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Final Verification Sampling Plan

Riley Pass Uranium Mines Site (North Cave Hills)
Harding County, South Dakota

Project No.: 114-560486A

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1.0 INTRODUCTION

Tetra Tech Inc. prepared this verification sampling plan (VSP) for the United States Forest Service (USFS) to provide a framework for conducting cleanup verification surveys of the surface soils and solid media at the Riley Pass Abandoned Uranium Mine Site (Riley Pass). Since 2006, the Riley Pass site has been under the jurisdiction of the USFS, which is authorized under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as the primary federal land manager responsible for site cleanup actions. This document was developed in accordance with the *2015 Action Memorandum [2015 Action Memo]* (USFS 2015). Numerous documented studies at the site have shown heavy metals and radionuclide concentrations are present in soil at levels posing a threat to human health and the environment. The primary contaminants of concern identified in the 2015 Action Memo include arsenic and radium-226 (Ra-226); both contaminants are driving risk factors to human health and the environment. Removal action with on-site disposal and stabilization of soils and solid media is the selected remedy for this CERCLA site.

The primary objective of this document is to provide clear and detailed, cost-effective, defensible, and statistically valid guidance to the USFS and the contractor deemed responsible for conducting the cleanup verification surveys at the Riley Pass site. This VSP presents the cleanup verification survey methodology that will be performed after removal action has been completed, with the goal of assessing whether the risk-based soil cleanup standards have been attained for CERCLA sites. The methodology presented in this report allows for a phased approach in the likely event that the removal action is carried out in a phased approach. In addition to assessing whether cleanup standards have been attained, a secondary goal of the surveys is to provide detailed information on the spatial extent of concentrations in soil that remain at each study area after remedial actions have been conducted. The simultaneous characterization of concentrations in soil will provide useful data in the event cleanup objectives are not attained and additional remedial action is necessary, thus providing significant cost savings by eliminating the need to return to this remote site for characterization.

Given the nature of radionuclide contamination and to ensure a defensible and statistically valid methodology, Tetra Tech referenced a combination of the most recently published guidance documents from the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA) in the development of this document. All of the statistical tests and environmental monitoring sampling methodology presented here are backed by these federal regulatory agencies and are specifically useful for conducting cleanup verification at CERCLA sites. Guidance found in the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC 2000), *Methods for Evaluating the Attainment of Cleanup Standards Volume 1: Soils and Solid Media* (EPA 1989), and the *Guidance for the Data Quality Objectives Process* (EPA 1994), and a number of other documents were used to design this VSP. In developing this document, the Data Quality Objective (DQO) process was followed to ensure an adequate amount of data with sufficient quality is collected to meet the project objectives.

Tetra Tech has integrated aspects of the *final status survey* approach using guidance available from the NRC, and more specifically the MARRSIM, because the site has radiological contamination. The MARSSIM document has the consensus support of the EPA, NRC, the U.S. Department of Energy (DOE), and the U.S. Department of Defense (DoD) and provides guidance on planning, implementing, and evaluating all radiological surveys needed for decommissioning radioactive sites (scoping, historical survey assessments, characterization, remedial action support, and final status surveys). Since many of these surveys have been completed already at the site, the MARSSIM guidance targeted toward the final status survey was used in developing this VSP. Final status surveys are performed to demonstrate risk-based criteria for cleanup of radiologically contaminated land areas have been satisfied. The Riley Pass site does not fall under NRC authority, nor is it a Uranium Mill Tailings Remediation Act (UMTRA) site; therefore, an alternative approach is taken, and the term "final status survey" is replaced with "cleanup verification survey." However, many of the elements of the final status survey approach are utilized in the methodology presented in this document.

The cleanup verification surveys presented in this report consist of performing X-ray fluorescence (XRF) field surveys, gamma radiation surveys, and soil confirmation sampling. The XRF field surveys will be performed in accordance with EPA Method 6200 (EPA 2007). The gamma radiation surveys will be performed in accordance with MARSSIM (NRC 2000). Geostatistical methods will be applied to the gamma radiation survey scan data to generate grid-block averaged 100-square-meter (m^2) units. When all of the study areas within the Riley Pass site demonstrate compliance with the criteria specified in the 2015 Action Memo (USFS 2015), it may be released for restricted use.

Another important objective of the VSP is to provide data quality assessment and quality assurance/ quality control procedures to ensure the data collected during the cleanup verification surveys are of the correct type, quality, and quantity to support the intended use of making a statistically sound conclusion regarding the cleanup attainment status of the entire site. Therefore, detailed standard operating procedures are included as appendices to this report. However, a final quality assurance project plan (QAPP) will be required by the contractor responsible for the cleanup verification surveys before the work begins. Additionally, as a result of the potential risk of radiation exposure during cleanup, a detailed Health and Safety Plan (HASP) approved by a Certified Health Physicist (CHP) will also be required before work begins.

The primary objectives of this report are as follows:

- Perform and summarize the results of the DQO process.
- Present the risk-based cleanup standards selected for removal action at the site.
- Present the verification sampling approach methodology to be followed during all future cleanup verification surveys at the site.
- Provide study boundaries and proposed sampling quantities and types to be performed during all future cleanup verification work.
- Present the statistical methods to be used to determine if cleanup objectives are attained.
- Provide the quality assurance and quality control methods for the cleanup verification surveys.
- Provide reporting requirements of cleanup verification survey reports.

This verification sampling plan is organized into the following sections:

1. Introduction - briefly describes the document's contents, purpose, and objectives.
2. Site Background - contains a description of the site background.
3. Data Quality Objectives - outlines a systematic procedure for defining the site criteria by which the data collection design is satisfied.

4. Sampling Approach - provides the cleanup verification survey sampling approach to be followed after the removal action has been completed.

5. Field Activities - presents the field activities to be performed that will meet the project DQOs.

6. Statistical Methods - provides an overview and step-by-step procedures on the statistical tests to be used in assessing attainment of cleanup standards.

7. Sampling Location and Frequency - presents the study area boundaries, the basis for land area classification, and the survey unit design.

8. Quality Assurance and Quality Control - presents the quality assurance and quality control (QA/QC) procedures for the survey methods.

9. Reporting - provides detailed reporting requirements to be followed for the cleanup verification survey reports.

10. Conclusions.

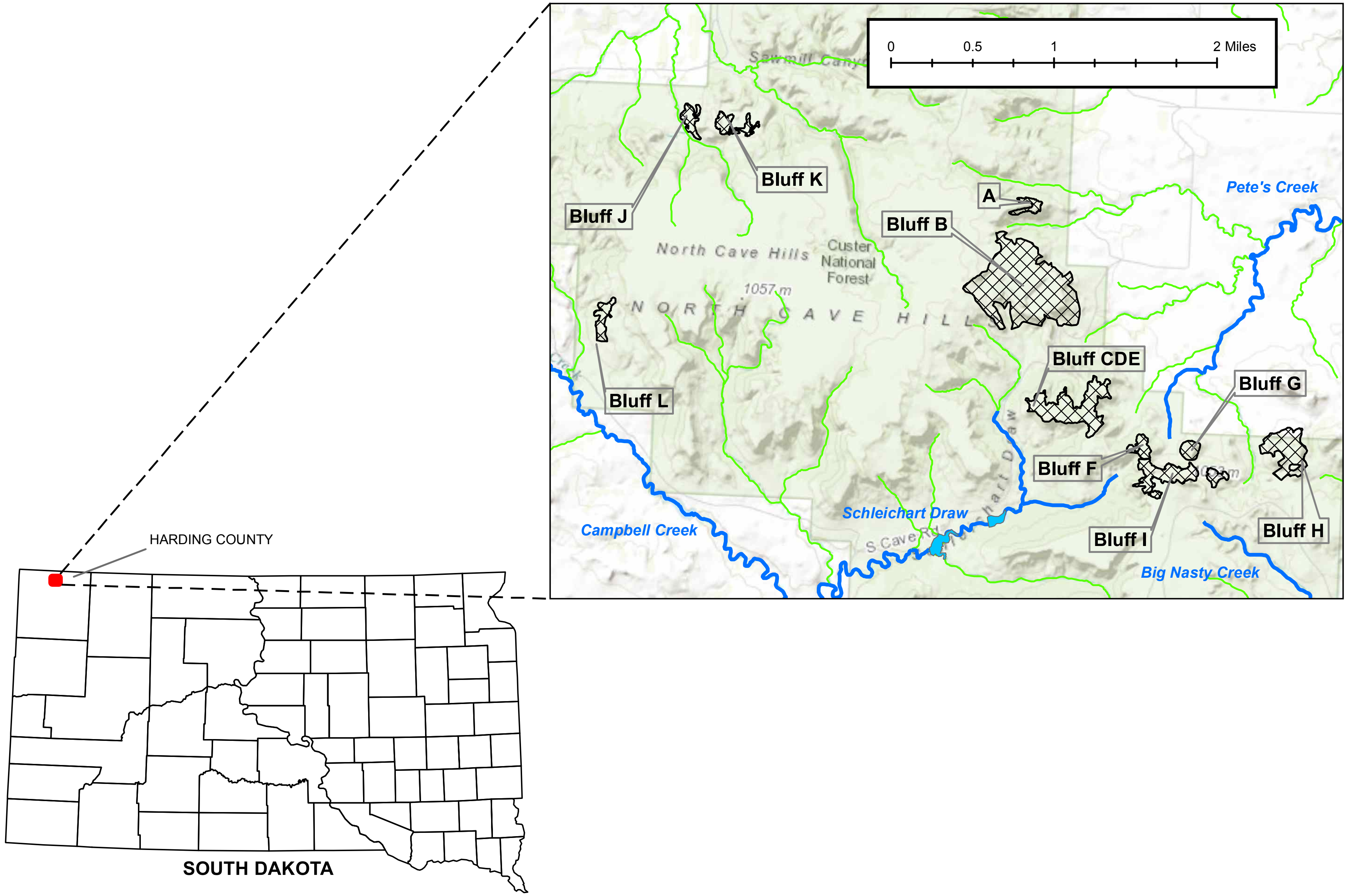
2.0 SITE BACKGROUND

Uranium exploration began in the North Cave Hills in 1954 when the Atomic Energy Commission recorded radiation anomalies over the North Cave Hills (Curtiss 1955; Stone et al. 2009). The first claims were staked in August 15, 1954; extensive mining started in the early 1960s in an effort to supply contracts for uranium, but all mining ceased in 1964. Riley Pass is part of the North Cave Hills complex contained within the Sioux Ranger District, Custer Gallatin National Forest, in Harding County, South Dakota. The site is located 25 miles north of Buffalo, South Dakota. The nearest town is Ludlow, South Dakota, which lies 5 miles to the east. A small fraction of the site is situated on private land (USFS 2007). The Riley Pass site was originally identified as 12 study areas referred to as Bluff A through Bluff L. In 2013, Bluff C, Bluff D, and Bluff E were re-designated as “Bluff CDE.” The Riley Pass site now consists of 10 study areas referred to as Bluff A, Bluff B, Bluff CDE, Bluff F, Bluff G, Bluff H, Bluff I, Bluff J, Bluff K, and Bluff L. A site location map is presented in Figure 1.

The site includes steep-sided and flat-topped buttes rimmed with sandstone cliffs. From a geomorphic perspective, this area contains evidence of geologically rapid retreat (Stone et al. 2007). The climate in the region is intercontinental arid characterized by warm dry summers and cool dry winters, with an average precipitation of 12 inches per year. Snowfall does not typically contribute to the total precipitation amount. The uranium mines located in this region were lignite mines located on top of the buttes. Mining features include bluffs, mine waste, overburden piles (spoils), and hazardous erosional openings and highwalls. Samples of spoils materials have been characterized as sandy clay and clayey sand. Within the North Cave Hills, documented mine sites, spoils, and exploration activities cover almost 1,000 acres. However, the estimated disturbed areas within the Riley Pass site include 300 acres of highwalls, pit floors, and spoils piles. Spoils were pushed over the edges of the buttes onto the steep slopes below the rimrocks during mining. Additional spoils have been deposited on these slopes by erosion.

Under the General Mining Laws, per the Atomic Energy Act of 1946 and Public Law 357, unrestricted strip mining took place within the North Cave Hills during the 1950s and 1960s. The strip mining involved removal of uranium-bearing lignite coal beds, with no requirements for environmental restoration or for establishing post-mining responsibility (USFS 2006). The nature of mining at the site resulted in acute environmental degradation and has eroded the soils and affected drainages and water supplies. Previous investigations conducted at the site have shown impacts of heavy metal and radionuclide releases associated with the mining.

Numerous studies have been performed at the Riley Pass site. A detailed evaluation of all the relevant studies performed to date at the site is presented in *Waste Characterization Evaluation Report* (Tetra Tech 2015d). Refer to Figure 2 of Tetra Tech (2015d) for a detailed timeline of all site activities, including: general site actions, reclamation and verification activities, regulatory documents pertaining to the site, and other major site documents. Detailed characterization studies were performed at the site by Millennium Science Engineering (MSE) and Tetra Tech in 2008 and by Tetra Tech in 2012; the results of these studies are presented in MSE (2009) and Tetra Tech (2013b). The data collected from these two characterization studies are the basis for development of this VSP. These studies provide delineation of the nature and extent of contamination for both arsenic and Ra-226 within the study areas at the Riley Pass site, and this information is used (NRC 2000) for area classification and survey unit design, as presented in Section 7.0.



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NORTH_FIPS_4001_FEET

Riley Pass Site Location
Study Area Boundaries
Major Drainage
Minor Drainage

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Title:
RILEY PASS SITE LOCATION

Location:
HARDING COUNTY, SD

Figure:
Figure 1

Project no.:
114-560486

Date:
OCTOBER 2015

3.0 DATA QUALITY OBJECTIVES

Tetra Tech used the DQO process to develop a sampling strategy to satisfy the Superfund program objectives. The DQO process involves seven formalized steps discussed in the EPA *Guidance for the Data Quality Objectives Process* (EPA 1994). Figure 2 provides a flowchart of the DQO process. The DQO process is a systematic data collection planning process developed by EPA to ensure the right type, quality, and quantity of data are collected to support decision making (EPA 1994). DQOs are qualitative and quantitative statements to fulfill the following objectives:

- Clarify the study objectives.
- Define the most appropriate data to collect.
- Determine the most appropriate conditions for collecting the data.
- Specify acceptable levels of decision errors to be used as the basis for establishing the quantity and quality of data needed to support the decision.

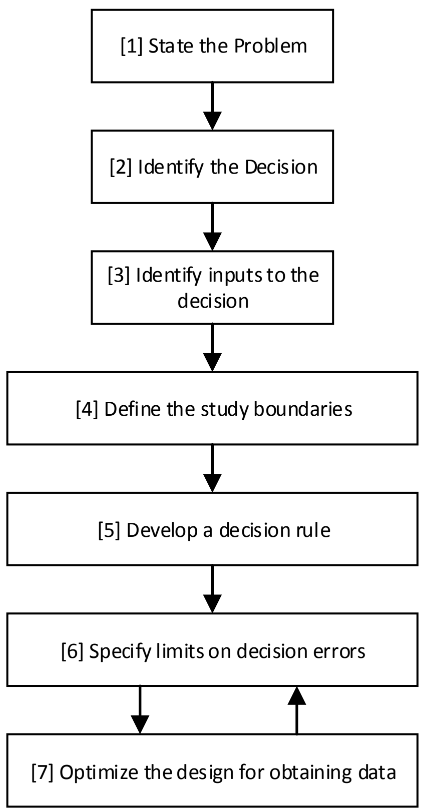


Figure 2 DQO Process Flow Chart

This section presents the step-by-step decisions of the site-specific application of the DQO process used in developing this VSP for the Riley Pass site.

3.1 State the Problem

Historical strip mining in the North Cave Hills resulted in wide-spread contamination of heavy metals and radionuclides in soils and solid media within the 10 study areas located at the Riley Pass site. This VSP will be used to determine whether residual concentrations of arsenic and Ra-226 in surface soil at the Riley Pass study areas comply with the risk-based cleanup criteria as defined in the 2015 Action Memo. Descriptions of the key elements for showing compliance with the 2015 Action Memo are provided in Section 3.2. Compliance with the 2015 Action Memo will be demonstrated using guidance found in MARSSIM (EPA 2000) and EPA (1989). Specifically, compliance will be demonstrated by performing cleanup verification surveys.

3.2 Identify the Decision

The study areas shown in Figure 1 are to be geographically divided into "survey units" based on their potential for contamination using guidance from MARSSIM (NRC 2000). Decommissioned sites are released survey unit by survey unit; survey units are the fundamental compliance units. The decision for the cleanup verification survey is whether the risk-based cleanup criteria identified in the 2015 Action Memo have been met in individual survey units. The spatial extent of areas with contaminant concentrations above the risk-based soil cleanup criteria are established from the characterization surveys and are well documented (MSE 2009; Tetra Tech 2013b, 2015d); the impacted areas are classified as "Class 1" or "Class 2" survey units. Surface materials have been sampled and analyzed at most areas throughout the project site, future characterization work of sub-surface materials will be conducted as needed. Cleanup verification surveys will be performed within the Class 1 and Class 2 survey units. A detailed discussion on survey unit classification and procedures for selecting survey unit locations and size are provided in Section 7.3.

Risk-based criteria for arsenic and Ra-226 have been established for the Riley Pass site. Specifically, the 2015 Action Memo has identified risk-based cleanup criteria for arsenic and Ra-226 in soils. This VSP refers to the risk-based soil cleanup criteria as derived concentration guideline levels (DCGL) values. Typically, as stated in MARSSIM (NRC 2000), the DCGLs are intended for designation of radioisotopes; however, for this project, a DCGL is also assigned for arsenic, a stable element. The 2015 Action Memo requirements are as follows:

1. Soils exceeding the DCGL guideline of 30 picocuries per gram (pCi/g) Ra-226 will be excavated and stabilized.
2. Soils exceeding the DCGL of 142 milligrams per kilogram (mg/kg) arsenic will be excavated and stabilized.

Table 1 contains the DCGL values for Riley Pass site. DCGLs are radionuclide-specific concentration limits used to guide cleanup of a decommissioning site to meet radiological criteria for license termination for NRC sites; while this site is not under NRC jurisdiction, DCGLs are assumed to be applied to arsenic and Ra-226. The values represent the risk-based concentrations in soil for the contaminants of concern (COC) identified at the site for surface soils derived from the 2015 Action Memo. These values were based on a human health and ecological risk assessment performed by Portage Environmental Inc. (Portage) in 2006 (Portage 2006), as part of the Final Engineering Evaluation and Cost Analysis (EE/CA) at Riley Pass (USFS 2006). A review of the risk assessments was performed by Tetra Tech (2015d). The DCGLs will be applied to areas the size of survey units within the study areas. The $DCGL_W$ is the limit applicable to relatively large areas of diffuse contamination as opposed to discrete small areas and is the appropriate metric for this VSP. The mean of a number of measurements in a survey unit will be compared with the $DCGL_w$.

Table 1 Derived Concentration Guideline Levels for Riley Pass Site

Contaminant	Unit	$DCGL_w$
Arsenic	mg/kg	142
Radium-226	pCi/g	30.0

$DCGL_w$= derived concentration guideline level
Note: DCGL according to MARSSIM (NRC 2000) are specifically intended for use with radionuclides, however, for this project, a DCGL applies to arsenic, a non-radionuclide.

The decision is whether the risk-based cleanup criteria ($DCGL_w$) identified in Table 1 have been met for individual survey units within each study area.

3.3 Identify the Inputs to the Decision

Guidance provided in MARSSIM (NRC 2000) and EPA (1989) was used as the basis for developing this VSP. The MARSSIM (NRC 2000) presents a process for demonstrating compliance with a dose- or risk-based regulation, including an overview of statistical considerations important for final status surveys and how these relate to decision making and survey design processes. The document was authored by the EPA, NRC, DOE, and DoD with the intent of providing regional project managers and their contractors with sampling and analysis methods for evaluating whether a soils remediation effort has been successful at CERCLA sites. The guidance in EPA (1989) describes and illustrates how to use statistical tests to evaluate the attainment of risk-based cleanup standards for soil and solid media.

Information on the arsenic and Ra-226 concentrations in soil must be collected from surface soils for the cleanup verification survey sampling. A more detailed discussion of specific field activities is included in Section 5.0. Two techniques will be used in the field to generate information pertinent to the verification sampling plan requirements for arsenic: (1) in situ XRF field surveys, and (2) surface soil confirmation sampling. Similarly, two techniques will be used in the field to generate information pertinent to the verification sampling plan requirements for Ra-226: (1) gamma radiation surveys, and (2) surface soil confirmation sampling. A systematic grid based sampling approach will be followed for both the in situ XRF field survey and the gamma radiation survey. A simple random sampling approach will be followed for the soil confirmation sampling. Detailed discussion on how these sampling approaches were selected is presented in Section 4.0.

3.3.1 XRF Field Survey

In situ XRF field surveys have been shown to be an effective tool to measure concentrations of specific heavy metals at a definitive level at the Riley Pass site (Tetra Tech 2013b; 2015d). Definitive data are generated using rigorous analytical methods, such as EPA-approved reference methods (such as EPA Method 6200), compared with screening data, which are conducted by rapid, less precise methods, with less rigorous sample preparation (EPA 2000a). The XRF analytical method is often used for screening-level data; however, following EPA Method 6200 (EPA 2007), the XRF can be used as a definitive tool if a high correlation ($R > 0.8$) is developed between the in situ XRF measurements and the laboratory-reported soil confirmation samples. The primary heavy metal of concern driving the risk-based cleanup decisions at Riley Pass is arsenic (USFS 2006; Portage 2006; Tetra Tech 2015d). Following EPA Method 6200 (EPA 2007), a strong correlation was developed at a definitive level (correlation coefficient, R, is greater than 0.8) between in situ XRF arsenic measurements and laboratory-reported arsenic concentrations, as presented in Tetra Tech (2013b). An in situ XRF arsenic measurement of 105 parts per million (ppm) has been determined to be equal to 142 mg/kg of total arsenic concentration in surface soils. The XRF action level of 105 ppm is to be used during remedial action support surveys. The relationship between the in situ XRF arsenic measurements and laboratory-derived arsenic concentrations is presented in Section 5.2 and Appendix A of this document and in Tetra Tech (2013b, 2015d). Table 2 lists the XRF field survey instruments to be used at the Riley Pass site and the approximate detection sensitivities of the instrumentation. A more detailed discussion of the XRF field survey activities is included in Section 5.2 and Appendix A.

Table 2 XRF Instruments and Approximate Detection Sensitivity

Description	Application	Approximate Detection Sensitivity (mg/kg)
Thermo Scientific Niton XRF	In situ field surveys on pre-determined systematic sampling grid patter	Arsenic (9)[1]

[1]Varies with instrument

3.3.2 Gamma Radiation Survey

Gamma radiation surveys have been shown to be particularly effective at identifying the spatial extent of and predicting the concentrations of Ra-226 in surface soils at the Riley Pass site. Use of global positioning system (GPS)-based gamma radiation survey systems has become a mature methodology for characterizing the distribution of gamma radiation emitted by naturally occurring radioactive materials (NORM) in soils (Whicker 2015). Previous site-specific studies (MSE 2009; Tetra Tech 2013b) have demonstrated there is a direct correlation between gamma exposure rate (microroentgen per hour [µR/hr]) and Ra-226 concentrations in surface soils (pCi/g) for all of the study areas at the Riley Pass site. Gamma radiation surveys will be performed through systematic walkovers with a detector height of 1 meter above the ground surface within the Class 1 areas after remedial action has been completed.

Table 3 lists the radiological field survey instruments to be used at the Riley Pass site and the approximate detection sensitivities. These instruments will be used to characterize the Ra-226 concentrations in soil. A more detailed discussion of the gamma radiation survey is included in Section 5.3 and Appendix B.

Table 3 Gamma Scan Instruments and Approximate Detection Sensitivity

Description	Application	Approximate Detection Sensitivity (pCi/g)[1]
Ludlum Model 44-10; 2 x 2 inch, NaI(Tl) gamma scintillation detector	Gamma scans at 1 meter detector height of all surfaces	Ra-226 (2.8); total uranium (80); Th-230 (2,120)
Ludlum Model 2350-1 rate meter	Readout instrument for gamma scintillation detector	na

[1]Calculated site-specific detection sensitivities for Tonawanda Formerly Utilized Sites Remedial Action Program (FUSRAAP) following approach in NUREG-1507 (NRC 1998).
na = not applicable

3.3.3 Soil Confirmation Sampling

Samples will be collected from surface soils to support the cleanup verification surveys and to validate the accuracy of the in situ surveys. This sampling approach is referred to as *soil confirmation sampling*. There are two goals of the soil confirmation sampling:

1. Confirm the efficacy of the XRF field surveys and gamma radiation surveys.
2. Verify that the arsenic and Ra-226 concentrations in soil meet the cleanup criteria within each study area.

The primary data collection activities for the Riley Pass site involve soil samples within the designated survey unit areas after remedial action has been conducted. Samples will be representative of the top 15 centimeters (cm) (6 inches) of soil. A more detailed discussion of the soil confirmation sampling procedures and sampling frequency is provided in Section 5.4 and Appendix C.

3.4 DEFINE THE STUDY BOUNDARIES

The Riley Pass site consists of 10 primary study areas ranging in size from 3.78 acres (Bluff G) to 143 acres (Bluff B), as shown in Figure 1. The level and range of contamination vary significantly between study areas. Table 4 presents the study area boundary size, characterization date, and reclamation status.

Table 4 Summary of Riley Pass Study Boundaries

Study Area	Surface Area (acres)	Surface Area (ft^2)	Original Characterization Date	Reclamation Status
Bluff A	6.03	262,449	2009	Not Reclaimed
Bluff B	153	6,667,729	2012	Not Reclaimed
Bluff CDE	48.0	2,092,884	2012	Not Reclaimed
Bluff F	7.54	328,346	2009	Partially Reclaimed
Bluff G	3.78	164,744	2012	Partially Reclaimed
Bluff H	33.7	1,466,553	2012	Not Reclaimed
Bluff I	30.8	1,342,509	2009	Partially Reclaimed
Bluff J	8.75	381,150	2009	Reclaimed
Bluff K	10.6	460,892	2009	Reclaimed
Bluff L	15.03	654,707	2009	Not Reclaimed
All Bluffs	**317**	**13,821,963**	**-**	**-**

To date, the soils at most of the study areas have been characterized for arsenic and Ra-226. The Non-Tronox Bluffs (Bluffs A, F, I, J, K, and L) were characterized in 2008 by MSE and Tetra Tech (MSE 2009). The Tronox Bluffs (Bluffs B, CDE, G, and H) were characterized in 2012 by Tetra Tech (Tetra Tech 2013b). Three of the 10 study areas have been partially reclaimed, and two study areas have been fully reclaimed. Study boundaries have been identified for all of the study areas and are discussed in detail in Section 7.1. The spatial variability of these boundaries has been identified with confidence from previous historical assessment surveys, scoping, and characterization surveys. Waste areas referred to as Class 1 areas (discussed in Section 7.2) were identified using data from the characterization studies (MSE 2009; Tetra Tech 2013b). These areas are defined as areas exceeding 142 mg/kg arsenic or 30 pCi/g Ra-226 concentrations in soil. Characterization data were collected in areas where no remediation was performed; these data are considered valid. Most locations outside of the Class 1 area boundaries are considered Class 3 areas requiring no further sampling or remediation. There also exists locations where limited characterization data is available and where proximity to Class 1 areas warrants identifying areas as Class 2 (potential for contaminants of concern greater than background) and will require further characterization (see Figure 8). All Class 1 areas will be divided into survey units for the purposes of verification sampling.

