SUPPLEMENTAL CHARACTERIZATION WORK PLAN

Section 27

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Acronyms / Abbreviations

ALSA	Ambrosia Lake Study Area
ASTM	ASTM International (formerly American Society for Testing and Materials)
Bi-214	bismuth-214
bgs	below ground surface
BTV	background threshold value
cm	centimeters
CFR	Code of Federal Regulations
COC	chain of custody
CPM	counts per minute
DGPS	differential global positioning systems
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GSA	geographic sub-area
HPD	New Mexico Historic Preservation Division
IL	investigation limit
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentrations
MMD	New Mexico Mining and Minerals Division
mrem/hr	millirem per hour
NESA	Non-Economic Storage Area
NIST	National Institute of Standards and Technology
NMED	New Mexico Environmental Department
Pb-214	lead-214
pCi/g	picocuries per gram
PIC	pressurized ion chamber
PPE	personal protective equipment
QA/QC	Quality Assurance/Quality Control
Ra-226	radium-226
Rn-222	radon-222
RAL	Reclamation Action Level
RSE	Removal Site Evaluation
SOW	Statement of Work
SWCC	soil water characteristic curve
TAL	target analyte list
Th-230	thorium-230
THQ	Non-cancer total hazard quotient

TR	target cancer morbidity rate
UNC	United Nuclear Corporation
USCS	Unified Soil Classification System
UTL	upper tolerance limit

1 Introduction

In a letter dated October 14, 2022, the New Mexico Mining and Minerals Division (MMD) requested that United Nuclear Corporation (UNC) revise the *Supplemental Closeout Plan, Section 27 Mine Site, New Mexico, Permit No. MK005RE* (*Supplemental Closeout Plan*) dated June 27, 2011 (MWH, 2011) for the Section 27 Mine site (the Site). MMD requested that UNC update the *Supplemental Closeout Plan* to meet the requirements set forth in the *Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico* document (*Joint Cleanup Guidance*) (MMD and NMED, 2016). On May 17, 2021, the United States Environmental Protection Agency (EPA) requested that UNC perform Removal Site Evaluations (RSE) at former UNC mine sites in the Ambrosia Lake Study Area (ALSA), McKinley County, New Mexico, including at the Site (EPA, 2021). During a telephone communication with EPA (Region 6) on March 31, 2023, EPA indicated that UNC should proceed with work at the Site under state oversight and surface investigation of other UNC mine sites in the ALSA under EPA oversight.

On May 26, 2023, UNC met with representatives of MMD and NMED to discuss the technical scope of the supplemental characterization activities needed to update the *Supplemental Closeout Plan*. On July 20, 2023, UNC submitted a letter to MMD and NMED on describing proposed next steps for surface reclamation at the Site and the planned development of a Supplemental Characterization Work Plan (Work Plan) detailing supplemental characterization activities including the area planned for supplemental characterization. The purpose of the supplemental characterization is to address additional data needs to evaluate the lateral and vertical extent and volume of mining-related materials at the Site using investigation levels (ILs) that meet the requirements in the *Joint Cleanup Guidance.* UNC contracted Stantec Consulting Services Inc. (Stantec) to develop this *Section 27 Supplemental Characterization Work Plan* to describe planned supplemental characterization activities at the Site.

1.1 Background

The Site was an underground shaft uranium mine located approximately 35 miles north of Grants, New Mexico. The Site is located east of the Ambrosia Lake uranium mill site, also known as the Philips Mill, and the Rio Algom Mill tailings impoundment in the Ambrosia Lake District of McKinley County (Figure 1). Prior to closeout construction conducted in 2010, features at the Site included two shafts, three vent holes, two small piles of non-economic mine materials containing overburden rock, sands, and gravels, one small ore stockpile, two topsoil stockpiles and several small piles of ball mill reject materials. The Site is currently inactive, and the mining features encompass approximately 14 acres.

UNC produced uranium ore from the Site during operations from 1970 to 1977. The Section 27 mineral lease covered approximately 200 acres in the southern half of the Site and was surrendered in 1988. Surface ownership at the mine is currently held by AMD Distribution and to the best of UNC’s knowledge, ownership of the mineral estate is held by Hecla Mining Company.

