes	No	
2. Sampling team or leader	Yes	No	
3. Physical description of sampling location	Yes	No	
4. Sample depth (soils)	Yes	No	
5. Sample collection technique	Yes	No	
6. Field preparation technique	Yes	No	
7. Sample preservation technique	Yes	No	
8. Sample shipping records	Yes	No	

II. Level B - Must be fully documented.	**Yes**	**No**	**Comments**
1. Field instrumentation methods and standardization complete	Yes	No	
2. Sample container preparation	Yes	No	
3. Collection of field replicates (1/20 minimum)	Yes	No	
4. Proper and decontaminated sampling equipment	Yes	No	
5. Field custody documentation	Yes	No	
6. Shipping custody documentation	Yes	No	
7. Traceable sample designation number	Yes	No	
8. Field notebook(s), custody records in secure repository	Yes	No	
9. Completed field forms	Yes	No	

Data Validation Checklist for Metals Samples Analzyed by ICP or GFAA

Site:
Project:
Sample Date(s):
Data Validator:
Laboratory:

Case No:
Sample Matrix:
Analysis Date(s):
Validation Date(s):
Analyses:

Quality Control Item	**Yes**	**No**	**Not Applicable**
1. Holding Times			
Populate Table 1			
Were any data flagged because of holding time?	Yes	No	
Were any data flagged because of preservation problems?	Yes	No	
Actions Taken/Comments:			
2. Instrument Calibration			
Was the Tune analysis performed?	Yes	No	NA
Was the peak widths and resolution of the masses within the required control limits?	Yes	No	NA
Was the percent relative standard deviation ≤ 5% for all analytes in the Tune solutions?	Yes	No	NA
Was Instrument successfully calibrated at the correct frequency?	Yes	No	
Was Instrument calibrated with appropriate standards and blanks?	Yes	No	
Were Initial Calibration Verification (ICV) and Continuing Calibration Verification (CCV) samples analyzed?	Yes	No	
Were ICV and CCV results within the control window?	Yes	No	
Were any data flagged because of calibration problems?	Yes	No	
Actions Taken/Comments:			
3. Blanks			
Were Initial and Continuing Calibration Blanks (ICB and CCBs) analyzed?	Yes	No	
Were ICBs and CCBs within the control window?	Yes	No	
Were Initial and Continuing Calibration Blanks (ICB and CCBs) analyzed at the appropriate frequency?	Yes	No	
Were Method Blanks (MBs) analyzed at the frequency of 1 per analytical batch?	Yes	No	
Were MBs within the control window?	Yes	No	
Were any data flagged because of blank problems?	Yes	No	
Actions Taken/Comments:			
4. Interference Check Samples			
Were ICP Interference Check Samples (ICS) within the control limits?	Yes	No	
Were ICP results within the control window?	Yes	No	
Were any data flagged because of ICS problems?	Yes	No	
Actions Taken/Comments:			
5. Laboratory Control Samples			
Were Laboratory Control Samples (LCS) analyzed at the frequency of 1 per batch?	Yes	No	
What was the source of the LCS?	Yes	No	
Were LCS results within the control window?	Yes	No	
Were any data flagged because of LCS problems?	Yes	No	
Actions Taken/Comments:			
6. Duplicate Sample Results			
Were Laboratory Duplicate Samples (LDS) analyzed at the frequency of 1 per batch?	Yes	No	
Were LDS results within the control window?	Yes	No	
Were any data flagged because of LDS problems?	Yes	No	
Actions Taken/Comments:			

Data Validation Checklist for Metals Samples Analzyed by ICP or GFAA

Site:
Project:
Sample Date(s):
Data Validator:
Laboratory:

Case No:
Sample Matrix:
Analysis Date(s):
Validation Date(s):
Analyses:

Quality Control Item	Yes	No	Not Applicable
7. Matrix Spike Sample Results			
Were Laboratory Matrix Spike Samples (LMS) analyzed at the frequency of 1 per batch?	Yes	No	
Were LMS percent recovery (%R) results within the control window?	Yes	No	
Were any data flagged because of LMS problems?	Yes	No	
Actions Taken/Comments:			
8. ICP Serial Dilutions			
Were ICP Serial Dilutions (SD) analyzed at the frequency of 1 per batch?	Yes	No	
Were SD percent differences (%D) results within the control window?	Yes	No	
Were any data flagged because of SD problems?	Yes	No	
Actions Taken/Comments:			
9. Internal Standards			
Were internal standards added to each sample in the analytical batch?	Yes	No	
Were the percent relative recoveries (%RI) within the control window?	Yes	No	
Were any data flagged because of internal standard problems?	Yes	No	
Actions Taken/Comments:			
10. Field Blanks			
Were field blanks submitted as specified in the Sampling Analysis Plan (SAP)?	Yes	No	NA
Were field blanks within the control window?	Yes	No	NA
Were any data qualified because of field blank problems?	Yes	No	NA
Actions Taken/Comments:			
11. Field Duplicates			
Were field duplicates submitted as specified in the Sampling Analysis Plan (SAP)?	Yes	No	NA
Were the field duplicates within the control window?	Yes	No	NA
Were any data qualified because of field duplicate problems?	Yes	No	NA
Actions Taken/Comments:			
12. Overall Assessment			
Are there analytical limitations of the data that users should be aware of?	Yes	No	
If Yes, explain:			
13. Authorization of Data Validation			

Data Validator Name: ____________
Data Validator Signature: ____________
Date ____________

Reviewer Name: ____________
Reviewer Signature: ____________
Date ____________

Data Validation Checklist for Metals Samples Analzyed by ICP or GFAA

Site:	**Case No:**
Project:	**Sample Matrix:**
Sample Date(s):	**Analysis Date(s):**
Data Validator:	**Validation Date(s):**
Laboratory:	**Analyses:**

Table 1. Holding Times

Laboratory	Method	Analyte(s)	Matrix	Batch	Holding Times*	Collection Date(s)	Analysis Date(s)	Holding Time Met (Y/N)	Affected Data Flagged (Y/N)

*Reference for Holding Times ______

Data Validation Checklist for XRF Metals Sample Analysis

Site:	**Case No:**
Project:	**Sample Matrix:**
Sample Date(s):	**Analysis Date(s):**
Data Validator:	**Validation Date(s):**
Laboratory:	**Analyses:**

Quality Control Item	**Yes**	**No**
1. Holding Times		
Populate Table 1		
Were any data flagged because of holding time?	Yes	No
Were any data flagged because of preservation problems?	Yes	No
Actions Taken/Comments:		
2. XRF Quality Control		
What sample preparation steps were performed (i.e. drying and sieving, grinding)?		
Were the samples prepared according to the SAP?	Yes	No
Was energy calibration performed at the frequency of once per day?	Yes	No
Were initial and continuing calibrations performed at the frequency in Table 8-1 of the XRFLAP?	Yes	No
Were initial and continuing calibration results within control windows?	Yes	No
Were laboratory duplicate results within control window?	Yes	No
Was laboratory duplicate analysis performed at the frequency of 1 per 20?	Yes	No
Was laboratory replicate analysis performed at the frequency of 1 per 20?	Yes	No
Were laboratory replicate results within control window?	Yes	No
Was cross-contamination check sample analyzed at the frequency of 1 per 50?	Yes	No
Was cross-contamination check sample results within control window?	Yes	No
Was sand blank analysis performed at the frequency of 1 per 50?	Yes	No
Was sand blank result within control window?	Yes	No
Were any data flagged because of XRF analysis?	Yes	No
Actions Taken/Comments:		
12. Overall Assessment		
Are there limitations of the data that users should be aware of?	Yes	No
If Yes, explain:		
13. Authorization of Data Validation		

Data Validator Name: ______________________ Reviewer Name: ______________________

Data Validator Signature: ______________________ Reviewer Signature: ______________________

Date ______________________ Date ______________________

Data Validation Checklist for XRF Metals Sample Analysis

Site:
Project:
Sample Date(s):
Data Validator:
Laboratory:

Case No:
Sample Matrix:
Analysis Date(s):
Validation Date(s):
Analyses:

Table 1. Holding Times

Laboratory	Method	Analyte(s)	Matrix	Batch	Holding Times*	Collection Date(s)	Analysis Date(s)	Holding Time Met (Y/N)	Affected Data Flagged (Y/N)

*Reference for Holding Times ____________

Corrective Action Report/ Corrective Action Plan

Project ID	Project Name	Document ID

Preparer's Signature/Submit Date	Submitted to:

Description of the requirement or specification	
Reason for the Corrective Action	
Location, affected sample, affected equipment, etc. requiring corrective action	
Suggested Corrective Action	
Corrective Action Plan	
Corrective Action Plan - Approval signature/date:	
Approval of corrective actions required by EPA?	
Corrective Action Plan - EPA approval name/date:	
Corrective actions completed name/date:	
Preventative Action Plan	
Preventative actions completed name/date:	