3.5 DEVELOP THE DECISION RULE

The decision rule for the Riley Pass site relies on statistical tests in conjunction with geostatistical methods as outlined in (EPA 1989, 1996; NRC 1994, 1998). The decision rule presented in this report for the cleanup verification surveys consists of two statistical tests. The first statistical test, the Sign test (as outlined in MARSSIM [NRC 2000]), will be performed on the in situ XRF field survey and the gamma radiation survey results and compared with the $DCGL_w$ values for arsenic and Ra-226. The second test is the comparison of the 95 percent upper confidence level (UCL) of the mean (as outlined in EPA [1989]) from the analytical laboratory results of the soil confirmation samples and compared with the $DCGL_w$ values for arsenic and Ra-226. Detailed discussion of both of these statistical tests is provided in Section 6.0.

Figure 3 is a flow diagram illustrating the sequence of events to be performed in each Class 1 survey unit applied specifically to the XRF field survey and gamma radiation survey measurement data. The information presented in this flow chart is intended to provide guidance to determine whether a survey unit meets the risk-based soil cleanup criteria ($DCGL_w$), survey unit by survey unit. If contamination above the $DCGL_w$ requirements is encountered in a survey unit based on statistical testing, the data collected during the cleanup verification survey will be used for additional remedial action design, and additional action will be required. If the data are determined to be insufficient for identifying the additional remedial action design, then additional data may be required.

Figure 4 is a flow diagram illustrating the sequence of events to be performed to evaluate the soil confirmation data collected at each study area. The 95 percent UCL of the mean concentration for arsenic and Ra-226 from all of the soil confirmation laboratory results will be compared with the risk-based cleanup criteria ($DCGL_w$) for each contaminant. If the 95 percent UCL of the mean concentration is less than the risk-based cleanup criteria ($DCGL_w$) for each specific contaminant, then the study area is considered to have attained the cleanup objectives for the site.

Further information on the statistical methods used to determine if cleanup objectives are achieved are discussed in detail in Section 6.0. The EPA statistical software package, ProUCL, will be used for the statistical tests, as discussed in Section 6.3.

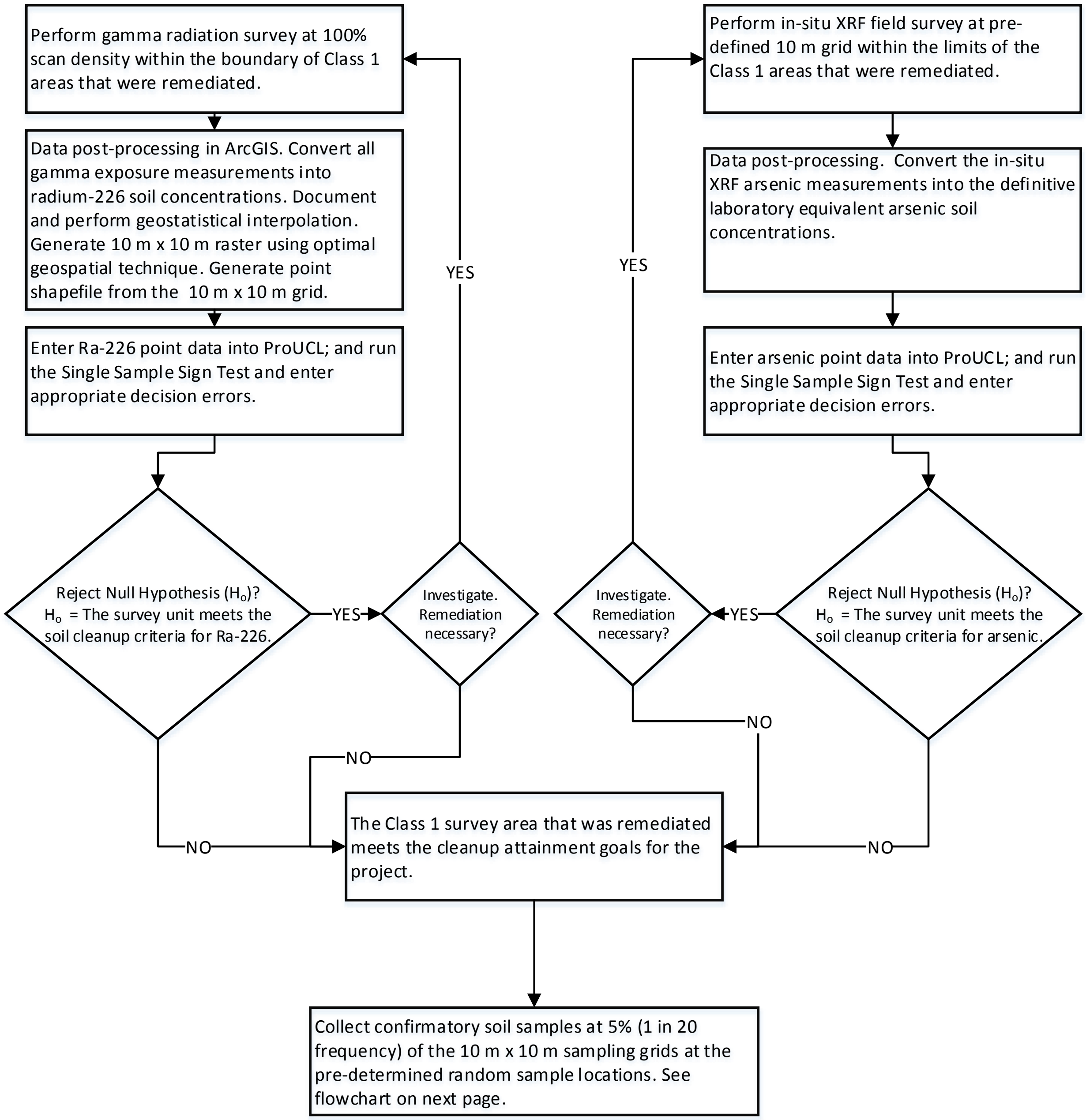


Figure 3 Decision Flow Diagram for Class 1 Units- XRF and Gamma Survey

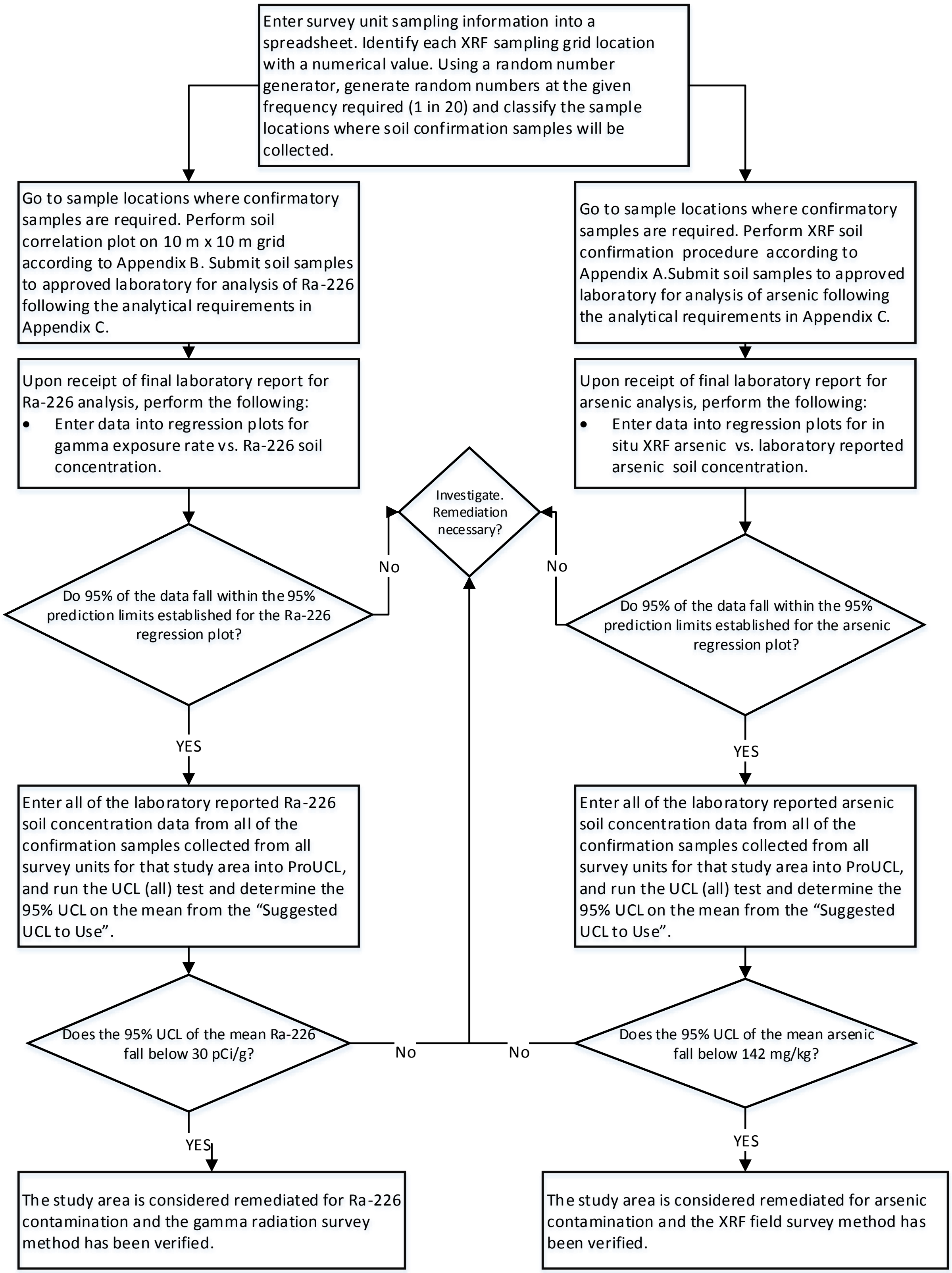


Figure 4 Decision Flow Diagram for Class 1 Units- Soil Confirmation Sampling

3.6 Specify Limits on Decision Errors

A statistical decision error occurs when the null hypothesis is rejected when it is true (Type I), or not rejected when it is false (Type II). While the possibility of a decision error can never be totally eliminated, it can be controlled (NRC 1998). Descriptions and acceptable rates on Type I and Type II decision errors are outlined as follows:

- A Type I error occurs if a survey were to be incorrectly classified as having **attained** the cleanup criteria. The Type I error is referred to as "α." The α will be set at 0.05 (meaning there is a 5 percent chance a Type I error will occur) for the cleanup verification survey assessments.

- A Type II error occurs if a survey were to be incorrectly classified as having **not attained** the cleanup criteria. The Type II error is referred to as "β." The β will be set at 0.05 (meaning there is a 5 percent chance a Type II error will occur) for the cleanup verification survey assessments.

As mentioned in Section 3.3, a systematic grid based sampling approach will be followed for the cleanup verification surveys (XRF field surveys and gamma radiation surveys). Statistical hot spot locating techniques are needed to select an appropriate grid size achieving a desired probability of *not* finding a hot spot of contamination as described in EPA (1989) and Gilbert (1987). These techniques rely on decision errors including the probability of not finding a hot spot (referred to as probability and indicated by "β_2"), the shape factor (S) of the hot spot (elliptical, circular, or some other shape), and the length of the semi-major axis of the hot spot size (denoted as "L"). Descriptions of the acceptable decision errors for establishing a grid spacing is as follows:

- The acceptable probability of not finding a hot spot of a given size and shape is 5 percent (β_2 = 0.05)

- The hot spot is assumed to be circular (S =1) with a radius of 6 meters (L = 6 m).

The verification survey was designed using a combination of an XRF field survey, gamma radiation surveys, and off-site laboratory analysis of surface soil samples to manage uncertainty. Sampling uncertainty will be controlled by collection of field quality control soil samples. The acceptable limits of these quality control samples is discussed in detail in Section 7.4.

3.7 Optimize the Design for Obtaining Data

The DQO process is iterative. The seventh step in the process is to evaluate the information from the previous six steps and optimize the study design for obtaining the data.

4.0 SAMPLING APPROACH

There are a number of sampling approaches that can be used to achieve the project objectives. Generally, the goal is to find cost-effective alternatives that balance sample size and measurement performance, given the feasible choices for sample collection techniques and analytical methods (EPA 1994). A number of sampling approaches were considered, including simple random sampling, stratified random sampling, sequential random sampling, systematic sampling, double sampling, adaptive sampling, and composite sampling. The sampling approach presented in this VSP used a combination of double sampling, systematic sampling, and simple random sampling.

The MARRSIM (NRC 2000) provides detailed guidance for final status surveys. The objective of the final status survey is to demonstrate that the residual radioactivity in each survey unit satisfies release criteria (cleanup standards). The final status survey is not conducted for the purpose of locating residual activity; the historical site assessment and the characterization surveys fulfill these functions. Since the Riley Pass site includes a contaminant of concern (arsenic) that is not radioactive, an alternative approach including the elements of the final status survey is still considered, but the process approach used in this VSP incorporates a combination of EPA and NRC guidance for radionuclide contamination. The characterization and verification data collected at the various study areas at the Riley Pass site showed with certainty the contaminant levels are below cleanup criteria and can therefore be used as final status survey data where appropriate (Albequist 2001).

The sampling design options listed above were all evaluated to consider cost and the ability of each approach to meet the DQO constraints. A combination of double sampling, systematic sampling, and simple random sampling was selected as the most resource-effective data collection design that satisfies all of the DQOs. Systematic and grid sampling are used to search for hot spots and to infer means, percentiles, or other parameters and are also useful for estimating spatial patterns or trends over time (EPA 2002a). Therefore, an unaligned systematic square grid sampling approach using double sampling XRF and gamma survey techniques is selected as the primary sampling approach to be used for the cleanup verification surveys after remedial action. Additionally, confirmatory soil samples will be collected using a simple random sampling approach. The following subsections present the sampling methodology for the sampling approaches to be used during the cleanup verification surveys.

4.1 DOUBLE SAMPLING

It is more effective to use less expensive and less precise analytical methods in some cases where high spatial variability occurs, such as Riley Pass, so a larger number of samples can be collected (EPA 1994). Double sampling is described in Appendix A of EPA (1996) and in Gilbert (1987) as an innovative sampling design with the potential for reducing costs and decision errors compared with a simple random sampling approach. The definition of double sampling is where an appropriate number of measurements of two different qualities and costs are obtained to improve estimates of means and totals. For example, inexpensive in situ measurements can be combined with a few expensive, but more accurate, laboratory analyses to estimate the mean. Double sampling allows for in situ XRF measurements used in combination with laboratory arsenic analysis data in a linear regression equation to estimate the mean (EPA 2002a); similarly, this method can also be applied to gamma exposure rate measurements used in combination with Ra-226 laboratory analyses in a linear regression equation.

Two types of double sampling approaches are considered for verification sampling at the Riley Pass site: (1) in situ XRF field surveys, and (2) gamma radiation surveys. These two approaches have been proven (MSE 2009; Tetra Tech 2013b) effective for the estimation heavy metals (arsenic) and radionuclides (Ra-226) to a definitive level of certainty. Definitive data are generated using rigorous analytical methods, such as approved EPA reference methods (such as EPA Method 6200) and the data are analyte-specific, with confirmation of identity and concentration (EPA 2000). Both of these analytical methods have been shown to be more cost-effective for estimating the mean compared with conventional soil sampling in a simple random sampling or systematic sampling approach.

The sampling approach selected for the verification sampling at Riley Pass will involve a combination of double sampling (XRF field surveys and gamma radiation surveys) using a systematic square grid-based sampling approach. The XRF field survey approach is described in Section 5.2, and the gamma radiation survey approach is described in Section 5.3. Using these sampling approaches, the sampling is more cost effective, resulting in a higher quantity of sampling collection compared with conventional soil sampling methods using a simple random sampling or systematic sampling approach. The following subsection describes the hot spot location techniques used in selecting an appropriate sized grid spacing system to be followed in conjunction with the double sampling methods.

4.2 Systematic Sampling

In random systematic sampling, an initial sampling location is chosen at random and the remaining sampling sites are specified so they are located according to a regular pattern (EPA 2002a). Systematic sampling is easier to implement under field conditions than are simple or stratified sampling plans (Gilbert 1987). Additionally, systematic sampling provides uniform coverage of the survey units (areas within the study areas where attainment decisions are to be made), yielding more accurate estimates of mean concentrations. In certain cases where unexpected periodicities occur in space or time, a systematic sampling approach may be misleading, resulting in biased estimates of the mean concentration (Gilbert 1987). The assumption for this project is these periodicities will not be present in the units being surveyed for cleanup verification; therefore, a systematic sampling approach is the best approach compared with simple random or stratified random sampling.

As described in Section 4.1, a cost-effective double sampling approach was selected for the sampling design. A benefit of using the in situ double sampling measurement techniques on a pre-defined grid-based sampling design is that it allows assessment of attainment of cleanup standards for each survey unit while simultaneously providing characterization of concentrations in soil. Survey units are compliance units and are described in more detail in Section 7.0. If a survey unit is sampled and determined not to attain the cleanup criteria objectives based on the statistical methods presented in this report, then further characterization would be required to assess the area needing additional remediation. However, using the proposed sampling approach, this information would have already been collected during the cleanup verification survey. Using an established reference grid system for sampling provides information needed to adequately obtain spatial information needed for further remedial design and field efforts, while also providing a sufficient number of data points to determine if the mean concentration is below the cleanup standard. One method for selecting an appropriate spacing of a pre-defined grid is to use hot spot characterization techniques presented in Gilbert (1987) and EPA (1989). Impacted areas will be gridded in square grid sampling at pre-determined intervals with consistent grid spacing for all impacted areas. Non-impacted areas previously characterized will not be gridded or sampled.

A hot spot statistical approach is presented here for development of the systematic grid-based sampling design. Hot spot locating techniques can be used to verify cleanup attainment by documenting that no hot spots could be identified in a given survey unit. An alternative approach is presented here where the hot spot locating techniques are used solely to justify a specified systematic grid size to be used for both the in situ XRF field survey and for gamma surveying. The grid size will be established based on an acceptable large probability, $(1 – \beta_2)$, of finding a circular hot spot with a given diameter. The calculated grid size based on these decision errors will be used for the sample locations. If hot spots are located, further characterization may be warranted if the overall mean concentration for the survey unit of interest does not meet the overall attainment objectives.

The probability that a hot spot will not be found is referred to as β_2. Therefore, the probability of finding a hot spot is $(1 – \beta_2)$. The radius of the circular (S = 1) hot spot is referred to as L (in meters), and the grid size is referred to as G (in meters). An acceptable probability calculated to meet the project objective is 95 percent (β_2 = 0.05). Using a 10-meter by 10-meter grid for the cleanup verification surveys, the corresponding radius of a circular hot spot is 6 meters, using Figure 5 below.

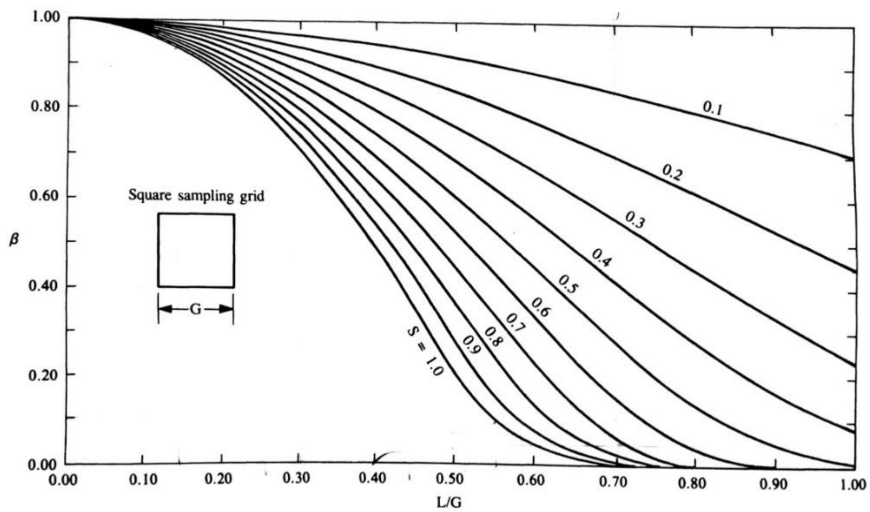


Figure 5 Hot Spot Determination Curves (Gilbert 1987)

A 10-meter by 10-meter systematic square grid system will be used for both the XRF field survey and the gamma radiation survey, effectively indicating a 95 percent probability of finding all hot spots greater than 12 meters in diameter. Note: gamma scanning will be performed at a 100 percent density (2 meter transects) as prescribed in NUREG-1505 (NRC 1998) and NUREG 1575 (NRC 2000) for the Class 1 areas identified in this report; however, geospatial interpolation techniques will be applied to the scan data and a 10-meter by 10-meter grid will be generated using the methods outlined in Section 6.4. A statistical analysis will then be applied to the 10-meter by 10-meter scanning grid points generated from the geostatistical methods which represent a 100 m^2 grid block average for Ra-226 concentrations. The XRF field survey will be performed on a separate 10-meter by 10-meter grid, and the in situ XRF arsenic measurements will be converted to definitive laboratory-equivalent arsenic concentrations, as described in Section 5.2. The same statistical tests for scanning (Ra-226 data) will be applied to the arsenic concentrations, also representing 100 m^2 grid block average for arsenic concentrations.

4.3 Simple Random Sampling

In addition to the XRF and gamma cleanup verification surveys, confirmation soil samples will be collected to verify cleanup criteria objectives are attained. A simple random sampling approach will be followed at a frequency of 1 in 20 for each study area. All of the confirmation soil samples collected within a specified study area will be evaluated using the statistical test presented in Section 6.2. In general, a minimum of three soil confirmation samples will be collected within each survey unit. The 95 percent UCL on the mean of arsenic and Ra-226 will be estimated using all of the soil samples collected within a given study area and compared with the risk-based cleanup levels ($DCGL_w$) established in the 2015 Action Memo. The methods for the soil confirmation sampling are presented in Section 5.4.

5.0 FIELD ACTIVITIES

This section describes the principal field activities to be conducted as part of the Riley Pass site cleanup verification survey.

5.1 OVERVIEW

The selection of the cleanup verification survey instrumentation and analytical techniques for this VSP were based on knowledge of the appropriate risk-based cleanup criteria and the nature of contaminant concentrations present at the site needing quantified assessment. The decision to use field-portable instruments was made for a number of reasons, including: cost, knowledge of contaminants, history of success at the site and other sites, and perhaps the most important — that decisions concerning the attainment of action levels can be made quickly at the site. The field-portable instrumentation and analytical methods described in this section have demonstrated that the methods result in acceptable minimum detectable concentrations (MDCs) capable of detecting contamination at the applicable DCGLs. The following field activities are to be performed after the removal action as part of the cleanup verification process at the Riley Pass site: XRF field surveys, gamma radiation surveys, and soil confirmation sampling. This section briefly describes the sampling methods for each of those activities; however, additional data quality and QA/QC procedures and detailed sampling procedures for each method are presented in appendices to this report.

5.2 XRF FIELD SURVEY

Soil samples will be analyzed on site for arsenic by EPA Method 6200 *Field Portable X-ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment* (EPA 2007). The collection of in situ XRF measurements for this project is referred to as *XRF field surveys*. XRF field surveys will be performed in accordance with Appendix A using a portable Niton XRF spectrum analyzer, or equivalent. The Niton XRF analyzer uses an x-ray tube to irradiate soil samples. The source x-rays excite electrons in the sample (EPA 2007), dislodging electrons from atomic shells and creating vacancies. The inner shell vacancies are filled by electrons with the emission of x-rays with a characteristic spectrum as the electrons cascade down to fill the vacancies. This process allows the XRF analyzer to identify elements present based on the unique spectra emitted and to estimate concentrations in soil based on emitted flux. A correlation between in situ XRF arsenic concentrations and analytical laboratory (EPA Method 6020A)-reported arsenic concentrations has been developed for the site (Tetra Tech 2013b, 2015d). This correlation will be the primary method for estimating arsenic concentrations in the field and for verification and is presented in Figure 6, below. A strong correlation ($R = 0.95$, $R^2 = 0.89$) exists between the in situ XRF arsenic measurements and the laboratory-reported total arsenic concentrations. An in situ XRF concentration of 105 ppm equates to the site's risk-based arsenic cleanup value of 142 mg/kg. The following equation can be used to convert the in situ XRF measurements to laboratory equivalent arsenic concentrations at the site:

Equation 1 $$Lab\ Arsenic = 10^{0.352+0.891 log_{10}(\text{XRF Arsenic})}$$

Where:

Lab arsenic = laboratory-reported arsenic concentration in surface soil (mg/kg).

XRF Arsenic = XRF measured arsenic concentration in surface soil (mg/kg).

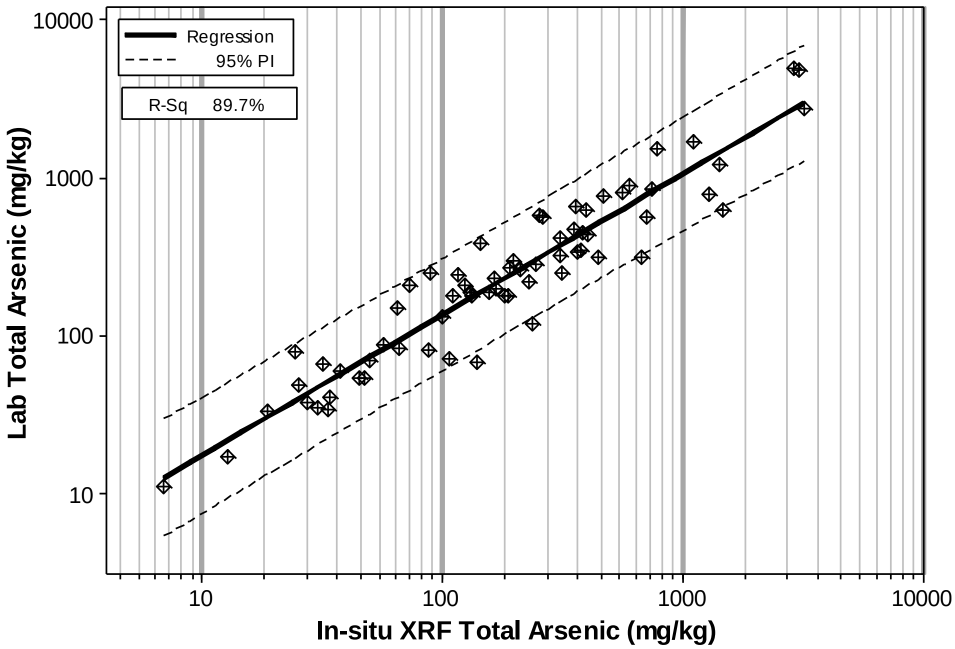


Figure 6 In Situ XRF Total Arsenic Concentration versus Laboratory-Reported Total Arsenic Concentration

The XRF field survey will be performed at sampling locations spaced over a 10-meter by 10-meter systematic square grid within in all of the survey units at all of the study areas. GPS locations and XRF measurement results will be logged in the field as specified in Appendix A. If an elevated measurement is recorded, additional measurements may be collected to characterize the extent of this area to guide potential additional removal action; however, these additional measurements will not be used for the statistical test— instead, they will be used only for characterization purposes when further remedial action is warranted by the lead field engineer. Statistical tests presented in Section 6.1 will be used to determine whether each survey unit has met the release criterion for concentrations of arsenic in soil.

While the correlation developed for the site meets the criteria for definitive-level estimates of concentrations of arsenic in soil, EPA Method 6200 specifies soil confirmation samples to be collected at a frequency of 5 percent (1 in 20). Therefore, XRF field surveys, in conjunction with discrete soil sampling, will be used in support of verifying cleanup standards for arsenic are attained at the Riley Pass site. Figure 4, Appendix A, and Appendix C provide specific information for how the soil confirmation samples will be evaluated to meet the project DQOs. Since a strong correlation has been established for the site with a significant amount of data, the additional results for the soil confirmation samples will be used to verify that the existing correlation in place is valid. If, for some reason, the additional data collected do not reflect the correlation based on the criteria in Appendix C, then further investigation will be required and the correlation may need to be changed to reflect the additional data collected. The project QC acceptance criteria is that 95 percent of the data pairs shall fall within the 95 percent UCL limits. Further investigation is warranted if these conditions are not met. Any changes to the site-specific correlation will be done by a qualified statistician or engineer familiar with EPA Method 6200 and will need to be approved by the on-scene coordinator. Further discussion on soil confirmation sampling is provided in Section 5.4.

5.3 GAMMA RADIATION SURVEY

Use of GPS-based gamma radiation survey systems has become a mature methodology for characterizing the spatial distribution of gamma radiation caused by NORM in soils (Whicker et al. 2008; Whicker et al. 2015; Johnson et al. 2006; Meyer et al. 2005; Vitkus et al. 2007). Soil samples will be analyzed on site for Ra-226 using gamma radiation survey methodology as described in Johnson et al. (2006) and Whicker et al. (2008) and in accordance with the sampling and QA/QC procedures in Appendix B and Tetra Tech (2013a, 2013b, 2015a, 2015b, 2015c, 2015d). Field instrumentation for this VSP has been selected to scan the surface soil for elevated direct radiation (gamma exposure rates), referred to as *gamma radiation surveys.* Thallium-activated sodium iodide scintillation [NaI(Tl)] detectors are widely used for scanning surface areas for elevated gamma radiation (NRC 1995). For the final cleanup verification surveys at Riley Pass, a 2-inch by 2-inch NaI(Tl) Ludlum Model 44-10 scintillation detector coupled to count rate meters (2350-1, Ludlum, or equivalent) will be used to perform the gamma radiation surveys. The systems will be fully integrated with GPS-based mobile backpack units. Table 3 shows the approximate detection sensitivity (2.8 pCi/g) for the instrumentation selected for this project is sufficient to achieve the desired DCGL (30 pCi/g) for Ra-226. Future down-hole gamma surveying to characterize sub-surface materials will utilize similar instrumentation. Due to the difference in instrument to material geometry encountered when conducting gamma measurements within a borehole, the gamma clean-up criteria established for surface materials cannot be directly applied to sub-surface gamma measurements.

The primary objective of the gamma radiation survey for this project is to generate enough data points to adequately estimate 100 m^2 grid-blocked averages of the Ra-226 concentration in soil across all of the study areas, which can then be used to assess the attainment of the cleanup standards for each survey unit. A 100 percent scanning coverage is required to provide sufficient amount of data to generate the 100 m^2 grid-blocked averages of the Ra-226 concentration in soil across all of the study areas. To obtain 100 percent coverage, the walkover surveys will be guided by real-time GPS positioning relative to pre-determined transect lines traversing across the study areas, which is assumed to include a transect width of 2-meter spacing traversed in a parallel fashion from north to south, equivalent to a 2-meter by 2-meter systematic square grid within in all of the survey units at all of the study areas. GPS locations and gamma exposure rate measurements will be logged in the field using software developed by Tetra Tech (Tetra Tech 2006) and specified in Appendix B.

Tetra Tech developed a site-specific gamma/Ra-226 correlation as described in Tetra Tech (2013b). The correlation is presented in Equation 2 and Figure 7, below. A strong correlation (R = 0.96; R^2 =0.92) was established between gamma exposure rate and the concentration of Ra-226 in soil. The following equation can be used to convert the gamma radiation measurements collected at the site to laboratory-equivalent Ra-226 concentrations in soil:

Equation 2

$$\text{Lab Ra} - 226 = 10^{-1.979+1.835\ log_{10}(Gamma)}$$

Where:

Lab Ra-226 = laboratory equivalent soil radium-226 concentration (pCi/g).

Gamma = gamma exposure rate measurement (µR/hr)

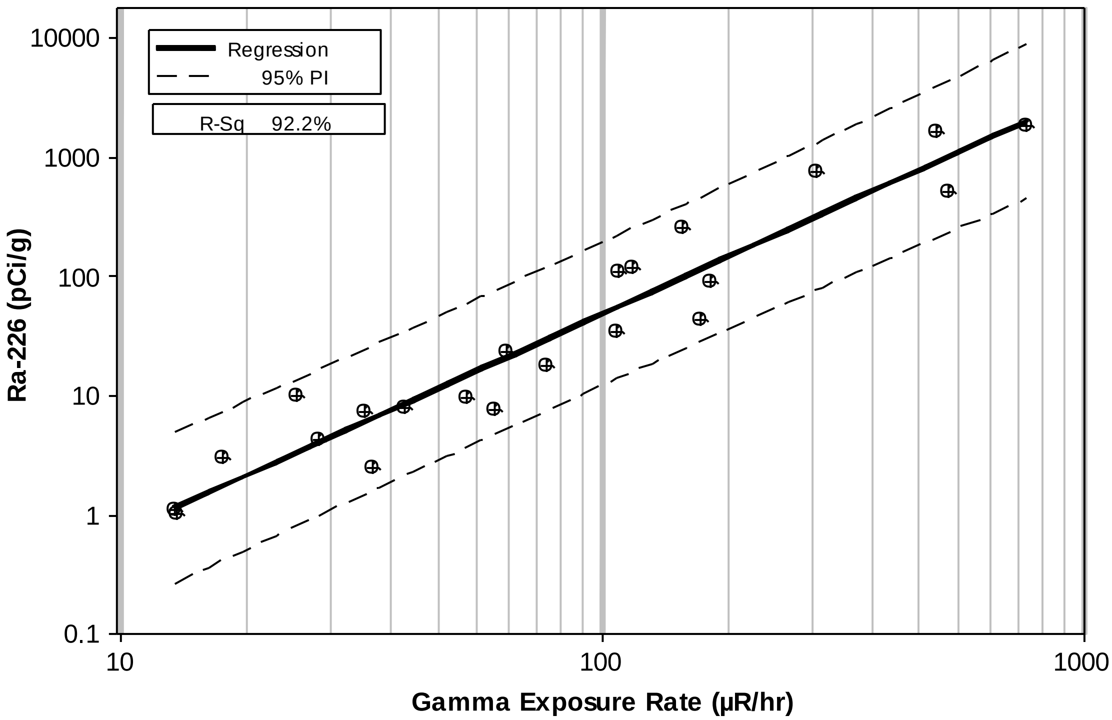


Figure 7 Gamma Exposure Rate versus Soil Ra-226 Mass Activity Concentration

The measured gamma exposure rates for all survey units will be converted into Ra-226 concentrations using Equation 2. The Ra-226 data sets will be geospatially interpolated and 10-meter by 10-meter grid-blocked averages will be generated following the methods outlined in Section 6.4 and Appendix B. (In other words, spatial averages will be calculated using geospatial interpolation techniques.) Using the site-specific correlation, the remedial action support surveys will ensure all grids meet the established gamma-Ra-226 criterion of 76.5 μR/hr (equivalent to 30 pCi/g Ra-226). At the conclusion of the verification scan of each survey unit designated, a distribution of average grid exposure rates will be developed, and the statistical test presented in Section 6.0 will be used to determine whether each survey unit has met the release criterion for Ra-226 concentrations in soil.

While the correlation developed for the site meets the criteria for definitive level estimates of Ra-226 concentrations in soil, discrete soil sampling will also be conducted at the same frequency and location for the XRF field surveys. Figure 4, Appendix B, and Appendix C provide specific information for how the soil confirmation samples will be evaluated to meet the project DQOs. Since a strong correlation has already been established for the site with a significant amount of data, the additional soil confirmation sample results will be used to verify that the existing correlation in place is valid. If for some reason the additional data collected do not reflect the correlation based on the criteria in Appendix C that 95 percent of the data pairs shall fall within the 95 percent UCL limits, then further investigation will be required and the correlation may need to be changed to reflect the additional data collected. Any changes to the site-specific correlation will be done by a qualified statistician or engineer familiar with the gamma radiation survey methodology specified in Johnson et al. (2006) and Whicker et al. (2008) and will need to be approved by the on-scene coordinator. The following subsection presents the soil confirmation sampling to be performed in conjunction with the XRF field surveys and the gamma radiation surveys.

5.4 SOIL CONFIRMATION SAMPLING

In addition to the in situ measurement techniques presented in this VSP, soil confirmation samples will also be collected as part of the cleanup verification survey process. Soil confirmation samples will be collected in accordance with the sampling and QA/QC procedures outlined in Appendix C. There are two goals of the soil confirmation sampling:

1. Confirm the efficacy of the XRF field surveys and gamma radiation surveys.
2. Verify that the arsenic and Ra-226 concentrations in soil meet the cleanup criteria within each study area.

Soil samples will be collected at a frequency of 1 in 20 in situ XRF measurements collected. A simple random sampling strategy, as described in Section 4.3, will be used to select the soil confirmation sample locations within each survey unit. For example, at a survey unit where 120 in situ XRF measurements are collected, a minimum of six soil confirmation samples would also be collected at six randomly selected locations on the grid. The soil confirmation sampling can be performed concurrently with the in situ measurement surveys (XRF field surveys and gamma radiation surveys) to save time and cost. Two separate soil samples will be collected for the randomly selected sample locations as follows:

- One XRF confirmation sample will be collected at each random location and submitted for laboratory analysis of arsenic following the procedures in Appendix C.
- A 10-meter by 10-meter correlation plot will be centered at the XRF point measurement, and nine aliquot soil samples composited into single sample and continuous gamma measurements at 100 percent density will also be collected within the correlation plot following the procedures in Appendix C.

The first goal of the soil confirmation sampling is to confirm the efficacy of the XRF field surveys and gamma radiation surveys by evaluating the resultant laboratory and in situ measurement data pairs with the existing correlation models. The laboratory results and in situ measurement combined will create one data pair generated from each soil confirmation sample. All of the data pairs collected from one study area (such as Bluff B) will then be plotted with the limits of the existing regression and prediction interval equations for arsenic and Ra-226 as described in Appendix C. In the event more than 5 percent of the data pairs fall outside of these limits, further investigation, including additional soil sampling and a review of the instrument QA/QC data, will be conducted by a qualified engineer. If 95 percent of the data pairs fall within the specified prediction limits, the in situ measurement techniques are validated.

The second goal of the soil confirmation sampling is to verify the arsenic and Ra-226 concentrations in soil of a study area meet the cleanup criteria within the individual survey units. The in situ measurements collected in each survey unit are the primary mode for ensuring cleanup objectives are attained. Soil confirmation sampling is the secondary mode for ensuring cleanup objectives are attained. The 95 percent UCL for the laboratory-reported mean arsenic and Ra-226 soil confirmation results collected from a given study area will be compared to the cleanup standards for both contaminants, as described in Section 6.2. If the 95 percent UCL on the mean is above the risk-based cleanup criteria for either contaminant, then further investigation will be warranted. If the 95 percent UCL on the mean is below the risk-based cleanup criteria ($DCGL_w$), then the study area is verified to attain the cleanup standards. All soil confirmation samples will be submitted to an approved radio-analytical laboratory for analysis in accordance with Appendix C.

6.0 STATISTICAL METHODS

A number of statistical tests are available to help decision makers and project teams in making correct decisions at a contaminated site that are both cost effective and protective of human health and the environment. This section describes the selected methods for determining the number of samples needed to obtain statistically valid comparisons with cleanup criteria and the methods for conducting the statistical tests with the resulting sample data. Additionally, this section presents statistical software and geostatistical methods to be used to evaluate attainment of cleanup standards for the Riley Pass site.

6.1 SIGN TEST

MARSSIM (NRC 2000) provides two alternative non-parametric statistical tests for establishing that a cleanup verification survey (final status survey) unit is in compliance with a $DCGL_w$. Non-parametric statistics require fewer assumptions on the underlying data distributions than parametric statistical tests. The two tests recommended by MARSSIM are the Sign test and the Wilcoxon Rank Sum (WRS) test. The Sign test is intended to be used at sites where the COCs are either not present in background media or are at concentrations significantly less than their $DCGL_w$ values. The WRS test is used at sites where one or more of the COCs is present in background media and their background concentrations are close to relevant $DCGL_w$ values. Background concentrations of various COCs were presented in various studies, including the EE/CA (USFS 2006) and the risk assessment (Portage 2006).

All of the COCs (arsenic and Ra-226) at the Riley Pass site are found to have background concentrations significantly less than their $DCGL_w$ values; consequently. the Sign test is the statistical method of choice to be used at Riley Pass to demonstrate each survey unit meets the $DCGL_w$. Compliance with the $DCGL_w$ values for Class 1 survey units will be assessed using results of the cleanup verification surveys and applying the Sign test to them as recommended in NUREG -1505 (NRC 1998) and MARSSIM (NRC 2000). A detailed discussion of survey units and area classification of study areas into Class 1, Class 2, and Class 3 areas is provided in Section 7.0. Cleanup verification surveys include the following in situ measurement techniques: (1) XRF field surveys to determine arsenic concentrations in soil, and (2) gamma radiation surveys to measure Ra-226 concentrations in for Class 1 survey units. Both of these sampling methods are discussed in Section 5.0.

The decisions necessary to evaluate compliance with the criteria for license termination are formulated into precise statistical statements called hypotheses (NRC 1998). The state presumed to exist in reality is expressed as the null hypothesis (denoted by $\mathbf{H_o}$); and the expression of what is believed to be the state of reality if the null hypothesis is not true is the alternative hypothesis (denoted by $\mathbf{H_A}$). The important decision for this VSP is whether the Riley Pass site meets the applicable risk-based cleanup criteria at a given survey unit within each of the study areas. The scenario encountered for this project for the null and alternative hypotheses are as follows:

$\mathbf{H_o}$**:** The survey unit meets the risk-based soil cleanup criteria.

$\mathbf{H_A}$**:** The survey unit does not meet the risk-based soil cleanup criteria.

The following discussion presents a method for establishing the number of samples required per survey unit area for the Sign test to be considered statistically valid.

Sample Size Determination for the Sign Test:

The null hypothesis (H_o) for the Sign test states the residual radioactivity in the survey unit meets the risk-based release criterion; therefore, if the null hypothesis is rejected the survey unit fails. Cleanup decisions at the Riley Pass site are based on risk-based cleanup criteria, also referred to as the $DCGL_w$. As stated in the previous subsection, Tetra Tech recommends using the non-parametric Sign test on the cleanup verification survey data (arsenic and Ra-226) collected within the Class 1 areas. The Sign test requires a certain number of samples for the test to be considered statistically valid. The number of data points needed to satisfy the Sign test is based on the following elements:

1. $DCGL_w$.
2. The expected standard deviation (σ) of the contaminant in the survey unit.
3. DQO inputs, including the probability of making a Type I and Type II decision error.
4. Lower boundary of the gray region (LGBR).
5. Relative shift, given by Δ / σ, where Δ = $DCGL_w$ – LBGR.

The Sign test requires a minimum number of samples for each survey unit to be considered statistically defensible. The following steps detail the procedure for selecting the number of data points required for the Sign test with each survey unit:

Step 1: Calculate the relative shift

The $DCGL_w$, LGBR, and the standard deviation of the contaminant of concern (arsenic and Ra-226) are used to calculate the relative shift, Δ / σ. Recall, Δ = $DCGL_w$ – LBGR; therefore, the relative shift is equal to ($DCGL_w$ – LBGR) / σ. The following information is used to determine these parameters:

- Determine $DCGL_w$: The $DCGL_w$ for arsenic is 142 mg/kg; the $DCGL_w$ for Ra-226 is 30 pCi/g. *Note: In MARSSIM (NRC 2000), the $DCGL_w$ is applied only to radionuclides, but in this situation and to save confusion, a $DCGL_w$ for arsenic is given. The Sign test can be applied to both radioactive and non-radioactive constituents.*
- Determine Standard Deviation: The standard deviation (σ) of each contaminant is obtained from a detailed analysis of the data collected from remedial action support surveys at the Riley Pass site to date.
- Determine LBGR: The Type II error rate is set at the LBGR. It is advantageous to set the LBGR at or above the expected median contaminant concentration in the survey unit. The median is used here and was calculated from a detailed analysis on the data collected from remedial action support surveys at the Riley Pass site to date.

MARSSIM recommends the standard deviation and LBGR be obtained from remedial action support surveys (if available) where remediation was performed. Removal actions have been conducted at the Riley Pass site and cleanup verification surveys have been performed at a number of areas that were remediated. Results from these verification reports are presented in Tetra Tech (2012a, 2013a, 2015a, 2015b, and 2015c). Tetra Tech performed a detailed analysis based on the results of the data collected at the successfully reclaimed areas to provide estimates on the standard deviation and median of the cleanup verification survey. Table 5 presents the results of the data analysis for the reclaimed areas. This information can be used to estimate the parameters needed for the determination of required samples for the Sign test.

Table 5 Summary of Verification Data from Reclaimed Areas at Riley Pass

Reclaimed Area	Reclamation Area (m^2)	Arsenic			Ra-226[1]		
		n	σ (mg/kg)	Median (mg/kg)	n	σ (pCi/g)	Median (pCi/g)
Bluff G1 - G5	3,522	29	20.8	88.9	34	2.62	9.05
Bluff I1-1	4,598	28	43.2	78.0	47	4.20	12.9
Bluff I1-7	1,068	8	18.0	113	8	2.09	13.4
Bluff I1-8	783	7	35.3	103	8	4.01	11.9
Bluff I2	19,212	81	13.1	33.9	195	0.82	2.09
Bluff I3-1	3,019	24	40.3	101	30	2.96	7.22
Bluff F1	9,348	34	22.4	61.5	94	6.98	11.5
Bluff F2	4,182	17	22.0	110	39	3.67	13.0
Spoils Pile A	4,959	20	13.2	117	47	2.64	12.7
Spoils Pile E	1,051	5	33.4	96.6	11	0.91	7.92
ALL AREAS	51,743	253	39.3	66.8	513	6.19	7.70

[1]The Ra-226 data was based on a 100 m^2 grid averaged approach for each reclaimed area using geostatistical methods on the raw gamma exposure rate converted to Ra-226 concentration data.

The standard deviation for arsenic and Ra-226 ranges from 13.1 mg/kg to 43.2 mg/kg arsenic and from 0.82 pCi/g to 6.98 pCi/g Ra-226. The median for arsenic and Ra-226 ranges from 33.9 mg/kg to 117 mg/kg arsenic and from 2.09 pCi/g to 13.0 pCi/gRad-226. The cumulative data was analyzed for the Sign test sample size evaluation to calculate the standard deviation and median for arsenic and Ra-226. The standard deviation for arsenic is 39.3 mg/kg and the standard deviation for Ra-226 is 6.19 pCi/g. The median is determined to be 66.8 mg/kg for arsenic and 7.70 pCi/g for Ra-226. Using the standard deviation to calculate the relative shift and the median for the LBGR provides a general estimate of what can be expected once remediation is conducted at each survey unit.

Using the information presented above, the relative shift, Δ / σ, is calculated for the arsenic concentration as follows:

$$\frac{\Delta}{\sigma} = \frac{DCGL_w - LBGR}{\sigma} = \frac{142\ mg/kg - 66.8\ mg/kg}{39.3\ mg/kg} = 1.91$$

Using the information presented above, the relative shift, Δ / σ, is calculated for Ra-226 concentration as follows:

$$\frac{\Delta}{\sigma} = \frac{DCGL_w - LBGR}{\sigma} = \frac{30\ pCi/g - 7.70\ pCi/g}{6.19\ pCi/g} = 3.60$$

Step 2: Determine sign p

The Sign p values are obtained from Table 5.4 in MARSSIM (NRC 2000), which contains a listing of relative shift values and values for Sign p. The Sign p values for arsenic and Ra-226 were calculated as follows:

- The Sign p for arsenic is 0.97
- The Sign p for Ra-226 is 1.0

Step 3: Determine decision error percentiles

The decision error percentiles were calculated during the DQO process and are presented in Section 3.6. The Type I error (α) was determined to be 0.05 and the Type II error (β) was determined to be 0.05, which exceed the default parameter requirements presented in MARSSIM (NRC 2000).

Step 4: Calculate the number of data points for Sign test

$$N_{arsenic} = \frac{\left(Z_{1-\alpha} - Z_{1-\beta}\right)^2}{4(Sign\ p - 0.5)^2} = \frac{(1.645 + 1.645)^2}{4(0.97 - 0.5)^2} = \frac{10.824}{0.88} = 12.3 \sim 13\ samples$$

$$N_{Ra-226} = \frac{\left(Z_{1-\alpha} - Z_{1-\beta}\right)^2}{4(Sign\ p - 0.5)^2} = \frac{(1.645 + 1.645)^2}{4(1 - 0.5)^2} = \frac{10.824}{1} = 10.8 \sim 11\ samples$$

Table 6 provides the minimum number of samples required for the Sign test for each COC using the methods above. The calculations are reaffirmed in Appendix D using the ProUCL software presented in Section 6.3.

Table 6 Minimum Number of Samples Required for Sign Test per Survey Unit Area

Contaminant of Concern	Standard Deviation, σ	Δ	Minimum Number of Samples Required per Survey Unit
Arsenic	39.3	75.2	13
Radium-226	6.19	22.3	11

6.2 95 Percent UCL of the Mean Hypothesis Test

As described in Section 5.4, soil confirmation samples will also be collected within each survey unit as part of the cleanup verification survey process to confirm the efficacy of the XRF field surveys and gamma radiation surveys and to verify the arsenic and Ra-226 concentrations in soil of a study area meet the cleanup criteria within the study areas. Since far fewer soil confirmation samples will be collected in comparison to the in situ measurements, an alternative hypothesis testing approach will be applied to the analytical laboratory results for the soil confirmation samples. EPA (1989) specifies alternative statistical approaches to verify the cleanup standard (C_s) have been attained, after remediation and cleanup. This verification involves estimation of the mean of the laboratory-reported arsenic and Ra-226 concentrations from the soil confirmation samples collected within each individual study area. Soil confirmation sampling methods are described in Section 5.4 and Appendix C. Statistical procedures following Chapter 6.0 of EPA (1989) "*Determining Whether the Mean Concentration of the Site is Less Than a Cleanup Standard*" will be applied to the confirmation soil sampling data sets for each study area (not individual survey units). A 95 percent UCL of the mean will be calculated using ProUCL software as described in Section 6.3. The sample size determination to estimate the population mean is needed to ensure enough soil confirmation samples are collected within each study area. The following normal distribution equation can be used to estimate sample size needed to estimate the mean (EPA 2013):

$$n = \frac{\sigma^2 z_{1-(\alpha/2)}^2}{\Delta^2}$$

Where:

Δ = allowable error margin in the mean estimate.
σ = standard deviation
$z_{1-\alpha/2}$ = the z-value for a given probability (1-α)

The population variance (σ^2) and standard deviation (σ) are known for both arsenic and Ra-226 using the values in Table 5 (39.3 mg/kg for arsenic; 6.19 pCi/g for Ra-226). The allowable margin of error (Δ) can be assumed to be 10 percent of the $DCGL_w$ for each contaminant (14.2 mg/kg for arsenic; 3.0 pCi/g for Ra-226). The acceptable probability (1-α) is 95 percent. Using these parameters, the minimum number of soil confirmation samples needed to be collected from each study area can be calculated. Table 7 shows the parameters used and the resulting minimum number of soil confirmation samples needed to estimate the mean for each study area. The calculations are reaffirmed in Appendix D using the ProUCL software presented in Section 6.3. *Note: This process can be repeated as data is collected in the field. For instance, if the standard deviation of arsenic at Bluff G is less than 39.3 mg/kg, then less samples would be required.*

Table 7 Minimum Number of Soil Samples Required to Estimate Mean Per Study Area

Contaminant of Concern	Standard Deviation, σ	Error Margin, Δ	Minimum Number of Soil Samples Required per Study Area
Arsenic	39.3	14.2	32
Radium-226	6.19	3.0	19

6.3 STATISTICAL SOFTWARE

Some of the methods require rigorous statistical analysis; therefore, Tetra Tech recommends utilizing a well-documented and defensible statistical software for the non-parametric Sign test for in situ measurements within each survey unit and comparison of the 95 percent UCL on the mean of the soil confirmation samples within each study area, as discussed in the previous subsections. The software to be used for the statistical tests presented in this VSP is ProUCL (EPA 2013), an EPA-approved software package designed for the analysis of environmental data sets, both with or without non-detect (ND) values. ProUCL software is designed to compute the rigorous statistical tests outlined in Section 6.1 and

Section 6.2. ProUCL represents a comprehensive statistical package equipped with statistical methods and graphical tools needed to address many environmental sampling and statistical issues as described in various CERCLA guidance documents. A qualified statistician will perform the statistical tests during the cleanup verification survey. Appendix D provides step-by-step guidance showing how to use ProUCL for the statistical tests presented in this VSP. To confirm the sample size calculations presented in Section 6.1 and Section 6.2 are correct, an analysis was performed for the statistical tests using the ProUCL software. Appendix D presents the results of the sample size determination analysis for both statistical tests. The output results using ProUCL confirm the number of samples required match the calculations provided in 6.1 and Section 6.2.

6.4 GEOSTATISTICAL METHODS

Geostatistical methods are useful for cleanup verification; these methods are especially useful for remedial investigations where the primary objective is to characterize the extent of contamination and can also be useful for evaluating certain soils remediation efforts (EPA 1989). These methods provide a method for mapping spatial data, enabling interpolation between existing data points and a method for estimating precision of the interpolation (EPA 1989). Kriging, a geostatistical tool, is an accepted tool for use in soil sampling (or XRF and gamma surveys) with the purpose of estimating the concentration in sampling units of given sizes (EPA 1992). Kriging, combined with semi-variograms, is useful in designing and conducting soil and waste sampling efforts (EPA 1992). Geostatistical methods will be used during the cleanup verification surveys targeted at developing concentrations in soil estimated for Ra-226 using the large data sets collected during the gamma radiation surveys.

Geostatistical methods used the Geostatistical Analyst extension in ArcGIS as described in Tetra Tech (2013b; 2015d) in the characterization studies at Riley Pass (MSE 2009; Tetra Tech 2013b), with the intent of mapping the spatial extent of contamination by arsenic and Ra-226 in soil. These techniques are especially warranted for the gamma radiation survey data collected because of the sheer quantity of sample points typically collected. The use of geospatial interpolation techniques allows for development of the grid-averaged approach recommended in the 2015 Action Memo. Often, there are duplicate samples or biased sample areas resulting from differences in scanning speed during the walkover gamma surveys, and the geospatial techniques provide smoothing effects and allow for development of continuous equally spaced surfaces. These techniques will be applied to the gamma radiation surveys data. It is recommended that a geostatistician familiar with these techniques be responsible for post-processing of the data sets after the surveys have been performed. The real-time scanning systems to be used in the field require the post-processing to occur in the field or shortly thereafter, followed by rigorous geostatistical analysis steps that are detailed in Appendix B.

7.0 SAMPLING LOCATION AND FREQUENCY

It is not possible to perform measurements or conduct sampling at the theoretically infinite number of locations at a site; instead, a survey should have as its objective collection of quality data from sufficient representative site locations, such that a statistically sound conclusion regarding the cleanup status of the entire site can be developed (NRC 1992). Meeting this objective requires a statistically driven sampling approach for selecting in situ measurement and soil confirmation sampling locations. This section presents the study area boundaries, the basis for area classification, the survey unit design, and the location frequency for each sampling method.

7.1 STUDY AREA BOUNDARIES

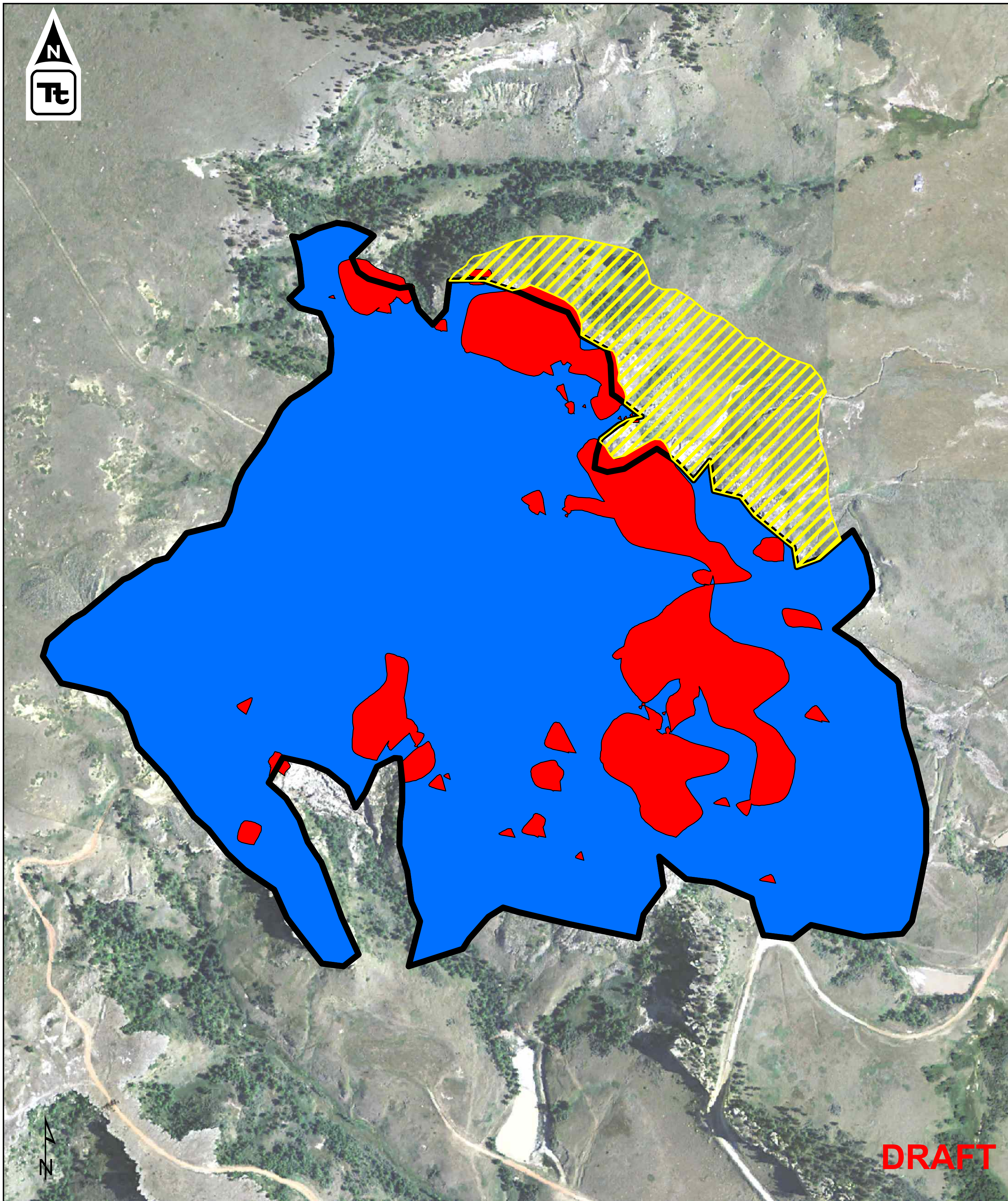
There are 10 study areas at Riley Pass, as shown in Figure 1 and presented in Table 4. The study area boundaries range in total surface area from 12,847 m^2 to 619,770 m^2, totaling approximately 0.5 square mile. Study areas are subdivided for the purposes of reclamation into *impacted* and *non-impacted* areas, and are then further classified into Class 1, Class 2, or Class 3 areas. Impacted areas are areas with potential (radioactive or heavy metal) or known contamination on the surface, and non-impacted areas are areas that are not classified as affected (NRC 1992). Classification of Class 1, Class 2, and Class 3 areas is discussed in Section 7.2.

The study areas can be delineated into impacted or non-impacted areas using the data collected in previous characterization surveys (Albequist 2000). Characterization surveys have been performed at each of the 10 study areas at the Riley Pass site, and rigorous geostatistics have been applied to generate continuous surfaces and boundaries delineating the contaminated areas. All areas of the site do not have the same residual contamination and therefore do not require the same level of survey coverage. The potential for contamination has been delineated for each study area. Therefore, the focus of the survey design involves only the impacted areas where contamination is known to exist.

7.2 AREA CLASSIFICATION

Following MARSSIM (NRC 2000) guidance, the impacted and non-impacted areas are further divided into Class 1, Class 2, and Class 3 based on potential for contamination. Decommissioned sites are released survey unit by survey unit; survey units are the fundamental compliance units. Class 1 areas are the most likely to be contaminated, such that the contamination levels are likely to exceed the $DCGL_w$ in some areas. Class 2 areas are expected to have residual radioactivity levels greater than background, but not at levels exceeding the $DCGL_w$. Class 3 areas are expected to be similar to background areas. The characterization surveys at Riley Pass provided necessary information to classify the Class 1 and Class 3 study areas for most study areas. Figure 8 shows the area classification for Bluff B, including a Class 2 area requiring further characterization. Additional characterization needs have been recommended in Tetra Tech (2015d).

MARRSIM (NRC 2000) recommends that survey units should be limited in size based on classification, unless rationale for selection of larger survey unit areas is developed during the DQO process. The following subsection provides procedures for survey unit design.



Study Area Boundary
Class 1 Areas
Class 2 Areas
Class 3 Areas

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NAD_1983_STATEPLANE
SOUTH_DAKOTA
NORTH_FIPS_4001_FEET

Title:

BLUFF B AREA CLASSIFICATION MAP

Prepared for:

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Location: HARDING COUNTY, SD

Project no.: 114-560486A

Date: OCT 2015

Figure: Figure 8

V:\T-Z\Tetra Tech Division\114-560486 - 2015 Riley Pass\120-GIS\MXD\Task 2 Figures\October Revised\Figure 8_Bluff_B_Area_Classification_NAD83.mxd September, 2015: daniel.workman

7.3 Survey Unit Design

The MARSSIM (NRC 2000) final status survey approach recommends survey units be limited in size based on classification. A suggested maximum area of 2,000 m^2 is recommended for Class 1 land areas. The limitation on survey unit size for Class 1 areas ensures each area is assigned an adequate number of data points. However, the suggested Class 1 area size requirements recommended in MARSSIM (NRC 2000) are intended for decommissioning sites to be released specifically for unrestricted use (such as residential development). However, the Riley Pass site will remain under USFS jurisdiction and the release criteria are intended for recreational users of the site and will not be designated for unrestricted use. Fortunately, as outlined in Section 2.6 of MARSSIM (NRC 2000), design protocols are flexible, and survey unit size may be adjusted to accommodate circumstances provided that reasonable and effective alternative strategies to demonstrate compliance are available and can be justified. A larger survey unit size of up to 12,000 m^2 is recommended for the Riley Pass site and justified because the release designation of the site is for recreational users and not for unrestricted use.

An example of how survey units should be developed is detailed in a step-by-step process for Bluff B. It is assumed this method will be applied to every distinct study area at the Riley Pass site to establish survey units. The following steps should be followed for designating survey units for a particular study area for the cleanup verification surveys:

Step 1: Identify Class 1 Areas

The characterization surveys performed at the Riley Pass site provide detailed spatial information for the first level of classification specified in MARSSIM (NRC 2000). This first level of classification requires the site to be divided into impacted and non-impacted areas. This report defines impacted areas as areas that have, or had, the potential for radioactive or heavy metals contamination. These areas are referred to as "Class 1 areas" as defined in MARSSIM (NRC 2000). All areas where contamination has been characterized to fall below the cleanup values for both arsenic and Ra-226 are considered non-impacted areas and are referred to as "Class 3 areas." Class 2 areas requiring further investigation have been identified on Figure 8. No additional sampling will be required in Class 3 areas because the characterization data are considered sufficient for considering these areas to be below the cleanup standards for the site. Cleanup verification surveys will be performed only within the Class 1 areas that are identified. The Class 1 areas are developed following the method in Section 7.2 and are presented for Bluff B in Figure 8.

Step 2: Overlay Grids on Class 1 Areas

In general, the areas identified as Class 1 are non-square and are difficult to group into exact 12,000 m^2 areas. Therefore, square grids are overlaid onto the study area. The most efficient approach is to generate a grid based system in ArcGIS or Civil 3D overlaying the Class 1 areas previously identified. The 2,000 m^2 grids will be overlaid on the study area as shown in Figure 9 for this VSP. The grids will later be combined to generate the larger survey units. In addition, some of the grids will fall outside of the Class 1 areas and will be removed later in Step 3. Figure 9 provides an example of a 2,000 m^2 grid overlaid on the Class 1 areas identified for Bluff B. The red lines show the 2,000 m^2 grid.

Step 3: Remove Unnecessary Grids and Align Over Class 1 Areas

As can be seen in Figure 9, not all of the Class 1 areas are contained within grid units. All grids not overlapping any portion of a Class 1 area will be deleted. Additionally, some Class 1 areas may be localized and small; therefore, individual survey units can be generated to encompass these smaller localized areas wherever possible. The left side of Figure 10 shows the remaining 2,000 m^2 grids intersecting or overlaying the Class 1 study areas.

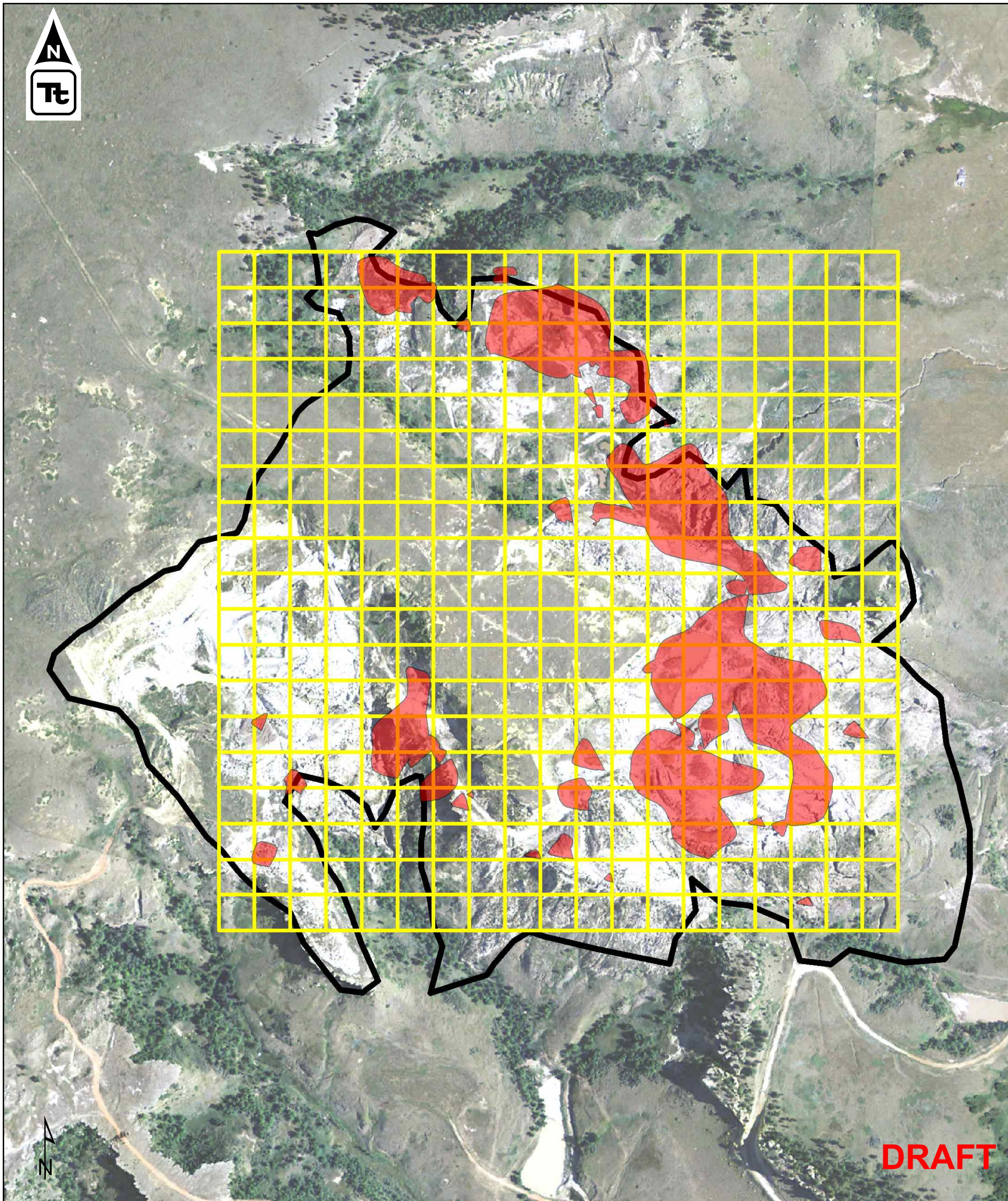
Step 4: Survey Unit Identification

The next step is to generate a unique identifier for each survey unit. This step should be a simple alphanumerical approach incorporating the spatial location and study area, and this identification process will be useful for combining the grids into larger area survey units as detailed in Step 5. For instance, the survey unit in the most northwestern area at study area Bluff B should be labeled “B1,” the grid directly to the east of B1 shall be labeled “B2,”, and so forth, moving in a west-to-east and north-to-south approach. An example of this grid classification scheme used to label each specific grid as shown on the right side of Figure 10.

Step 5: Survey Unit Design

A maximum survey unit size of 12,000 m^2 will be used for the cleanup verification surveys at Riley Pass. Therefore, a maximum of six 2,000 m^2 grids may constitute a survey unit. The survey unit design is subjective and an example for Bluff B is shown in Figure 11. A total of 21 survey units (B-SU-1 through B-SU-21) were generated ranging in size from 6,000 m^2 to 12,000 m^2 for the survey unit classification of Bluff B.

The steps outlined above can be applied for each study area individually, and the size and number of survey units will vary depending on the Class 1 areas within each study area. A systematic grid sampling approach will be used for the in situ XRF field surveys and gamma radiation surveys within each survey unit; additionally, soil confirmation samples will be collected within each survey unit. The following subsection presents the number of cleanup verification samples to be collected from the in situ XRF field survey, gamma radiation survey, and confirmation soil sampling compared with the required number of samples needed to satisfy the statistical requirements for the specified statistical tests to be performed.



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SOUTH_DAKOTA
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Bluff H Boundary
Class 1 Areas
Grid Overlay (2000 sq. meter)

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Title:

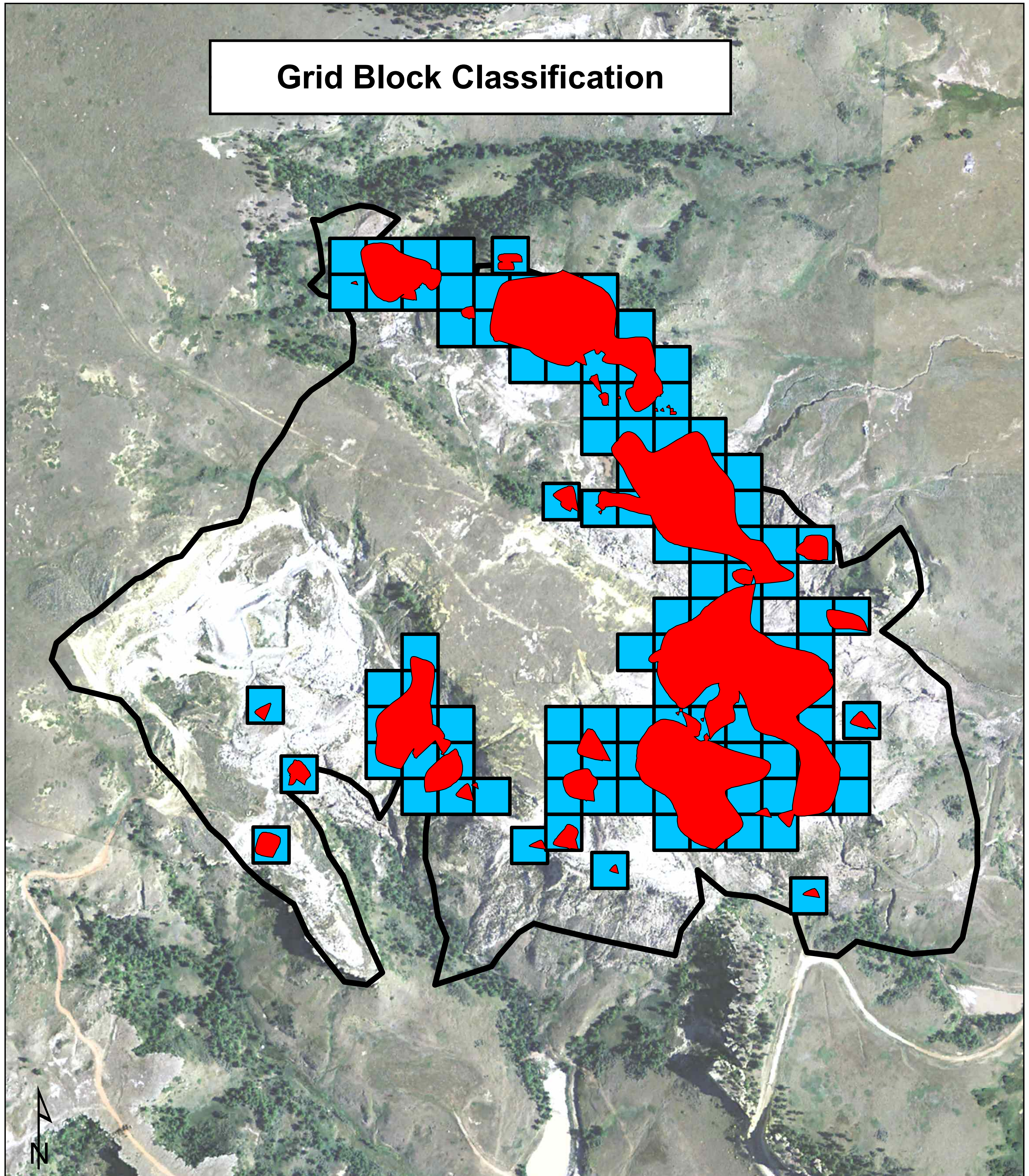
BLUFF B SURVEY UNIT DEVELOPMENT GRID OVERLAY

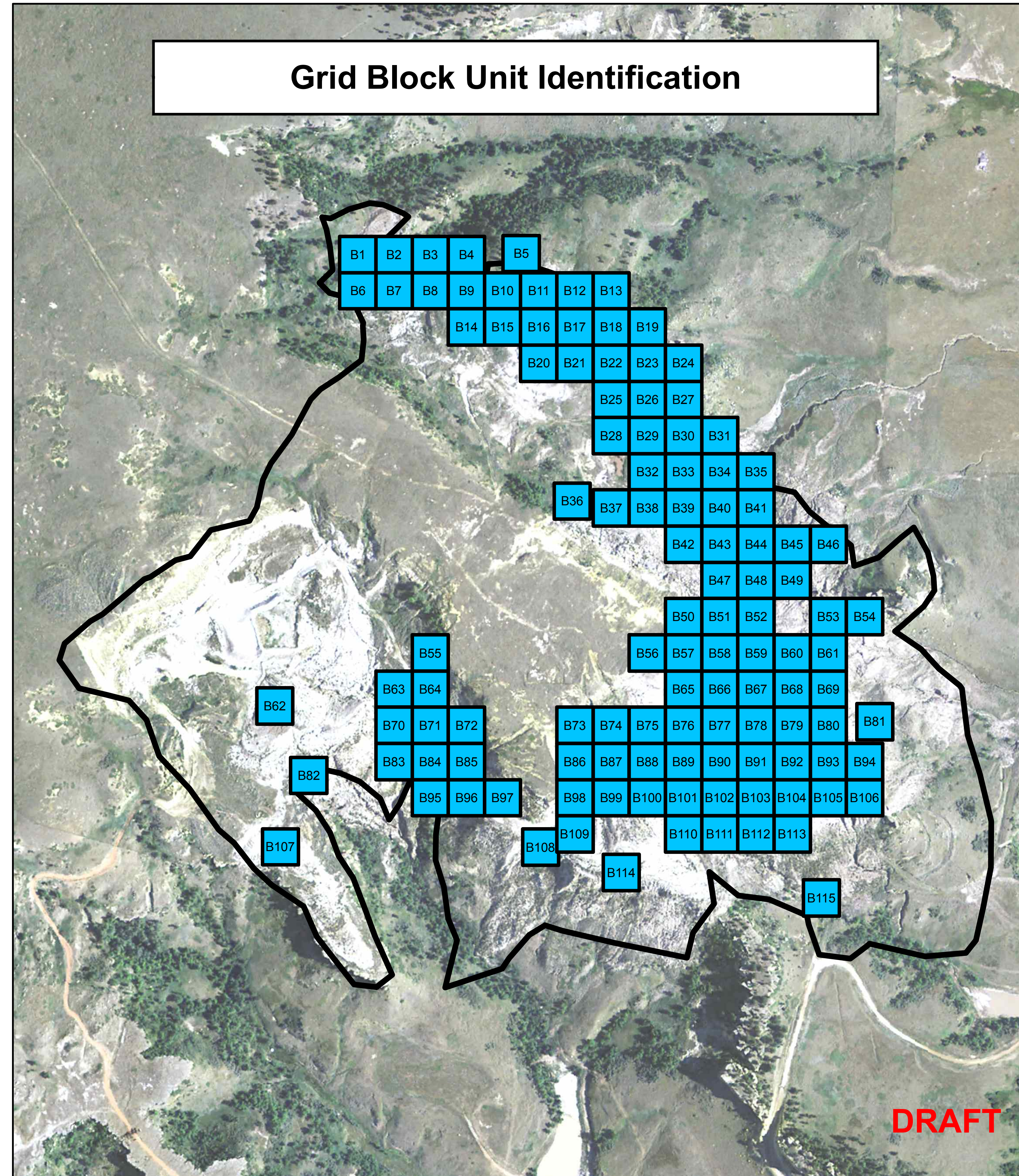
Location: HARDING COUNTY, SD

Project no.: 114-560486A

Date: OCT 2015

Figure: **Figure 9**





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Class 1 Areas

2000 Square Meter Grid Block

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Title:

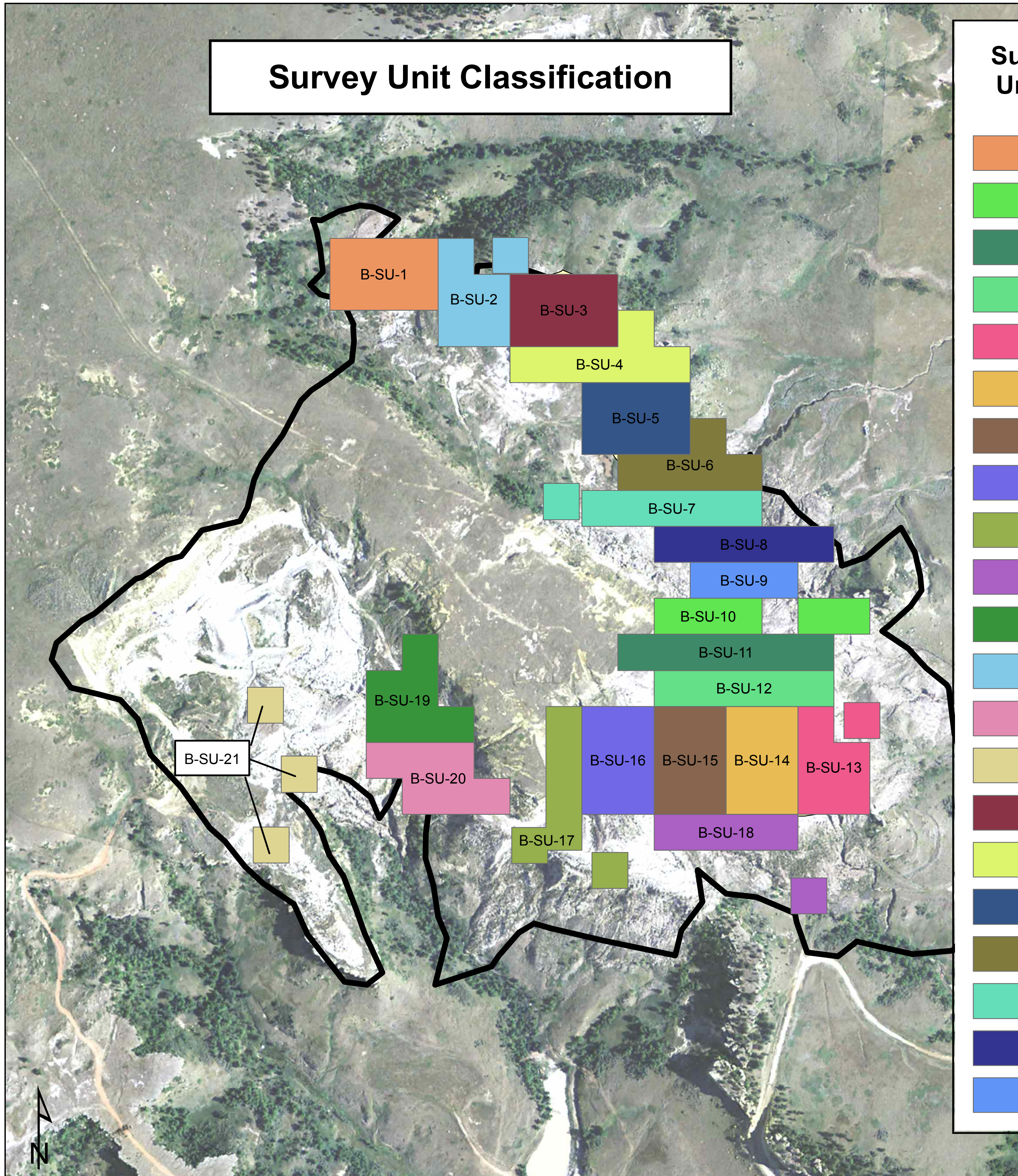
FIGURE 10 BLUFF B GRID BLOCK CLASSIFICATION AND IDENTIFICATION

Project Location: HARDING COUNTY, SD

Project no.: 114-560486A

Date of Issue: OCT 2015

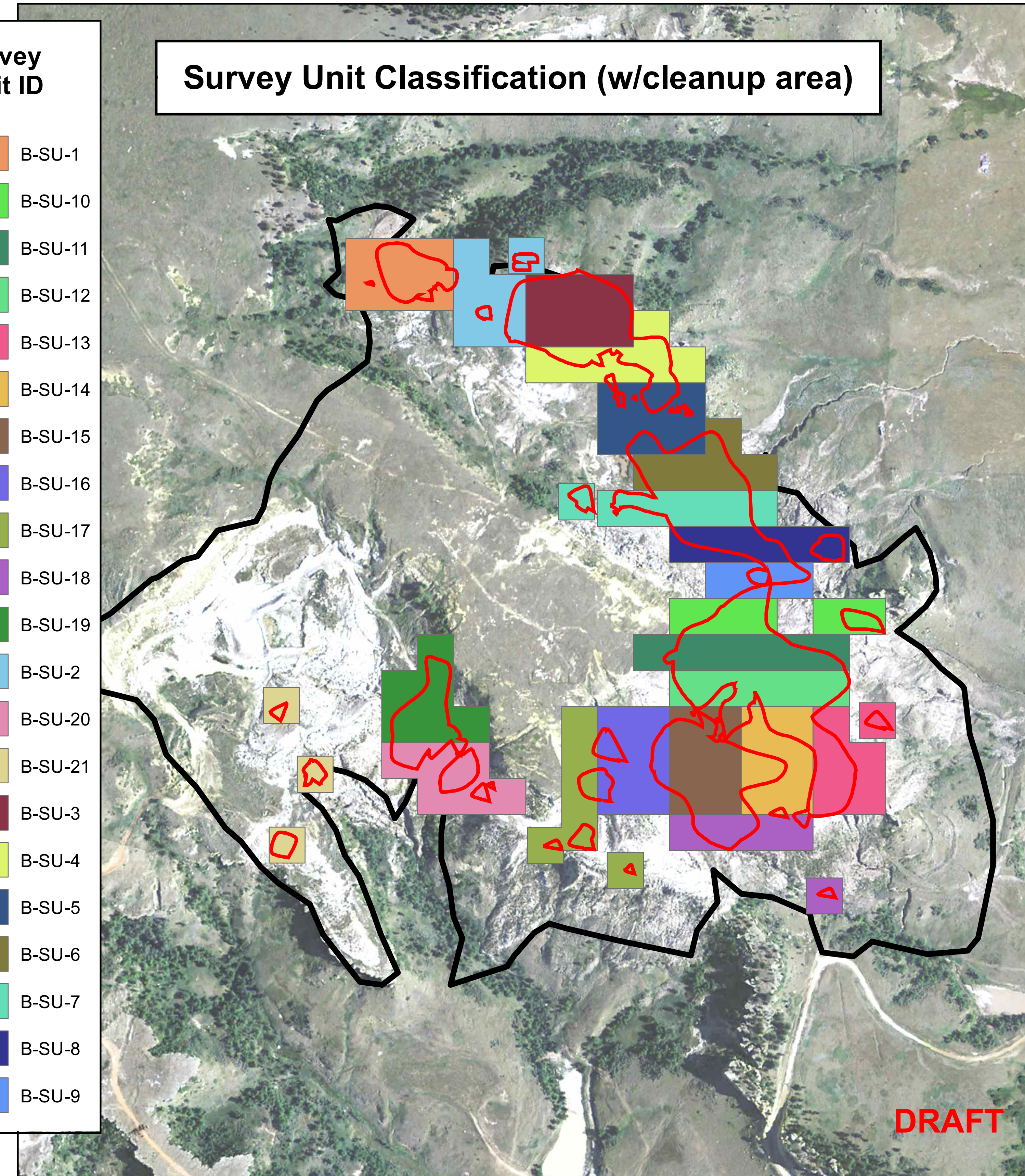
Survey Unit Classification



Survey Unit ID

- B-SU-1
- B-SU-10
- B-SU-11
- B-SU-12
- B-SU-13
- B-SU-14
- B-SU-15
- B-SU-16
- B-SU-17
- B-SU-18
- B-SU-19
- B-SU-2
- B-SU-20
- B-SU-21
- B-SU-3
- B-SU-4
- B-SU-5
- B-SU-6
- B-SU-7
- B-SU-8
- B-SU-9

Survey Unit Classification (w/cleanup area)



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SCALE IN FEET
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Study Area Boundary
Class 1 Area Boundary

Prepared For:

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Title:
FIGURE 11 BLUFF B SURVEY UNIT CLASSIFICATION MAP

Project Location: HARDING COUNTY, SD

Project no.: 114-560486A

Date of Issue: OCT 2015

7.4 SAMPLING FREQUENCY

A number of factors need to be considered in selecting the number of samples required during the cleanup verification surveys, including project budget, performance criteria and constraints, and resource-effective design. This subsection presents the sample size requirements for the XRF and gamma surveys and the soil confirmation sampling to be followed when performing the cleanup verification survey design at the Riley Pass site. The number of in situ measurements to be collected for each survey unit and the number of soil confirmation samples to be collected in each study area are presented in this subsection and compared with the required minimum number of samples for each statistical test.

7.4.1 In Situ Measurement Sample Size

The Sign test is the statistical procedure to be followed to evaluate the information collected from the XRF field and gamma radiation cleanup verification surveying. Procedures detailing the analysis required for establishing the number of samples based on the decision limits of a Type I and Type II error for the Sign test are presented in Section 6.1; the results of this analysis were based on the allowable decision errors for the Sign test (Type I and Type II error). The minimum number of required samples is 13 samples per survey unit.

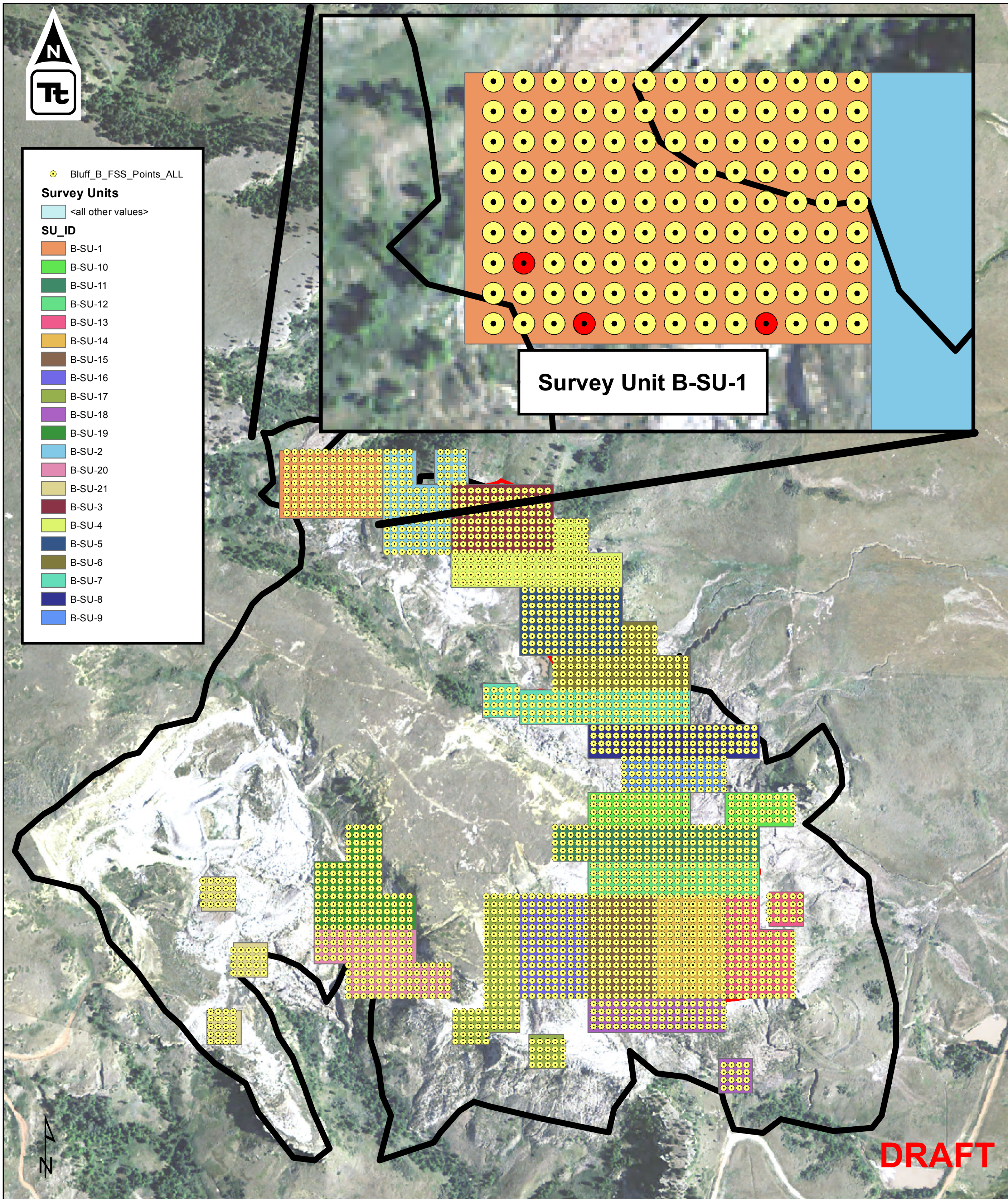
In addition to limits specified for the Type I and Type II decision errors presented in Section 3.6, decision error limits were also specified for hot spot locating techniques as described in Section 4.2. A systematic sampling approach of 10-meter by 10-meter square grid spacing within all the Class 1 survey unit areas is sufficient to provide the level of detail for the limits specified on decision error associated with detecting a circular hot spot of given size (12-meter diameter) for a given probability (95 percent). These decision error limits are necessary for determination of the minimum sample size required for the non-parametric Sign test. The sample size for the systematic approach is calculated below and compared with the requirements for the statistical test.

The maximum survey unit size for this project is 12,000 m^2. Equation 3 can be used to relate the systematic grid size with survey unit area to determine the number of samples per survey unit, where L is grid size in meters, A is survey unit size in m^2, and n is the number of samples per survey unit.

Equation 3 $$L = \sqrt{\frac{A}{n}}$$

$$\therefore n = \frac{A}{L^2} = \frac{12{,}000\ m^2}{100\ m^2} = 120$$

The minimum number of samples for a 12,000 m^2 survey unit using the systematic grid sampling approach is 120 samples. This number meets the requirements for the Sign test (13 samples) and satisfies the project objectives. Figure 12 provides an example of the grid based sampling locations proposed for Bluff B. This same procedure can be followed for all the study areas requiring cleanup verification surveys. The next subsection presents the minimum soil confirmation sample requirements compared with the statistical test requirements.



V:\T-Z\Tetra Tech Division\114-560486 - 2015 Riley Pass\120-GIS\MXD\Task 2 Figures\Figure 12 Survey Unit Sample Location.mxd June, 2015: aaron.orechwa

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NORTH_FIPS_4001_FEET

Study Area Boundary
Soil Confirmation Sample
In Situ XRF Measurement

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Title:

BLUFF B SURVEY UNIT DEVELOPMENT SAMPLE LOCATIONS

Location: HARDING COUNTY, SD

Project no.: 114-560486A

Date: JULY 2015

Figure: **Figure 12**

7.4.2 Soil Confirmation Sample Size

The statistical test selected for comparing laboratory-reported results of the soil confirmation samples is the determination of the 95 percent UCL of the mean and comparing it with the $DCGL_w$ for both arsenic and Ra-226 for each study area. The previous subsection showed that approximately 120 in situ measurements will be collected for a 12,000 m^2 survey unit. The frequency for collection of soil confirmation samples is 5 percent (1 in 20); therefore, a minimum of six soil confirmation samples will be collected for a 12,000 m^2 survey unit where 120 in situ XRF measurements are collected. The minimum number of samples to estimate the mean is 32 for arsenic and 19 for Ra-226, as shown in Section 6.2. Therefore, as long as the study area being verified has a minimum of six 12,000 m^2 survey units, the sample size requirements will be achieved. In the event that a study area does not have the sufficient number of in situ measurements, additional soil confirmation sampling will be required to achieve the minimum number of samples for the study area (39 for arsenic and 19 for Ra-226). Figure 12 shows the soil confirmation samples that will be collected at Bluff B following the methods presented in Appendix C.

8.0 QUALITY ASSURANCE AND QUALITY CONTROL

The cleanup verification field activities presented in this VSP consist of procedures to be used to collect large amounts of environmental data used in the regulatory decision making process for assessing attainment of the cleanup objectives for the Riley Pass site. For the decision makers (USFS) to have confidence in the quality of environmental data used to support these decisions, a structured process for quality must be in place (EPA 2001). All organizations conducting environmental programs funded by EPA are required to establish and implement a quality system (EPA 2001). Multiple sampling procedures have been presented in this VSP to meet the DQO requirements, each requiring specific technical and quality aspects for the environmental data collection operations.

The contractor selected for the cleanup verification surveys at Riley Pass will be required to develop an approved QAPP before the field activities can be conducted. Tetra Tech developed specific standard operating procedures (SOPs) including the associated QA/QC procedures for each field activity presented in this VSP. QA includes qualitative factors providing confidence in the results, while QC involves quantitative, field evidence supporting the validity of results. Tetra Tech uses data quality indicators as recommended in MARRSIM (NRC 2000) and MARLAP (NRC 2004) and developed the SOPs following EPA (2001) and EPA (2002b) to ensure the data being collected is of the highest quality and can be defendable. *Note: These documents were developed based on Tetra Tech-specific capabilities, but they can be used as a basis in the development of the final QAPP if a different contractor is selected to conduct the cleanup survey field activities.* The following documents are included as appendices:

- *Appendix A XRF Field Survey Standard Operating Procedures*
- *Appendix B Gamma Radiation Survey Standard Operating Procedures*
- *Appendix C Soil Sampling Standard Operating Procedures*
- *Appendix D Statistical Test Sample Size Determination ProUCL Outputs*

The quality system for the cleanup verification survey field activities is contained in detail in the appendices listed above. The information presented in these documents is the primary instrument for directing the QA effort for the project and for insuring the project DQOs are achieved.

9.0 REPORTING

Verification sampling procedures and results will be documented in a verification sampling report, following general guidance for Final Status Survey Reports found in MARSSIM. The verification sampling report will, at a minimum, contain the following information:

- A map showing the locations of XRF survey and gamma exposure rate scan data, and the results of the verification sampling for each survey unit.
- Tables of arsenic and Ra-226 concentrations within each survey unit, including, but not limited to, the individual survey results, measurement errors, detection limits, and sample depth.
- Summary statistics for analytical data, exposure rate scan data, and XRF measurement data from each survey unit.
- Summary statistics of soil confirmation sampling analytical data collected at each study area.
- Results of the Sign test and 95 percent UCL test for each survey unit and study area.
- QA/QC reports for each field activity, including copies of calibration documents.
- Scanned copy of the field logbook.
- Photographic log of verification sampling activities.

10.0 CONCLUSIONS

This VSP was prepared by Tetra Tech Inc. for the USFS under Task 2 of Contract GS-10F-0268K. This document is intended for use as guidance for the contractor responsible for conducting the cleanup verification surveys at the Riley Pass site after remedial action is complete. The *Data Quality Objective Process* was followed during the planning phase of this document to ensure the environmental data collected are adequate for the intended use — which is to provide a basis for measuring the success of the remedial objectives in a scientifically defensible manner. Risk-based cleanup criteria were verified in the 2015 Action Memorandum for the primary contaminants of concern for the site, which include arsenic and radium-226.

The primary goal of this VSP is to present a clear, cost-effective, defensible, and statistically sound approach to assessing whether the risk-based cleanup standards have been attained. The approach presented in this document followed the most recent guidance available from the EPA and NRC and are aimed at meeting the CERCLA requirements for assessing attainment of cleanup standards. The approach presented in this document was designed with the intent to allow for a phased cleanup verification approach in the event that the remedial actions are also performed in a phased approach.

A number of data collection and analysis designs were evaluated based on the results of the DQO process and other relevant site-specific information, including characterization information on contaminant deposition, past reclamation approaches, estimates of variance, and technical characteristics of the contaminants of concern. This document presents the sampling methods, statistical methods, and QA/QC procedures needed to conduct cleanup verification surveys at the Riley Pass site. A combined approach incorporating double sampling with a systematic grid-based sampling design was selected as the optimal method that balances cost and measurement performance for the Riley Pass site. The sampling methods presented are to be followed to verify attainment of the cleanup criteria for contaminants of concern established for surface soils. The methods presented in this report include XRF field surveys, gamma radiation surveys, and soil confirmation sampling. Additional subsurface investigations will be performed and will be directed by the USFS in the future.

During the planning process of this document, Tetra Tech erred on the side of conservatism wherever possible. If followed correctly, the data collected during the cleanup verification surveys will be of the highest quality and will ensure that the remedial action conducted at the site is protective of human health and the environment and meet CERCLA requirements.

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APPENDIX A

XRF FIELD SURVEY STANDARD OPERATING PROCEDURE

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1.0 SCOPE AND APPLICABILITY

The Riley Pass cleanup verification sampling plan (VSP) presented the results of the Data Quality Objectives (DQO) process, which identified three main field activities to be conducted at the site once the removal actions have been completed. These field activities include X-ray fluorescence (XRF) field surveys, gamma radiation surveys, and soil confirmation sampling.

This standard operating procedure (SOP) presents the sampling methods that will be followed during the XRF field surveys at the Riley Pass site, as outlined in the VSP. This SOP describes the procedures to be used at the Riley Pass site to analyze soil samples for concentrations of arsenic in soil using a Niton XRF analyzer. This SOP will be used in conjunction with the Niton XRF Manual. U.S. Environmental Protection Agency (EPA) Method 6200, "*Field Portable X-ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment*" (EPA 2007), will be used to analyze soil samples in situ using the XRF for verifying that the project cleanup objectives for arsenic in soils have been met. The cleanup level for arsenic in soil at the site is 142 milligrams per kilogram (mg/kg), which is equivalent to an XRF arsenic measurement of 105 parts per million (ppm) (Tetra Tech 2013). Any changes or modifications to these procedures will be documented by the field technician and approved by the project manager and the on-scene coordinator. This SOP also documents the quality assurance (QA) and quality control (QC) procedures that will be followed during XRF field surveys to assure that the results obtained are of the right type and quality needed and expected. Additionally, a section is included on the data quality and usability assessment to evaluate the data collection process and to ensure the project DQOs are achieved.

Generally, instrument precision is the least significant source of error in XRF analysis, and the operator- or application-related error is generally more significant and varies with each site and method used (EPA 2007). Some sources of interference can be minimized or controlled by the instrument operator, but others cannot. The methods and QA/QC program presented in this SOP are designed to reduce operator- or application-error whenever possible based on the recommendations from EPA Method 6200 and from the Niton User's Manual. This QA/QC program is designed to identify the greatest uncertainties and manage resources to control them, while allowing sufficient flexibility to adaptively manage quality control issues as they arise. To achieve this goal, there is a need for a qualified field and support team that can provide real-time data interpretation, troubleshooting, and feedback.

This SOP is intended specifically for the use of the Niton XL Series Analyzers and may not apply for all other XRF instruments from different manufacturers; however, in general, the principles and methods presented will apply to other XRF instrumentation. The following section presents the sampling methods for XRF field surveys at the Riley Pass site.

2.0 SAMPLING METHODS

This section presents the XRF field survey sampling methods that will be followed during the cleanup verification sampling at the Riley Pass site.

2.1 OVERVIEW

In situ XRF field surveys (*XRF field surveys*) have been shown to be an effective tool to measure concentrations of arsenic in soil at a definitive level at the Riley Pass site (Tetra Tech 2013). XRF field surveys will be performed in accordance with the sampling methods presented in this section using a portable Niton XRF spectrum analyzer (or equivalent) to meet the DQOs presented in the VSP. The source X-rays excite electrons in the sample (EPA 2007), dislodging electrons from atomic shells and creating vacancies. The vacancies are filled by the ray spectra as they cascade down to fill the inner shell vacancies. This process allows the XRF analyzer to identify elements present based on the unique spectra emitted and to estimate concentrations in soil based on emitted flux. Correlation between in situ XRF arsenic concentrations and (EPA Method 6020A) arsenic concentrations reported by the analytical laboratory has been developed for the site (Tetra Tech 2013). This correlation will be the primary method for estimating definitive concentrations of arsenic in the field and for verification purposes. Refer to Appendix C for the specific SOPs for soil confirmation sampling.

This SOP is to be used in supplement to EPA Method 6200 (EPA 2007), containing detailed instruction and guidance covering these procedures and corrective action to be taken based on instrument behavior and performance.

2.2 SAFETY PRECAUTIONS

The user will complete proper training for safe use of the instrument and radiation training before the instrument is used. Training will include participation in a formal training session by the Niton representative or by a field engineer already trained and familiar with safe XRF use. The field engineers will also refer to the operation manual for the XRF instrument for proper operation. The instrument user should also be aware of local, state, and national regulations that pertain to use and storage of radiation-producing equipment and radioactive materials. Compliance with all applicable regulations is required. When this procedure is used, minimize exposure to potential health hazards through the use of protective clothing, eye wear, and gloves. The operator should always be aware of the instrument's radioactive source and the direction of its beam of X-rays. The operator should never point the open source at anyone. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate.

Safety precautions, as specified by Niton, for use of the XRF instrument are as follows:

- Never point the XRF at yourself or others with the shutter open.
- Stand to the rear or side of the XRF when the shutter is open. Do not operate the instrument in a seated position; this position may expose your lower body to radiation.
- Do not fix the shutter in an open position (except in provided test stands).
- Do not leave the XRF unattended.

- Only trained personnel will operate an XRF.
- Open the shutter only with the sample in place.
- Never open the probe.
- Store the XRF in a safe place. Do not drop the machine (or put the instrument in a position where it will be likely to be dropped).
- Wear a dosimeter ring (if required by regulations).
- Perform wipe tests, per manufacturer's instructions.
- Women of child-bearing age should be aware of the potential damage to a developing fetus from radiation exposure.
- Transport XRF in a shock-proof case.
- Follow all manufacturer's training and instructions.

More detailed information and procedures are contained in EPA Method 6200, "Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment," Revision 0, February 2007.

2.3 Equipment and Materials

The following equipment materials are needed to conduct the XRF field survey:

1. Niton XL series XRF analyzer;
2. Global positioning system (GPS) device;
3. Logbook/field sheets;
4. National Institute for Standards and Technology (NIST) approved sample blanks and method blanks; and
5. Niton XRF stand.

2.4 Sampling Locations

XRF measurement locations will be collected at a 10-meter by 10-meter square grid spacing within the survey units that are designed for each study area, as described in the VSP. Before XRF surveying, the coordinates of each measurement location will be identified using a field-portable GPS unit with sub-meter accuracy. Locations may be adjusted in the field as necessary for access and to accommodate field conditions. The geospatial coordinates of the actual (adjusted) measurement locations will be recorded in the field logbook and with the GPS at the time of sampling. The coordinate system used in the field will be noted and included in the final verification sampling report, as described in the VSP.

2.5 Equipment Decontamination Procedures

The XRF analyzer window and protective Mylar film cover should be kept free of any particles of soil between measurements.

2.6 Pre-sampling Inspection

1. Inspect the sampling site and note any unusual conditions in the field logbook.
2. Take photographs to document sample site conditions and location.
3. Ensure that the soil moisture is between 5 percent and 20 percent. This measurement will require field judgment by based on geotechnical or soil engineering experience. Moisture content greater than 20 percent can affect performance, as high levels of moisture can absorb or reflect X-rays, resulting in bias.
4. Monitor the temperature and note any extreme temperature fluctuations that may require re-calibration of the XRF analyzer.

2.7 XRF In Situ Measurement Procedure

The following steps must be followed to perform the XRF field survey:

1. Properly store and charge the batteries for the XRF as described in the Niton User's Manual. Only an XRF with a full battery charge will be used for the XRF field surveys.
2. Turn on the analyzer by pressing the on/off/escape button on the control panel for approximately 10 seconds. The XRF Analyzer must be turned on 15 minutes prior to use in the field, as recommended by Niton.
3. Calibrate the touch screen by following the methods outlined in the Niton User Manual.
4. Before it is used the field, the instrument will be turned on and allowed to perform an internal calibration, which is done automatically as described in Section 4.1.2.
5. Once the instrument is calibrated, the field engineers will perform QC checks as described in Section 4.0 before field work begins. These include calibration checks of method blanks and standardized samples.
6. Select the proper mode on the instrument. For this project, the *Soil Mode* will be selected.
7. Attach the Niton test guard to the XRF analyzer.
8. Enter the field to the study area where the survey is to be performed.
9. Once at the desired sampling location, in situ XRF measurements are collected by first clearing the measurement location by removing any debris on the soil surface consisting of rocks, pebbles, leaves, vegetation, twigs, or roots and leveling the ground surface where the instrument window will be placed.
10. Level and smooth the soil surface with a stainless-steel or plastic trowel so that the probe window is in direct contact with the soil surface.
11. Lightly tamp the soil surface with the trowel to increase soil density and compactness. The soil should not be saturated or have a moisture content exceeding approximately 20 percent.

12. The Niton analyzer has a detachable Mylar film window that will be in place during in situ measurements, and care should be taken to keep this film clean between measurements.

13. Maintain the same distance between the window and each sample. The window of the probe should be in direct contact with the sample, which means that the sample should be flat and smooth to provide a good contact surface.

14. Once the location is prepared for in situ measurement, the XRF window is opened for a minimum of 60 seconds and the results of interest (arsenic) will be both saved within the device and recorded in the field logbook or in designated field sampling sheets.

15. The geospatial coordinates of the sample location will be recorded using a hand-help GPS or on the field logbook. Sample identification will follow the procedure in Section 2.8.

16. Once the XRF field survey activities have been completed for the day, the data will be removed using the USB port and Niton software as described in the Niton User's Manual, and the data will be entered into a project geodatabase by the lead field engineer.

17. After the data have been successfully been removed, the batter pack will be charged following the procedures in the Niton User's Manual.

18. Data post-processing involves conversion of the in situ arsenic measurements to definitive level concentrations of arsenic in soil, as described in Section 2.9.

2.8 SAMPLE IDENTIFICATION

Sample identification information will be entered into the XRF analyzer by field engineers and recorded in the field logbook. Sample identification should be done to ensure that post-processing of the data will be as simple as possible. Identifiers such as the study area or survey unit number will be used. An example for a recommended sample identification is as follows:

B-SU-1-1

Where:

B = Study area
SU-1 = Survey Unit #1
1 = Primary XRF measurement [2 = duplicate]

2.9 DATA POST-PROCESSING

Once the XRF field survey has been completed for a survey unit, the data must be post-processed to acquire definitive-level measurement data. The data post-processing for the cleanup verification survey involves conversion of the in situ XRF arsenic measurements into laboratory-equivalent arsenic concentration data. The DQO process presented in the VSP identified XRF field surveys will be performed to identify the concentrations of arsenic in surface soils to determine if the project cleanup goals have been achieved.

A strong correlation (R = 0.95, R^2 = 0.89) between in situ XRF arsenic concentrations and analytical laboratory (EPA Method 6020A)-reported concentrations of arsenic has been developed for the site (Tetra Tech 2013). This correlation will be the primary method for estimating arsenic concentrations in the field and for verification and is presented in Figure 1, below. An in situ XRF concentration of 105 ppm equates to the site's risk-based arsenic cleanup value of 142 mg/kg. The following equation can be used to convert the in situ XRF measurements to laboratory-equivalent concentrations of arsenic at the site after the XRF field survey has been completed:

Equation 1 $$Lab\ Arsenic\ = 10^{0.352+0.891 log_{10}(\text{XRF Arsenic})}$$

Where:

Lab arsenic = laboratory-reported arsenic concentration in surface soil (mg/kg).

XRF Arsenic = XRF measured arsenic concentration in surface soil (mg/kg).

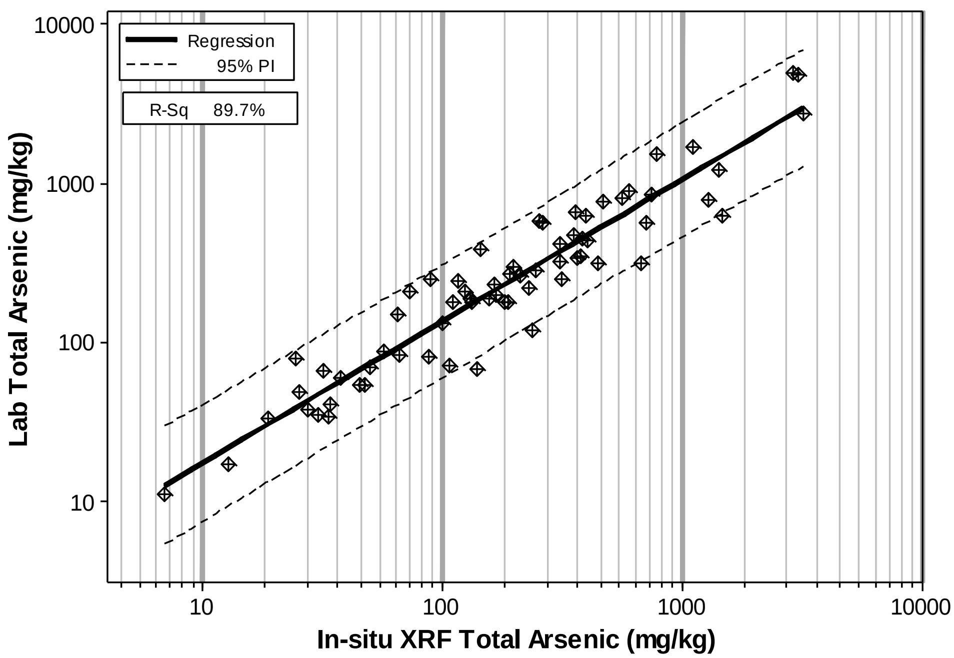

Figure 1 In Situ XRF Total Arsenic Concentration versus Laboratory-Reported Total Arsenic Concentration

3.0 QUALITY ASSURANCE AND QUALITY CONTROL

3.1 QUALITY ASSURANCE

The primary QA methods for the XRF include manufacturer recommend calibration and daily energy calibration checks as described below.

3.1.1 Calibration by Manufacturer

All XRF instrumented used at the project will be calibrated by the manufacture or at certified facility per manufacturer recommendations. The calibration documentation for each instrument will be included with the final verification sampling report.

3.1.2 Energy Calibration Check

An energy calibration check will be performed once daily by field engineers before any measurements will be initiated. The Niton analyzer will perform an internal re-calibration before any analysis is initiated following the methods outlined in the Niton User's Manual. The analyzer calibration screen will be displayed until calibration is complete. After the calibration has finished, the calibration results will be displayed. During operations, the ambient air temperature will be recorded for each measurement. If the ambient temperature changes by more than 10°F, the instrument will be recalibrated. Once the calibration has been completed, press the on/off/escape button or the Return icon to return to the Main Menu. The calibration results will be recorded in the field logbook. A copy of the field logbook will be included in the final verification sampling report.

3.2 QUALITY CONTROL

The primary QC methods for the XRF include the use of calibration checks, field duplicates, and precision measurements. All of these tools are critical for a good QC program for the XRF data to be used beyond a screening designation to more definitive uses, as is the case with this project. Calibration checks are performed by field engineers on a daily basis for a number of purposes (EPA 2008):

- They are used to identify whether the XRF unit is properly calibrated to measure unbiased measurements for the elements of concern in the range of concern.
- They are used over time to make sure the calibration stays constant.
- They can be used to identify and quantify potential interference effects.

Other QC methods include field duplicates and precision measurements that will be performed by field engineers in the field. The following operational and QC requirements also apply to operation of the XRF instrument and must be followed and documented in the field logbook maintained by the analyst.

3.2.1 Daily Calibration Checks

Calibration checks will be performed by field engineers before the XRF field survey is conducted each day. The daily calibration checks include method blanks and calibration verification checks. If the XRF instrument is rented, it is critical that appropriate NIST-traceable standard reference materials (SRMs) are provided by the rental institution. Additionally, blank silica/sand SRMs will also be required.

3.2.1.1 NIST Calibration Verification Checks

As part of the QC process for the field XRF instruments, soil standards from NIST-certified SRMs will be measured on a daily basis by field personnel and results compared with the provided arsenic reference values. The SRMs contain certified concentrations of arsenic in soil. Before each daily operational use period, the instrument will be turned on and allowed to perform an internal calibration, as described in Section 4.1.2. After this calibration, a performance check, using a minimum of one SRM that contains arsenic within the range of the site action level for arsenic (142 ppm), will be measured a minimum of 10 times. This check is done by measuring the SRM cup, removing the cup, and then placing it back for another measurement. Calibration verification checks will be performed with the XRF and SRM cup in the Niton test stand. These checks will be performed for each instrument to be used in the XRF field survey. The daily calibration check measurements will be documented in the field logbook and maintained in a control chart. A control chart is used to generate summary statistics for the arsenic calibration checks and will include the sample mean, the mean plus and minus one standard deviation of all QC checks, and the mean plus and minus two times the standard deviation of all the QC checks. The control chart will be a cumulative tool used to evaluate the data in real time and identify any discrepancies with the XRF instruments that are used in the field. An example of a control chart is provided in Figure 2, below.

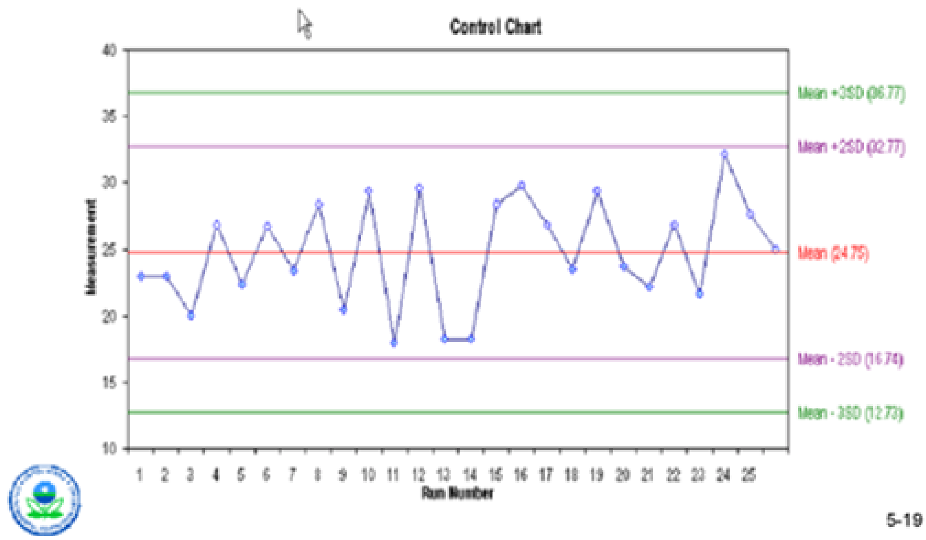

Figure 2 Example Control Chart for Calibration Checks (taken from EPA 2008)

The project QC acceptance criterion is that the percent difference (%D) between the XRF arsenic measurement and the arsenic value in the SRM should be less than 20 percent. If the calibration check %D is greater than 20 percent of the standard value, the operator will re-calibrate the instrument and re-analyze the standard. A method for calculating the %D is provided in Section 5.1.

3.2.1.2 Method Blanks

A method blank will be analyzed on a daily basis before the XRF field survey is initiated. The purpose of the method blank calibration check is to determine if contamination is entering the analytical procedure by verifying no contamination is on the analyzer window or other component that can be measured by the X-rays. A method blank will consist of a silicon dioxide blank provided with the analyzer; method blank measurements are to be performed with the XRF mounted in the Niton test stand. After the method blank calibration check is performed and it is confirmed that no contamination is present, the instrument is ready for analysis in the field. Field engineers will maintain records of all of the method blank calibration checks in the field logbook. A copy of the field logbook will be included in the final verification sampling report.

3.2.2 XRF Field Duplicate

One replicate samples will be collected for every 20 in situ XRF measurements collected in the field. It is recommended that the replicate sample be collected at the same locations where soil confirmation samples will be collected. The same method for measuring the primary XRF measurement is used to measure the XRF replicate measurement. The project QC acceptance criterion for XRF duplicate analysis is 50 percent relative percent difference (RPD) for this project. The method for calculating the RPD is presented in Section 5.3. The primary and replicate arsenic measurements will be recorded in the field logbook. A copy of the field logbook will be included in the final verification sampling report.

3.2.3 Precision Measurements

A precision measurement will be performed at a minimum of once per day for each instrument in use, which involves measurement of one sample location a minimum of seven times in replicate. The project QC acceptance criterion for precision measurement is that the relative standard deviation (RSD) must be less than 20 percent. The method for calculating the RSD is presented in Section 5.4. The precision measurements collected in the field will be recorded by the field engineer in the field logbook.

4.0 DATA QUALITY AND USABILITY ASSESSMENT

This section presents the data quality and data usability assessment procedures that will be followed to evaluate the quantitative results of the QC procedures described in Section 4.0. The project acceptance criterion is presented for each QC procedure.

4.1 NIST CALIBRATION CHECKS

NIST calibration checks will be performed following the methods presented in Section 4.2.1.1. The NIST soil cups will include a soil sample with a known concentration of arsenic. These checks will be performed once daily prior to field operations. The %D will be calculated for each NIST soil cup for each instrument. The following equation will be used to evaluate the %D:

$$\%D = \frac{|C_s - C_k|}{C_k} \times 100$$

Where:

%D = percent difference
C_k = known arsenic concentration
C_s = XRF determined arsenic concentration (mean of 10 measurements)

The project acceptance criterion is that the %D should be no greater than 20 percent. If the calibration check sample test reveals discrepancies in the reading, then the instrument will be re-calibrated. If the problem persists, the XRF may need to be sent to the manufacturer for inspection and repair. The results of the NIST calibration check measurements and the %D analysis will be included in the verification sampling report.

4.2 METHOD BLANKS

Method blanks will be analyzed once per day following the methods described in Section 4.2.1.2. The project acceptance criterion for evaluation of method blanks is that no concentrations of elemental arsenic above the established lower limit of detection should be in found in the instrument or method blank. If the method blanks test reveals discrepancies in the reading, then the instrument will be re-calibrated. If the problem persists, the XRF may need to be sent to the manufacturer for inspection and repair. The results of the method blank measurements will be included in the verification sampling report.

4.3 FIELD DUPLICATES

Field duplicates will be performed at a frequency of 5 percent (1 in 20) following the methods described in Section 4.2.2. The equation for calculating the RPD is as follows:

$$RPD = \frac{|S - D|}{\frac{(S + D)}{2}} \times 100$$

Where:

RPD = relative percent difference, non-detects are excluded

S = arsenic concentration of primary XRF measurement
D = arsenic concentration of duplicate XRF measurement

The project acceptance criterion for field duplicates is that the RPD between the primary result and the duplicate result will be no greater than 50 percent. If the field duplicate analysis reveals discrepancies in the reading, then the instrument will be re-calibrated. If the problem persists, the XRF may need to be sent to the manufacturer for inspection and repair. The results of the field duplicate measurements and the RPD analysis will be included in the final verification sampling report.

4.4 PRECISION MEASUREMENT

Precision measurements will be performed at least once daily per instrument during the XRF field surveys, as described in Section 4.2.3. Each precision sample will be involve a minimum of seven measurements in replicate to be conducted in the field. The RSD of the sample mean is used to assess method precision. The RSD should not be greater than 20 percent for XRF data to be considered adequately precise. Only in situ measurements will be collected for this project. The equation for calculating RSD is as follows:

$$RSD = \frac{\sigma}{\mu} \times 100$$

Where:

RSD = relative standard deviation for the precision measurement for the analyte (arsenic)
σ = standard deviation of the concentration for the analyte (arsenic)
μ = mean concentration for the analyte (arsenic)

The project acceptance criterion for precision measurements is that the RSD should not be greater than 20 percent. If the precision measurements reveal discrepancies in the readings, then the instrument will be re-calibrated. If the problem persists, the XRF may need to be sent to the manufacturer for inspection and repair. In the event that the XRF instrument does not meet the project acceptance criterion, then the data will be considered invalid and will be flagged. The instrument may need to be shipped to the manufacturer or certified repair facility for inspection. The results of the precision measurements and the RSD analysis will be included in the final verification sampling report.

5.0 RECORDS

Documenting scanning results and observations from the field is important (NRC 2000). XRF field surveys will be recorded as follows:

- All in situ XRF measurements will be recorded in the field logbook.
- Photographs will be collected in the field as deemed necessary by the lead field engineer.
- XRF field surveys will be documented in writing. The person performing the survey is responsible for correct and accurate documentation of survey data.
- XRF field surveys will be documented as they are performed whenever possible in a clear and legible manner using black or blue ink.
- Survey points or sample locations must be indicated, as applicable, and the associated measurements recorded. Sufficient detail must be provided to adequately describe each specific area surveyed.
- Quality control records will be included with the survey records in the field logbook.
- A copy of the field logbook will be included in the final verification sampling report.

6.0 REFERENCES

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APPENDIX B

GAMMA RADIATION SURVEY STANDARD OPERATING PROCEDURE

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LIST OF FIGURES

1.0 SCOPE AND APPLICABILITY

The Riley Pass cleanup verification sampling plan (VSP) presented the results of the Data Quality Objectives (DQO) process, which identified three main field activities to be conducted at the site once the removal actions have been completed at the site. These field activities include X-ray fluorescence (XRF) field surveys, gamma radiation surveys, and soil confirmation sampling.

This standard operating procedure (SOP) presents the sampling protocol and methods that will be followed for performing a continuous mobile gamma radiation survey (gamma survey) as part of the Riley Pass cleanup verification surveys, as outlined in the VSP. This SOP describes the procedures to be used at the Riley Pass site to estimate the radium-226 (Ra-226) concentrations in soil using continuous logging global positioning system (GPS)-based mobile gamma radiation detectors for verifying that the project cleanup objectives for Ra-226 in soils have been met. The soil Ra-226 cleanup level for the site is 30 picocuries per gram (pCi/g), which is equivalent to a gamma exposure rate of 76.5 microroentgens per hour (μR/hr) (Tetra Tech 2013). Any changes or modifications to these procedures will be documented by the field technician and approved by the project manager and the on-scene coordinator.

The methods presented in this document include equipment operation, survey techniques, and the quality assurance (QA) and quality control (QC) procedures that will be followed when conducting gamma surveys to assure that the results obtained are of the right type and quality needed and expected. Additionally, a section is included on the data quality and usability assessment to evaluate the data collection process and to ensure the project DQOs are achieved. This SOP is intended to document planning results for the gamma survey operations and to provide a project-specific “blueprint” for obtaining the type and quality of environmental data needed for cleanup verification surveys at Riley Pass. This document was generated to ensure that the data collected during the gamma survey process are of the highest quality, are defensible, and meet the project DQOs. The key documents used in the development of this SOP include the following:

- *EPA Requirements for Quality Assurance Project Plans (EPA 2001)*
- *EPA Guidance for Quality Assurance Project Plans (EPA 2002)*
- *Multi-Agency Radiation Survey and Site Investigation Manual [MARSSIM] (NRC 2000)*
- *Multi-Agency Radiological Laboratory Analytical Protocols Manual [MARLAP] (NRC 2004)*

The following section presents the sampling methods for conducting gamma surveys at the Riley Pass site.

2.0 SAMPLING METHOD

This section presents the gamma survey sampling methods that will be followed during the cleanup verification sampling at the Riley Pass site.

2.1 OVERVIEW

Gamma radiation surveys have been shown to be particularly effective at identifying the spatial extent and predicting the concentrations of radionuclides in surface soils at the Riley Pass site, specifically in predicting Ra-226 concentrations in soil. Use of GPS-based gamma radiation survey systems has become a mature methodology for characterizing the distribution of gamma radiation caused by naturally occurring radioactive materials (NORM) in soils (Whicker 2015). Previous site-specific studies (MSE 2009; Tetra Tech 2013) have shown there is a direct correlation between gamma exposure rate (µR/hr) and Ra-226 (pCi/g) for all of the study areas at the Riley Pass site. Gamma radiation surveys will be performed through systematic walkovers with a detector height of 1 meter above the ground surface within the Class 1 areas after remedial action has been completed.

The primary objective of gamma radiation survey for this project is to generate enough data points that can used to sufficiently estimate 100 square meter (m^2) grid block averages of the Ra-226 concentration in soil within each survey unit. A 100 percent scanning density of all Class 1 survey units will be performed after remedial activities have been completed, as described in the VSP, to achieve this objective. The 100 percent scanning density is achieved using a transect width of 2-meter spacing traversed in a parallel fashion from north to south. The risk-based cleanup criterion for Ra-226 at the site is 30 pCi/g, and the detection sensitivity of a 2 inch by 2 inch sodium iodide (NaI) detector for Ra-226 is 2.8 pCi/g; therefore, the instruments specified in the VSP have sufficient detection sensitivities to detect the Ra-226 at concentrations well below and above the action level.

The following subsection presents the equipment and materials needed to conduct the gamma radiation surveys as part of the cleanup verification process.

2.2 EQUIPMENT AND MATERIALS

The following equipment and materials are required, at a minimum, to successfully complete the gamma radiation surveys at the Riley Pass site:

(1) USB compatible laptop or mobile computer installed with Tetra Tech *ScanSystem* software, *GammaViewer* software (Tetra Tech 2006) and a global mapping software.

(1) Standard backpack or ATV (shown on Figure 1)

(2) *USGlobalSat* GPS Receiver with USB Interface (or equivalent)

(1) Ludlum 44-10 NaI scintillation detector (shown in Figure 2)

(1) Ludlum 2350-1 data logger (shown in Figure 2)

(1) 4 port USB hub

(1) 3-foot Ludlum coaxial cable

(1) RS232 Serial to USB Converter

(1) Ludlum RS232 data cable

Figure 1 Mobile GPS Integrated Gamma Survey System – Backpack (left) and ATV (right)

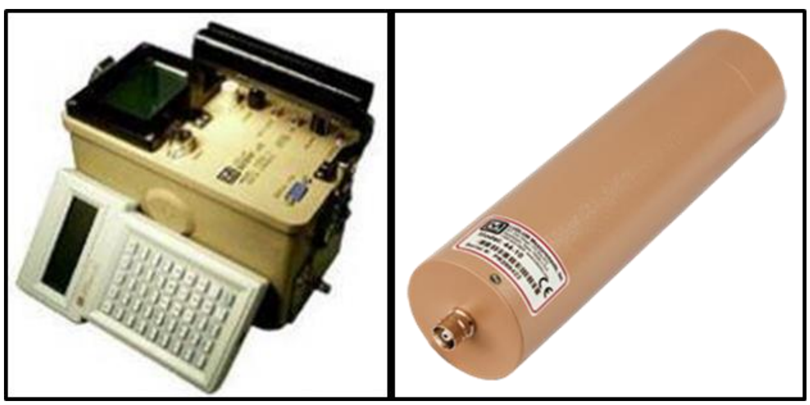

Figure 2 Ludlum 2350-1 Data Logger (left) and Ludlum 44-10 NaI Scintillator

2.3 Backpack and System Setup

Ensure the 2350-1 data logger has sufficient battery voltage, which is defined as greater than 5.6 volts (V). If there is less than 5.6V, place four new D-size batteries correctly without allowing the battery to drop directly into the battery compartment. Connect the RS232 serial converter to the RS232 port on the Ludlum 2350-1 datalogger. Connect GPS receivers and the serial converter to the 4-port USB hub and connect the USB hub to field computer. Open “Device Manager” and note which COMM ports have been assigned to the USB devices.

2.4 SCANSYSTEM SOFTWARE OPERATIONS

A scanning software is needed to collect simultaneous gamma exposure rate measurements and GPS points. Tetra Tech recommends using *ScanSystem* software, a proprietary software developed by Tetra Tech (Tetra Tech 2006). ScanSystem software will be used to record simultaneous GPS location data and gamma exposure rate date. When the program is first launched, click the "Configure" button, then the "Disable Ports" function. Assign the correct COMM port ID to the Rad and GPS locations. Select "Enable Ports" and close the window. Next click "Start GPS". Both GPS and gamma exposure rate data should now be displayed in real time on the ScanSystem main screen. A screenshot showing ScanSystem menu is shown in Figure 3.

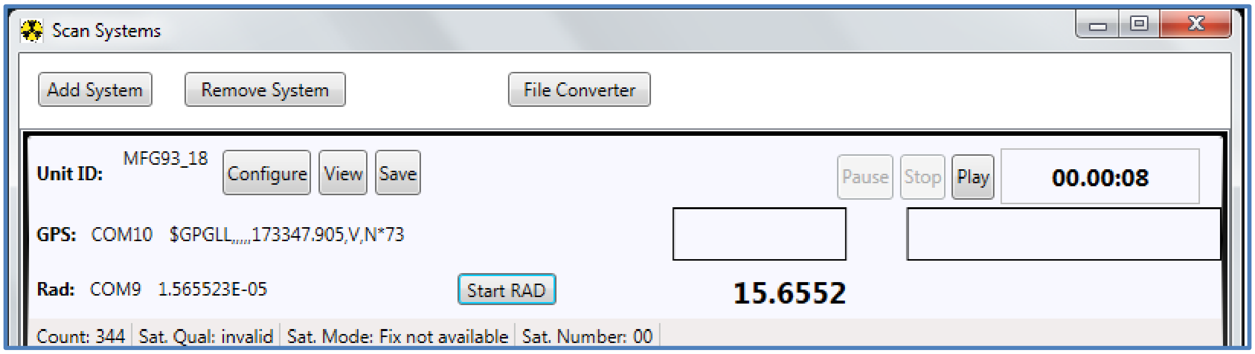

Figure 3 ScanSystem GUI Screenshot

Click the "Play" button to log data. The software will ask if previous data are to be overwritten (Figure 4). To save data, click "Stop" then the "Save" icon, select a directory, and name the text file. Warning: if you select "Overwrite Data" by mistake, you should save a new file with a different name to avoid erasing the existing scan data file.

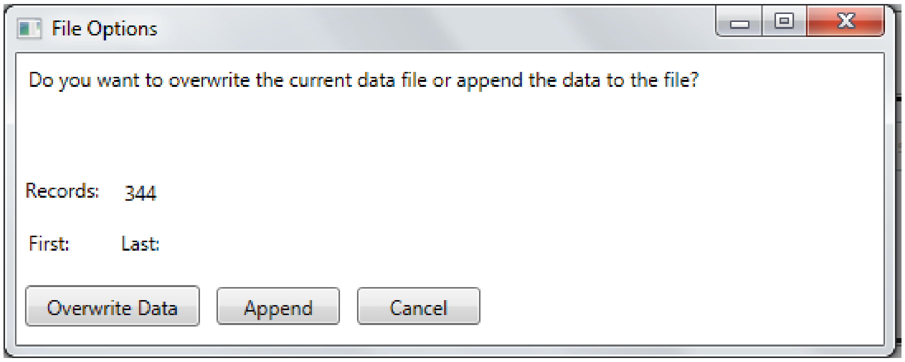

Figure 4 Screenshot of GUI Interface (overwrite screen)

Text file names should include the detector ID, date and time, and project identification (ID). The software will ask if current data are to be cleared from the application at this point (Figure 5). If you will continue scanning for the day, do not clear the application. Clear the application only at the beginning of a new scanning day. If you do clear the application by mistake, just save a new file and continue to append to the new file.

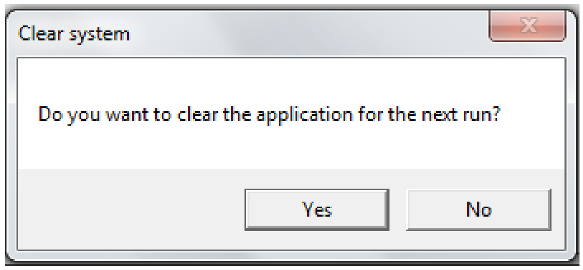

Figure 5 Screenshot of GUI Interface (clear screen)

2.5 Mapping Software

Tetra Tech recommends that field engineers use a mapping software to visually guide operators over the pre-defined survey path. It displays current location overlaid on shapefiles. Shapefiles, as long as properly projected, are supported with different software types. WGS84 datum is preferred to avoid confusion. It is recommended to use mapping software with pre-entered transect lines, to be viewed on a laptop or hand-held GPS device.

2.6 Scan Process

The gamma detector will be positioned at a height of approximately 1 meter above ground surface, whether backpack or ATV mounted. The detector "sees" gamma radiation with relatively good efficiency from a circular area with a radius of approximately 1 meter when held at a height of 1 meter. The following procedures will be followed to successfully perform the gamma radiation survey and meet the project DQOs:

- Scanning will be conducted by traversing the survey unit at a rate of approximately 1 meter per second.
- The scan transects will be approximately 2 meters apart for the 100 percent coverage required to meet the DQOs.
- Data will be downloaded in gamma viewer at least once per day and the map checked to make sure the required coverage is attained.
- As necessary, additional transects will be surveyed to attain the coverage required to meet the project DQOs.
- QA/QC procedures will be followed according to Section 4.0.
- Data post-processing will be performed in accordance with Section 3.7.
- Survey records will be collected and maintained in accordance with Section 3.8.

Care must be taken during scanning to prevent slips, trips, and falls as well as contact with biological hazards such as snakes and insects.

2.7 Data Post-Processing

Once a gamma radiation survey is completed for a survey unit, the data must be post-processed. The data post-processing for the cleanup verification survey will first involve conversion of the gamma exposure rate data into Ra-226 soil concentration data using an established site-specific correlation between gamma exposure rate (µR/hr) and soil Ra-226 (pCi/g), as described in Section 3.7.1. The second data post-processing step involves geospatial interpolation of the converted data sets to generate a 10-meter by 10-meter grid block averaged Ra-226 concentrations in soil across the survey unit, as described in Section 3.7.2.

2.7.1 Soil Correlation

The DQO process presented in the VSP identified gamma radiation surveys will be used to provide information on the Ra-226 concentrations of surface soils within surveys units and to determine if these values meet the project cleanup objectives. The purpose of the gamma radiation survey is to collect gamma exposure rate measurements within each survey unit after the remedial action is completed. Each gamma exposure rate data (µR/hr) point can then be converted into an equivalent Ra-226 concentration (pCi/g) in soil using a site-specific regression model that was developed in Tetra Tech (2013), as shown in Figure 6.

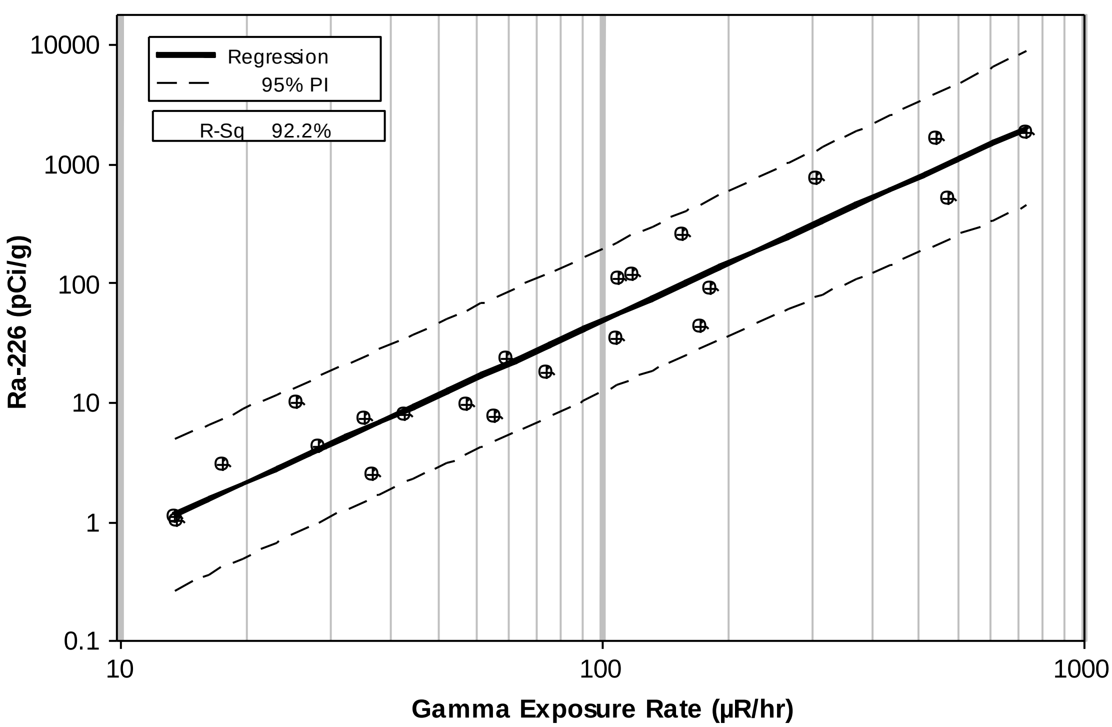

Figure 6 Gamma Exposure Rate versus Soil Ra-226 Mass Activity Concentration

A strong correlation (R = 0.96, R2 = 0.92) was established between gamma exposure rate and the Ra-226 concentration in soil. The following equation will be used to convert the gamma exposure rate measurements collected at the site to laboratory-equivalent Ra-226 concentrations in soil:

Equation 1 $$\text{Lab Ra} - 226 = 10^{-1.979+1.835\ log_{10}(Gamma)}$$

Where:

Lab Ra-226 = Laboratory-equivalent soil radium-226 concentration (pCi/g).

Gamma = Gamma exposure rate measurement (µR/hr).

Using Equation 1, a gamma exposure rate of 76.5 µR/hr corresponds to a laboratory-reported Ra-226 concentration in soil of 30 pCi/g. After the gamma data are converted into Ra-226 concentrations in soil, a geospatial interpolation analysis will be performed as described in the following subsection.

2.7.2 Geospatial Analysis

A large number of data points are collected during the gamma radiation surveys, allowing for an accurate geospatial analysis to obtain 100 m^2 grid-blocked averaged Ra-226 concentrations in soil within the area that is surveyed. The data collected in each survey unit are at a 100 percent scan coverage (2-meter transect width), allowing for a large number of data points to be geospatially interpolated into grid-blocked averaged measurements. After the interpolation is completed, 100 m^2 grid-blocked averaged data points will be evaluated using the Sign test as described in the VSP. The following step-by-step procedures will be followed using ArcGIS 10.1 (or equivalent) and will be performed by a qualified geostatistician or engineer familiar with geospatial interpolation methods:

Geospatial Interpolation Procedure:

1. Import the converted Ra-226 shapefile data for the survey of interest.
2. Select *Geostatistical Analyst* → *Geostatistical Wizard.*
3. Determine which method you will use: (1) *Deterministic,* or (2) *Geostatistical*
4. Select *Dataset* and *Data Field* of interest for interpolation. Click *Next.*
5. Select *Use Maximum* for handling of coincidental samples. Select *OK.*
6. Select *Method Properties* (general properties, search neighborhood, or other parameter). Click *Next.*
7. Note the *Prediction Errors* in a spreadsheet for use in comparative analysis table. Select *Finish.*
8. Right click on the resulting geostatistical layer, and select *Properties*, change the *Layer Name* to the Scenario of your choice (such as Scenario A).
9. Perform a sensitivity analysis for each method by changing the model parameters.
10. Repeat these steps for a number of method types and generate multiple scenarios.

After each model run, perform a data validation analysis to compare the predicted values with the measured values as follows.

Data Validation and Optimal Model Selection Procedure:

1. Right click on the geostatistical layer of interest, *Data* → *Export to Raster,* choose desired output cell size for the map unit (for example, 32.8 feet) and output raster location and name.
2. Select *Environments* → *Raster Analysis* → *Mask*, select the desired *Mask* (survey unit boundary layer). Click OK. Click OK.
3. Select the resulting raster file. Select *Conversion Tools in ArcToolbox* → *From Raster* → *Raster to Point,* select *Input Raster* of choice.
4. Select the Ra-226 shapefile data set that represents the points that are contained within the study area boundary. Right-click and select → *Joins and Related* → *Joins and select* "Join data from another layer based on spatial location," choose raster points data as (1), for (2) select bottom bubble option (select closest point). Click OK.
5. Select the "Join_Output" shapefile that was created from Step 2, and export this database for analysis. Open *Attribute Table* of the Join table and export data into a *dBASE Table*.
6. Perform desired statistical analysis by qualified geostatistician or engineer.
7. Select the scenario and method that best fit the original data set; this step requires knowledge of geospatial mapping techniques. The optimal method will have a combination of the highest data validation correlation and minimized error and variance of the interpolated surface.
8. Once an optimal method is selected, export the final raster into a point file with 10-meter cell size.
9. Select the optimal model using the criteria described above. This model will be the final Ra-226 100 m^2 grid block averaged data set for the survey unit. Apply the Sign test using ProUCL as described in the VSP.

2.8 Survey Records

Documenting scanning results and observations from the field is very important (NRC 2000). Survey documentation will involve the following:

- Survey information will be recorded in the field logbook in a clear and legible manner using black or blue ink by field personnel. The person performing the survey is responsible for correct and accurate documentation of survey data.

- Survey information will include daily instrument QC field check data, location and possible reasoning for radiation anomalies (such as extreme events), weather conditions, photographs, GPS of soil sample locations, survey unit being evaluated, date, time, and any other information that is pertinent to the project DQOs.

3.0 QUALITY ASSURANCE AND QUALITY CONTROL

All radiological characterization projects conducted by Tetra Tech incorporate specific data QA/QC procedures. In general, QA includes qualitative factors that provide confidence in the results, while QC involves quantitative, field evidence that supports the validity of results. Tetra Tech utilizes QA/QC methods as data quality indicators that are outlined in NRC (2000). The QA/QC survey procedures used by Tetra Tech are industry-accepted techniques that ensure the data collected are of the highest quality and reliability.

3.1 QUALITY ASSURANCE

An important QA protocol includes instrument calibration. All of the radiation detection equipment employed during the field work must be factory calibrated within the past 12 months. Data developed using any of the field-qualified instruments are then interchangeable, allowing instruments to be substituted if needed. Under the QA program, factory-calibrated instruments must also meet on-site field test criteria. Calibration refers to the determination and adjustment of the instrument response in a particular radiation field of known intensity (NRC 2000). Calibration of all radiation detection equipment is the primary method for QA that is used to ensure the data collected are of high quality and are reliable. All instruments used during radiological projects will be factory calibrated within 12 months per the manufacturer's recommendation. Scanned copies of calibration documentation for all instruments will be included with the cleanup verification survey report.

3.2 QUALITY CONTROL

Calibration checks are measurements to verify instrument performance repeated each time an instrument is used (NRC 2000); these checks are quantitative and are to be performed in the field by trained field engineers. The primary QC method for the gamma radiation survey involves calibration checks. These checks are measurements performed for each instrument that is used during the gamma survey. The specified protocol used on this project involves quantitative calibration checks measuring background radiation as well as a known radioisotope source. The QC calibration checks that will be performed as part of the cleanup verification survey include:

- **Pre-survey and Post-survey Calibration Checks:** Pre-survey and post-survey background and check source QC measurements will be performed at a designated location off site before and within 1 week after the conclusion of the gamma survey.

- **Daily Calibration Checks:** Background check, field strip check, and cesium-137 (Cs-137) source check measurements will be conducted twice daily. These measurements will be collected on site at a designated background location selected by the lead field engineer.

The following subsections describe both of these QC procedures that will be followed during the cleanup verification gamma radiation surveys.

3.2.1 Pre-Survey and Post-Survey QC Calibration Checks

The first gamma survey QC procedure involves pre-survey and post-survey QC calibration checks. The purpose of the pre-survey and post-survey QC protocol is to quantify the consistency of readings among the various detection systems and to ensure the instruments are working properly during a survey. These surveys will be performed at a designated indoor location for each detector that may be used during the gamma survey. The pre-survey and post-survey calibration checks consist of collecting a minimum of 1,000 background and 1,000 Cs-137 source check static measurements collected at a static location. The summary statistics of these measurements will be assessed as described in Section 5.1.

3.2.2 Daily QC Calibration Checks

Each day before the gamma radiation survey, instrument comparison QC measurements will be collected for all NaI detectors potentially used to survey the site. These QC calibration checks include background checks, field strip checks, and Cs-137 source checks. These measurements will be collected twice daily – before the gamma survey is initiated and at the conclusion of the survey for the day. Descriptions of each daily QC measurement procedure are as follows:

1. Background check measurements are collected at a location in the vicinity of the site consistent with the background gamma radiation for the site. A minimum of 10 background measurements will be collected during each QC check.

2. Field strip check measurements will be collected by scanning in a 10-meter line outward from the background measurement location. A minimum of 10 measurements will be collected along the field strip check transect. The daily field strip check provides an indication of total measurement uncertainty from turbulent movement for each mobile system being used in the field. The same field strip will be used throughout the project.

3. Source check measurements will be collected at the same location as the background check measurement location by holding a Cs-137 source to the detector and performing a 60-second average analysis using the scanning software.

The daily QC calibration checks will be performed at the same outdoor each day during the survey if possible. If for some reason the location changes, the reason will be noted in the field logbook. The GPS coordinates of the location and the QC measurements will be recorded in the field logbook. The data will be compiled and analyzed each day following the methods outlined in Section 5.2.

4.0 DATA QUALITY ASSESSMENT AND DATA USABILITY

The data quality assessment (DQA) process, is the final process of the overall data assessment of a project and is intended to evaluate the suitability of project data to answer the underlying project questions or the suitability of project data to support the project decisions (NRC 2004). EPA (2001) defines DQA as a statistical and scientific evaluation of the data set to assess the validity and performance of the data collection design and statistical test and to determine the adequacy of the data set for its intended use. Data usability is the process of ensuring or determining whether the quality of data produced meets the intended use of the data (EPA 2001). The DQA and data usability process as it is applied to the gamma radiation survey is intended to ensure the data collected meet the DQOs and are statistically and scientifically defensible. Under the QC program, the factory-calibrated instruments must meet on-site field test criteria described below. This section presents the DQA and data usability methods used to evaluate the results of the quantitative measurements collected as part of the QC program and to assure the data collected during the gamma radiation surveys are usable, high quality, defensible, and meet the project DQOs.

4.1 PRE-SURVEY AND POST-SURVEY QC CALIBRATION CHECKS

Pre-survey and post-survey QC calibration check procedures are described in Section 4.2.1 and will be collected at an indoor location for each NaI detector that may be used during the gamma radiation survey. The data collected during the pre-survey and post-survey will be analyzed and compared with each other. A minimum of 1,000 background measurements and 1,000 Cs-137 source check measurements will be collected during the pre-survey and the post-surveys. The data will be compiled into probability plots and frequency histograms using the Minitab 16.0 statistical software (or equivalent). An example of the probability plot and histogram analysis is shown in Figure 7 and Figure 8.

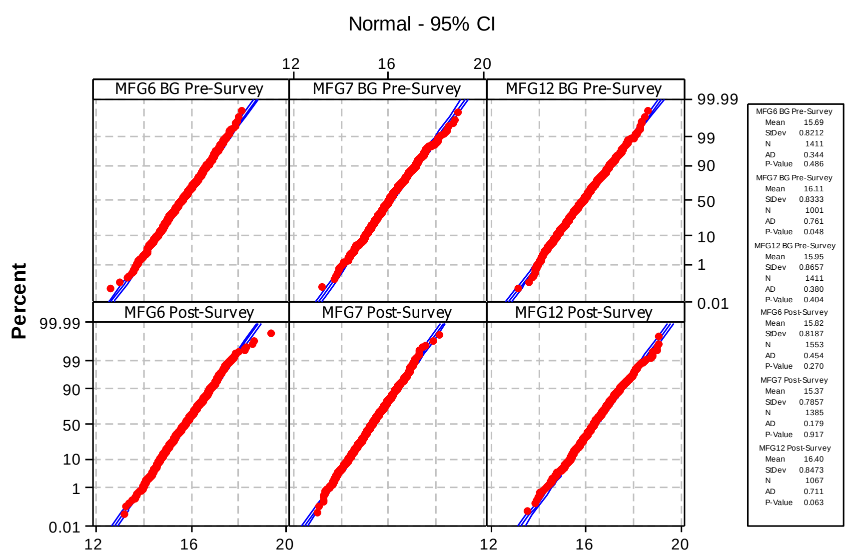

Figure 7 Example of Probability Plot Comparisons

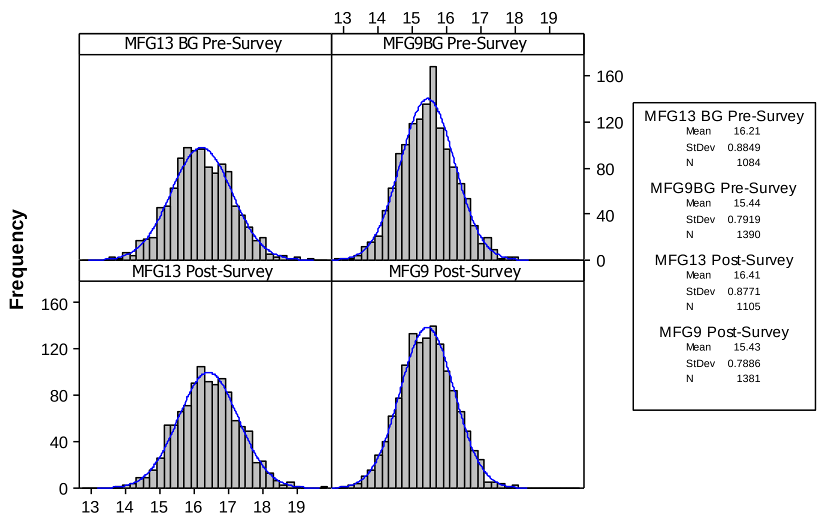

Figure 8 Example of Frequency Histogram Comparisons

These statistical plots are used to evaluate the normality of the pre-survey and post-survey data sets. The data collected from both surveys should be normally distributed. In general, Minitab provides an Anderson Darling (AD) value and a p-value. The p-value should be greater than 0.05 for the data to be considered normal. The lower the AD value, the more normally distributed the data are. Probability plots can also be used to assess the normality of the data sets. If the data do not follow a normal distribution, further investigation is warranted, and the data collected for that particular instrument will be flagged and subsequently removed from the final project database. In addition to assessing normality of the pre-survey and post-survey data sets, further comparisons are made to ensure the data collected from each instrument are valid. The following criteria must be met for the data from the instrument to be used:

- The mean, median, standard deviation, and 95th percentile of the gamma exposure rate measurements (background and Cs-137 source checks) will be calculated for the pre-survey and post-survey data sets for each instrument used in the field.
- The relative percent difference (RPD) will calculated for each of these parameters as follows:

$$RPD(\%) = \frac{|PRE - POST|}{\frac{(PRE + POST)}{2}} \times 100$$

where:

RPD = Relative percent difference

PRE = Pre-survey QC measurement (mean, median, standard deviation, or 95th percentile)

POST = Post-survey QC measurement (mean, median, standard deviation, or 95th percentile)

The project QC acceptance criterion for this project is that the RPD must be less than 10 percent for all of these parameters for the data to be used by that particular instrument. Further investigation is required if the RPD is greater than 10 percent, and the data collected from that particular instrument will be removed from the final project database. If the data fall within the 10 percent range, they will be considered valid and included in the final project database.

4.2 Daily QC Calibration Checks

Daily QC calibration check procedures are described in Section 4.2.2 and will be collected at a designated background location before and after gamma surveys are performed in the field. Calibration check results will be plotted daily on control charts for field measurements. A control chart is a graphical plot of measurement results with respect to time and help monitor performance of the radiation detection instrumentation (NRC 2000). An example of a control chart is provided in Figure 9 below.

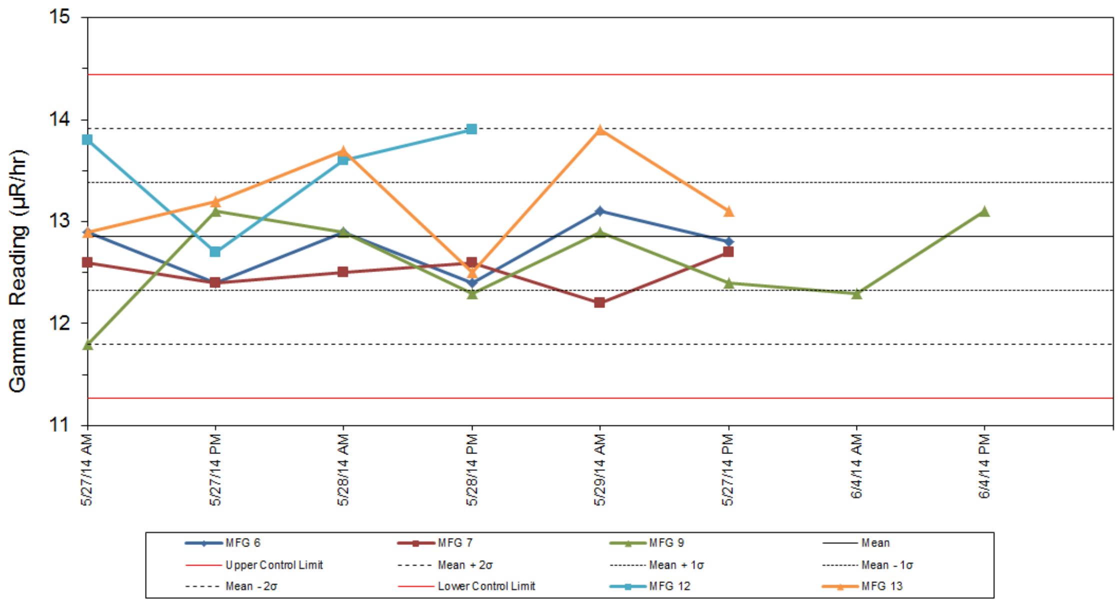

Figure 9 Example of Control Chart

For normally distributed data, 99 percent of all measurements are expected to fall within ±3 standard deviations from the mean. Daily count rate variations within these limits are functions of several possible variables, including exact placement of detector systems during daily checks, and recent variations in barometric pressure. Low detector count rates at very low background gamma exposure rates contribute significantly to variability in count rates. Differences in detector internal characteristics, including minor issues with the NaI detector crystal or optical interface variations in the photomultiplier tube, can also affect NaI detector readings.

The following conditions must be met for the data to be considered valid and usable to meet the project DQOs:

- Any instrument with a QC measurement result falling outside ±3 standard deviations from the mean of all QC measurements on the field check control chart require investigation. A detector exceeding control limits on any QC check (background or source check) is replaced with a pre-qualified spare detector and sent back to the manufacturer for evaluation, repair, and recalibration.

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APPENDIX C

SOIL SAMPLING STANDARD OPERATING PROCEDURE

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1.0 SCOPE AND APPLICABILITY

The Riley Pass cleanup verification sampling plan (VSP) presented the results of the Data Quality Objectives (DQO) process which identified three main field activities to be conducted at the site once the removal actions have been completed at the site. These field activities include: x-ray fluorescence (XRF) field surveys, gamma radiation surveys, and soil confirmation sampling.

This Standard Operating Procedure (SOP) presents the sampling protocol and methods for the soil confirmation sampling as part of the Riley Pass cleanup verification surveys as outlined in the VSP. This SOP addresses the procedures to be followed to assure that the needs expressed by the DQOs are met. There are two goals of the soil confirmation sampling:

1. Confirm the efficacy of the XRF field surveys and gamma radiation surveys.
2. Verify that the arsenic and Ra-226 concentrations in soil of meet the cleanup criteria within each study area.

There are two primary soil confirmation sample types: 1) XRF confirmation samples and 2) soil Ra-226 correlation samples. These two types have unique sampling methods that must be followed. This SOP describes the procedures to be used at the Riley Pass site to perform both the XRF confirmation sampling and the soil Ra-226 correlation sampling. This SOP also addressed sample handling, labeling, documentation, preservation, shipping, and laboratory analysis. This SOP also addresses the quality assurance and quality control (QA/QC) procedures that will insure that the decision maker has reliable data of known quality.

2.0 SAMPLING METHODS

This section presents the soil sampling methods that shall be followed during the cleanup verification sampling at the Riley Pass site.

2.1 OVERVIEW

Samples will be collected from surface soils to support the cleanup verification surveys and to validate the accuracy of the in situ surveys. This sampling approach is referred to as *soil confirmation sampling*. There are two goals of the soil confirmation sampling:

1. Confirm the efficacy of the XRF field surveys and gamma radiation surveys.
2. Verify that the arsenic and Ra-226 concentrations in soil meet the cleanup criteria within each study area.

The primary data collection activities for the Riley Pass site involve soil samples within the designated survey unit areas after remedial action has been conducted. Samples will be representative of the top 15 centimeters (cm) (6 inches) of soil.

2.2 PRECAUTIONS

The following precautions will be observed during sampling:

- All sample containers shall be inspected for cleanliness and flaws prior to use.
- Latex or nitrile gloves shall be worn during sample collection.
- Sample collection equipment shall be decontaminated as described in Section 2.5.

2.3 EQUIPMENT AND MATERIALS

The following equipment is required for the collection of soil samples:

- field logbook or equivalent and permanent black pens
- sample containers (plastic one-gallon bags)
- stainless steel spoons, stainless steel mixing bowls
- scoop or shovel
- engineers tape (graduated in centimeter (cm) increments)
- decontamination equipment and supplies
- disposable latex / nitrile gloves
- digital camera
- ALS laboratory chain of custody sheets (COC)

2.4 Sampling Frequency and Sample Location

Soil samples will be collected at a frequency of 5 percent (1 in 20) of the in situ XRF measurements collected within each survey unit or as required by the minimum number of samples of a study area (e.g. Bluff B) for the statistical test (Section 6.2 of VSP). If there are not enough samples collected using the 5 percent frequency to satisfy the minimum number of samples for the statistical test, then additional samples will be collected as necessary to meet the statistical testing requirements.

Soil sampling locations will be determined using a random number generator assuming a normal distribution. This can be accomplished by identifying all of the proposed in situ XRF sample locations with a numeric identified and selecting the random locations from a random number generator. If additional samples are required to meet the statistical testing requirements, this process shall be repeated as necessary; however, additional samples must be collected at different locations than locations previously sampled.

Prior to soil sampling the coordinates of each sample location plot will be identified. The XRF confirmation sampling will be performed following the methods in Section 2.7 and the soil Ra-226 correlation sampling will be performed following the methods in Section 2.8. The XRF soil confirmation sampling location will be the center of the 10 meter by 10 meter soil correlation plot location. Sampling plot locations will be initially located using a hand-held GPS device. Sampling locations may be adjusted in the field as necessary for access and to accommodate field conditions. The GPS coordinates of the actual (adjusted) sampling locations will be recorded in the field logbook at the time of sampling.

2.5 Equipment Decontamination Procedures

Sampling equipment will be decontaminated between sample collection points, if the equipment is not disposable, in order to avoid cross contamination between samples. Decontamination equipment may include pump sprayers, spray bottles, deionized water, phosphate free soap solution, scrub brushes, buckets, disposable gloves, paper towels, etc. Field personnel will wear disposable gloves while decontaminating equipment.

The following sampling equipment decontaminated procedures will be followed:

1. Visually inspect sampling equipment for adhered soil; a disposable paper towel or stiff brush will be used to remove any visible material.
2. If visible contamination remains, wash the field equipment with phosphate free soap and water, rinse with distilled water, and air dry or wipe with disposable paper towels.
3. Deposit all disposable items, such as paper towels and disposable gloves, into a garbage bag and dispose of properly.

2.6 Pre-sampling Inspection

1. Inspect the sampling site and ensure that it has not been disturbed.
2. Note in the field logbook the soil type and note any unusual conditions.
3. Take photographs to document sample site conditions and location.

4. Document the sample location using a GPS and collect the coordinates in the field logbook.

5. Document the sample identification as described in Section 2.12.

2.7 XRF Soil Confirmation Sample Procedure

The XRF soil confirmation sample procedure involves the collection of one soil sample at the random sample location selected to be tested for arsenic. The following procedure will be followed to perform the XRF soil confirmation sampling:

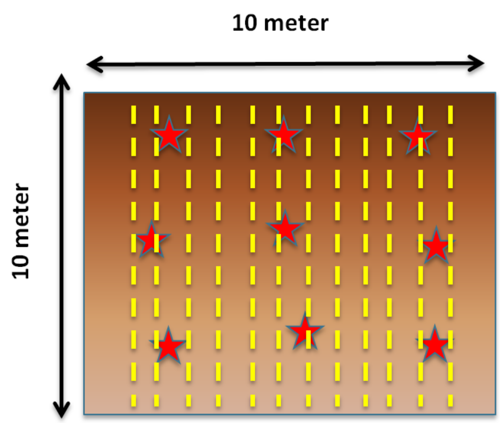
1. Identify the soil sampling location.
2. Perform a pre-sampling inspection as described in Section 2.6. This involves sample identification documentation and collection of photograph.
3. Prepare two plastic bags by writing sample identification information with a black permanent marker on each bag. Four plastic bags will be prepared for sample locations where field duplicates are to be collected (two for primary and two for field duplicate).
4. Collect an in situ XRF measurement following the procedures outlined in Appendix A.
5. Document the arsenic concentration in the field logbook and record in the Niton XRF.
6. Collect a soil sample at the location directly below where the Niton XRF test guard was placed on the ground surface to a depth of approximately 15-cm below ground surface.
7. A minimum sample size of 500 grams will be collected.
8. The sample will be collected using a trowel or shovel as appropriate for the material.
9. Decontaminated stainless steel bowl and spoon will be used for homogenization of composite samples.
10. Place soil sample in in plastic bag. Place the bag in the second plastic bag. This same step applies for field duplicate samples.
11. Decontaminate sample equipment as described in Section 2.5.

2.8 Soil Ra-226 Correlation Sample Procedure

The soil Ra-226 correlation sample procedure involves the collection of nine aliquot soil samples over 10 meter by 10 meter grid and composited in a single sample to be tested for Ra-226. The following procedure will be followed to perform the soil Ra-226 correlation sampling:

1. Identify the soil sampling location.
2. A 10 meter grid will be mapped out, with the XRF soil confirmation sampling being the centroid of the 10 meter by 10 meter soil correlation plot location.
3. Perform a pre-sampling inspection as described in Section 2.6. This involves sample identification documentation and collection of photograph.

4. Prepare two plastic bags by writing sample identification information with a black permanent marker on each bag. Four plastic bags will be prepared for sample locations where field duplicates are to be collected (two for primary and two for field duplicate).
5. Perform a gamma radiation survey at 100 percent density (2-meter transect width) within the 10 meter by 10 meter plot following the methods in Appendix B.
6. Document the gamma exposure rate in the field logbook.
7. Collect nine sub-samples each to a depth of 15-cm as shown with the red stars:



8. The sub-samples will be collected using a trowel or shovel and placed in a decontaminated stainless steel bowl. A spoon will be used for homogenization of composite samples. Visible soil will be brushed off the sampling tools between sub-samples.
9. A minimum sample size of 500 grams will be collected.
10. Place soil sample in in plastic bag. Place the bag in the second plastic bag. This same step applies for field duplicate samples.
11. Decontaminate sample equipment as described in Section 2.5.

2.9 LABORATORY PROCEDURE

The XRF confirmation samples will be analyzed for arsenic and the soil Ra-226 correlation samples will be analyzed for Ra-226. Table 1 presents the laboratory analytical methods and method detection limits for each analyte.

Table 1 Laboratory Analytical Methods

Parameter	CAS Number	Laboratory Method	Detection Limit	Reported Units
Radium-226	7440-14-4	EPA Method 901.1	0.2	pCi/g
Arsenic	7440-38-2	6020A	0.2	mg/kg

2.10 Sampling Handling and Custody

2.10.1 Sample Containers

Proper sample preparation practices will be observed to minimize sample contamination and potential repeat analyses due to anomalous analytical results. Appropriately sized re-sealable freezer plastic bags will be used. The sample bags will be labeled as described in Section 2.11.

2.10.2 Sample Preservation

No sample preservation is required for soil samples.

2.10.3 Sample Holding Times and Analyses

Sample holding times are established to minimize chemical changes in a sample prior to analysis and/or extraction. A holding time is defined as the maximum allowable time between sample collection and analysis and/or extraction, based on the nature of the analyte of interest and chemical stability factors. There is no holding time for samples to be submitted for Ra-226 analysis. A 180 day holding time is recommended for arsenic analysis.

After collection, samples will be labeled as described in the following section, prepared as described in the previous sections and placed in a cooler for delivery to the laboratory. The coolers will be taped shut and chain of custody seals will be attached to the outside of the cooler to ensure that the cooler cannot be opened without breaking the seal.

2.11 Sample Identification

Sample containers will be identified using the following labeling scheme. Each sample will identify the survey unit a sample was collected in, as well as the number corresponding to the sample plot. The date and time of each sample will be noted on the sample container as well.

For XRF confirmation samples the following labeling scheme will be used:

Primary Sample Label: **XRF-B-SU-23-05-01**

Field Duplicate Sample Label: **XRF-SU-23-05-01**

Where:

XRF = XRF verification sample
B= Study area
SU-23-05= Sample #5 in survey unit #23
01/02 = Primary or Field Duplicate Sample ID

For soil Ra-226 correlation samples the following labeling scheme will be used:

Primary Sample Label: **RA-B-SU-23-05-01**

Field Duplicate Sample Label: **RA-SU-23-05-01**

Where:

RA = Ra-226 verification sample
B= Study area
SU-23-05= Sample #5 in survey unit #23
01/02 = Primary or Field Duplicate Sample ID

2.12 Records and Reporting

2.12.1 Field Logbook

All information pertinent to field sampling shall be recorded in a field logbook or equivalent. The field logbook will be a bound book with consecutively numbered pages. All entries in logbooks will be made in waterproof ink and corrections will consist of line-out deletions. Entries in the logbook will include the following, as applicable:

- date and time of sample collection
- sample identification
- sample location
- sample depth
- physical description of sample (color, texture)
- weather conditions and physical/environmental conditions during field activity
- names of sampling personnel and any visitors
- photograph log
- sampling equipment and method
- information concerning sampling decisions
- field observations
- summary of daily tasks and information concerning sampling changes and scheduling modifications
- signature and date by personnel responsible for observations at bottom of each page

2.12.2 Sample Chain of Custody

During field sampling activities, traceability of the sample must be maintained from the time the samples are collected until laboratory data are issued. Establishment of traceability of data is crucial for resolving future problems if analytical results are called into question and for minimizing the possibility of sample mix-up. Initial information concerning collection of the samples will be recorded in the field logbook as described above. Information on the custody, transfer, handling, and shipping of samples will be recorded on a COC form.

The sampler is responsible for initiating and filling out the COC form. The COC form will be signed by the sampler when samples are relinquished to anyone else. A COC form will be completed for each set of samples collected and will contain the following information:

- sampler's signature and affiliation
- project number
- date and time of collection
- sample identification number
- sample type
- analyses requested (can provide laboratory project quote number)
- number of containers
- signature of persons relinquishing custody, dates, and times
- signature of persons accepting custody, dates, and times
- method of shipment
- shipping air bill number (if the samples are shipped)
- any additional instructions to the laboratory

The person responsible for delivering the samples to the laboratory will sign the COC form, retain a copy of the form, document the method of shipment, and send the original form with the samples. Tetra Tech will maintain a copy of the COC. Upon arrival at the laboratory, the person receiving the samples will sign the COC form and return a copy to the Project Manager. Copies of all COC documentation will be compiled and maintained in the central files. The original COC forms will remain with the samples until the time of final disposition. When returning samples for disposal, the laboratory will send the original COC to Tetra Tech. This COC will then be incorporated into the central files. COC forms will be provided by either the analytical laboratory or Tetra Tech.

2.12.3 Field Observations

The field logbook will contain sufficient information so that the sampling activity can be reconstructed without relying on the memory of field personnel. The logbook will be kept in the field technician's possession or in a secure place during sampling activities. Following sampling, the completed logbook shall be maintained and filed as part of the permanent project record. A scanned copy of the field logbook will be included as an appendix to the final report.

3.0 QUALITY ASSURANCE AND QUALITY CONTROL

3.1 QUALITY ASSURANCE

Protocols from regulatory guidance documents such as MARSSIM and MARLAP will be observed. Basic QA for soil sampling can be summarized as follows:

1. Field logbooks will be maintained to document field activities and observations, including date/time of sample collections, notes on conditions, particularly relevant or unusual observations, sampling ID number, sampling depth and GPS coordinates.
2. Standard equipment decontaminations procedures will be followed to prevent cross contamination of soil samples between collections.
3. Proper sample containers and labeling protocols will be followed.
4. Procedures regarding sample submittals and chain-of-custody will be followed.

3.2 QUALITY CONTROL

3.2.1 Field Duplicates

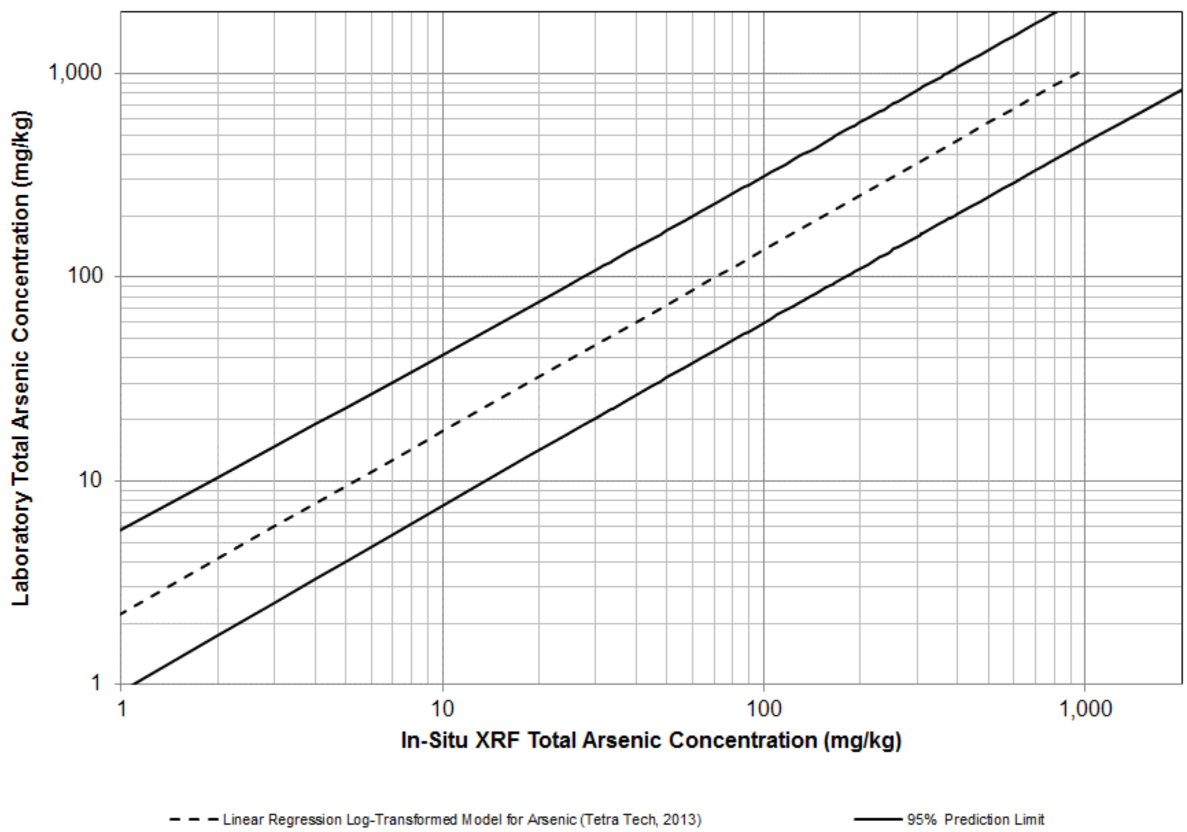
To measure the precision of the laboratory analysis methods, field duplicate QC samples will be collected and submitted for analysis to the laboratory. Field duplicates are samples obtained from one location, homogenized and divided into separate containers and treated as separate samples throughout the sample handling and analytical process. Field duplicates will be collected and submitted to the analytical laboratory at a minimum frequency of one duplicate sample for every 20 soil confirmation samples. Field duplicate samples will be sent to the laboratory along with primary correlation soil samples. The field duplicate data will be evaluated following the methods in Section 4.2.

3.2.2 Data Post-Processing

To evaluate the existing correlations, the laboratory reported arsenic and Ra-226 concentrations will be compared with the in situ measurements.

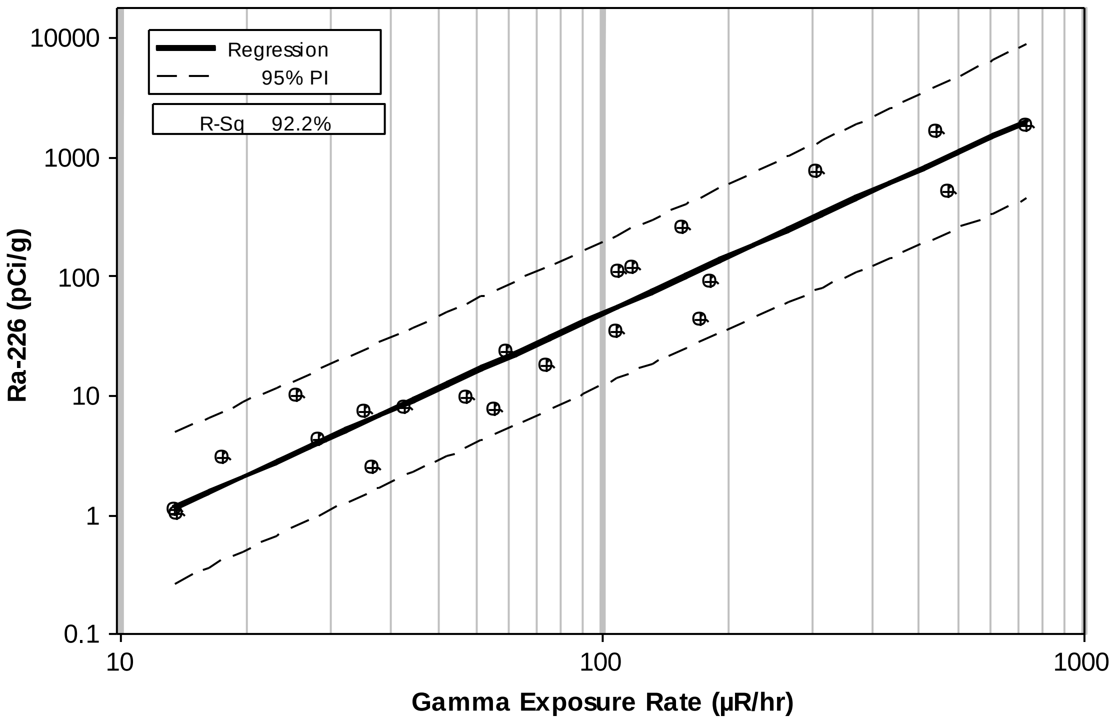
3.2.2.1 XRF Confirmation Sample Post-Processing

Once the arsenic laboratory reported concentrations are made available, the in situ XRF measurement and the laboratory total arsenic concentration will be plotted on the graph below. This graph was developed using the linear regression equation presented in the VSP and Appendix A. The XRF soil confirmation data will be evaluated following the methods in Section 4.2.



3.2.2.2 Soil Ra-226 Correlation Post-Processing

Once the arsenic laboratory reported concentrations are made available, the gamma exposure rate and the laboratory Ra-226 concentration will be plotted on the graph below. This graph was developed using the linear regression equation presented in the VSP and Appendix B. The soil Ra-226 correlation data will be evaluated following the methods in Section 4.3.



3.3 LAB QA/QC

Detailed laboratory control procedures will be followed by the laboratory selected for the project. The laboratory quality control reported will be evaluated as described in Section 4.4.

4.0 DATA QUALITY AND DATA USABILITY ASSESSMENT

4.1 FIELD DUPLICATE ANALYSIS

Data validation will be performed by Tetra Tech including a quantitative evaluation of precision between primary and field duplicate samples. Precision can be defined by the amount of scatter or variance that occurs in repeated measurements of a particular analyte. Two types of duplicate equations are used to evaluate the precision between the primary soil sample and the field duplicate soil sample. The first equation for precision acceptance and rejection for this project will be based on the relative percent difference (RPD) between the primary and field duplicate samples. The RPD equation is given by:

$$RPD(\%) = \frac{|S - D|}{\frac{(S + D)}{2}} \times 100$$

where:

RPD = relative percent difference, non-detects are excluded
S = concentration of primary sample
D = concentration of field duplicate sample

The second equation used is the duplicate error ratio (DER), which factors the uncertainties from both the unknown and duplicate sample into the equation. The DER is calculated when precision estimates are provided using the following equation:

$$DER = \frac{|S - D|}{\sqrt{{\sigma_s}^2 + {\sigma_d}^2}}$$

where:

S = primary sample result
D = duplicate sample result measured field sample concentration
σ_s = primary sample uncertainty
σ_d = duplicate sample uncertainty

The project QC acceptance limits are based on the RPD and DER testing results for all applicable samples. The DER will only be performed on the soil Ra-226 correlation samples, and will not be applied to the XRF confirmation sample field duplicates. Tetra Tech will evaluate the analyte results for the field duplicate soil samples by calculating the RPD and DER between the two samples when both values of the primary/field duplicate sample pair are greater than five times the reporting limit (RL) for a given analyte. The QC acceptance limits are an RPD of less than 30% and a DER less than 1.96. Data validation flags or data qualifiers are given to the analytical data which exceed the project QC acceptance limits. The data qualifiers shown in Table 2 are applied to the data that do not meet the performance acceptance criteria discussed above. The QC acceptance goal is that 85% of the samples shall meet the project QC acceptance criteria.

Table 2 Summary of Data QC Qualifiers

Data Qualifier	Description of Data Qualifier
K	RPD > 30% and the concentration is greater than five times the RL[1]
J	RPD > 30% and the concentration is less than five times the RL
G	DER > 1.96 and the concentration is greater than five times the RL
H	DER > 1.96 and the concentration is less than five times the RL

[1]RL = reporting limit

4.2 Evaluation of XRF Correlation

The in situ XRF arsenic measurements and laboratory reported total arsenic concentration data pairs will be plotted on the existing correlation limits as described in Section 3.2.2. The project QC acceptance criteria is that 95 percent of the data pairs shall fall within the 95 percent UCL limits. Further investigation is warranted if these conditions are not met. The results of the XRF correlation will be included in the final verification sampling report.

4.3 Evaluation of Gamma/Ra-226 Correlation

The gamma exposure rates and the laboratory reported Ra226 concentration data pairs will be plotted on the existing correlation limits as described in Section 3.2.2. The project QC acceptance criteria is that 95 percent of the data pairs shall fall within the 95 percent UCL limits. Further investigation is warranted if these conditions are not met. The results of the soil/Ra-226 correlation will be included in the final verification sampling report.

4.4 Evaluation of Laboratory Quality Control

The laboratory QC reports will be evaluated by Tetra Tech and the results of this evaluation will be reported in the final verification sampling plan.

5.0 REFERENCES

U.S. Nuclear Regulatory Commission (NRC). 2000. Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), (NUREG 1575, Revision 1). NRC. 360p.

NRC. 2004. Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP), (NUREG 1576,). EPA 402-B-04-001A. NTIS PB2004-105421. July 2004.

APPENDIX D

STATISTICAL TEST SAMPLE SIZE DETERMINATION PROUCL OUTPUTS

	A	B	C	D	E	F	G	H	I	J	K	L
1	Riley Pass Site Verification Sampling Plan				Sample Sizes for Single Sample Sign Test							
2	ARSENIC				Based on Specified Values of Decision Parameters/DQOs (Data Quality Objectives)							
3	Date/Time of Computation				6/19/2015 11:28:03 PM							
4	User Selected Options											
5	False Rejection Rate [Alpha]				0.05							
6	False Acceptance Rate [Beta]				0.05							
7	Width of Gray Region [Delta]				75.2							
8	Estimate of Standard Deviation				39.3							
9												
10					Approximate Minimum Sample Size							
11	One Sided Alternative Hypothesis				13							
12	Two Sided Alternative Hypothesis				15							

	A	B	C	D	E	F	G	H	I	J	K	L
1	Riley Pass Site Verification Sampling Plan				Sample Sizes for Single Sample Sign Test							
2	RADIUM-226				Based on Specified Values of Decision Parameters/DQOs (Data Quality Objectives)							
3	Date/Time of Computation				6/19/2015 11:32:30 PM							
4	User Selected Options											
5	False Rejection Rate [Alpha]				0.05							
6	False Acceptance Rate [Beta]				0.05							
7	Width of Gray Region [Delta]				22.3							
8	Estimate of Standard Deviation				6.19							
9												
10					Approximate Minimum Sample Size							
11	One Sided Alternative Hypothesis				11							
12	Two Sided Alternative Hypothesis				14							

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sample Determination for 95% UCL on Mean of Arsenic Using ProUCL**			**Sample Size for Estimation of Mean**								
2				**Based on Specified Values of Decision Parameters/DQOs (Data Quality Objectives)**								
3	Date/Time of Computation			6/25/2015 1:07:00 PM								
4	User Selected Options											
5	Confidence Coefficient			95%								
6	Allowable Error Margin			14.2								
7	Estimate of Standard Deviation			39.3								
8												
9					Approximate Minimum Sample Size							
10	95% Confidence Coefficient				32							

	A	B	C	D	E	F	G	H	I	J	K
1	Sample Determination for 95% UCL on Mean of Ra-226 Using ProUCL			Sample Size for Estimation of Mean							
2				Based on Specified Values of Decision Parameters/DQOs (Data Quality Objectives)							
3	Date/Time of Computation			6/25/2015 1:10:58 PM							
4	User Selected Options										
5	Confidence Coefficient			95%							
6	Allowable Error Margin			3							
7	Estimate of Standard Deviation			6.19							
8											
9					Approximate Minimum Sample Size						
10	95% Confidence Coefficient				19						