Previous site characterization and construction activities at the Site are described in Appendix A and summarized here. In 2007 site characterization activities commenced to evaluate the vertical and lateral extent of mine waste at the Site and evaluate borrow materials for use as cover materials and backfill. An initial phase of construction occurred in 2010 to consolidate material from the area of the North Shaft #2, the Ball Mill Reject Pile, East and West Ore Stockpiles and concrete foundation materials in the area of the Non-Economic Storage Area 1 (NESA-1). Cover material was placed on the NESA-1. Additional debris from reclamation activities were placed within NESA-2, including telephone poles, angular metal frames, and the largest pieces of demolished concrete foundation. NESA-2 was also covered with clean materials. A post-reclamation verification gamma survey was conducted after completion of the closeout construction activities over the disturbed areas.

As part of the 2010 reclamation activities, soil and material exceeding the gamma exposure rate of 29 microRoentgens per hour (µR/hr) were excavated from Ore Stockpile Areas, Ball Mill Reject Piles and shaft/vent areas and placed on the existing Non-Economical Storage areas 1 and 2. Based on the Site correlation, the 29 µR/hr exposure rate threshold of excavation in the above-mentioned areas is likely to be higher than the equivalent Ra-226 IL that meets the *Joint Cleanup Guidance* (MMD and NMED, 2016). The 2010 and 2011 post-reclamation gamma radiation survey data provide adequate Ra-226 level estimations in surface and subsurface soil within and just outside the Site permit boundary as shown in Figure 2. The Ra-226 levels in most of the areas both in and outside the permit boundary is above the cleanup criteria specified in the *Joint Cleanup Guidance*. The post-reclamation survey lacks data to delineate lateral and vertical extent of radiologic contamination to the IL, primarily outside the permit boundary. The characterization area needs to extend further outside the permit boundary to identify the cleanup criteria boundary. Based on the results of the previous characterizations, the proposed area for this supplemental characterization, shown in Figures 3 and 4, is expected to identify the boundary of contamination at the Site at the cleanup criteria specified in the *Joint Cleanup Guidance*.

1.2 Purpose

This Work Plan was prepared to detail the proposed investigations of, and approach to, the radiological investigation and data evaluation. Work will include site reconnaissance, radiological and geotechnical characterization, and ecological and cultural resource surveys. Specifically, this work will be done to meet the Reclamation Action Level (RAL) outlined in the *Joint Cleanup Guidance* (MMD and NMED, 2016) of:

1. An average of 5.0 picocuries per gram (pCi/g) radium-226 (Ra-226) above background over an area of 100 square meters in the first 15 centimeters (cm) of soil below the surface, and
2. An average of 15 pCi/g above background, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

Based on the widespread impacts of windblown tailings from the Phillips Mill (DOE, 1996) and the fact that DOE cleaned surface areas to a standard of 6.2 pCi/g, UNC is not able to characterize potential impacts from the Site to background levels as recommended by the *Joint Cleanup Guidance* (MMD and NMED, 2016). UNC intends to characterize surface impacts to the RAL described above.

Site reconnaissance will include reviewing current Site conditions during an initial Site visit, documenting erosion of current cover materials, and reviewing the intended background reference area and comparing it with on-site characteristics (geology, vegetation cover, etc.). Ecological and cultural resource surveys will be conducted by qualified individuals prior to ground-disturbing field activities. An ecological resource survey will be conducted to evaluate the presence of threatened and/or endangered species. Lone Mountain Archaeological Services completed a cultural resource survey at the Site in 2005, the survey was limited to the area within the permit boundary. The survey will be updated to include the projected lateral extent of subsurface disturbance.

A supplemental radiological investigation will be conducted to cover areas outside of the current survey to establish the extent of material that exceeds the proposed RAL. This investigation will include a supplemental survey that will extend from the boundary of the previous static gamma survey (which generally exceeds the proposed RAL) to areas below the RAL. Additional soil samples will also be collected to evaluate the horizontal and vertical extent of the radiological impacts above the RAL. This investigation will be conducted by AVM, a radiological specialist subcontractor in Grants, New Mexico, with oversight from Stantec. Field observations, radiological survey data, sample data, and sample/radiological data from previous Site characterization activities will be utilized to estimate the lateral and vertical extent and volume of mining-related materials at the Site. Mining-related materials outside of the current constructed on-site piles are proposed to be placed in an on-site repository or consolidation area.

Samples will be collected to characterize the geotechnical properties of the borrow source to be used for backfill and cover as well as to characterize mine waste material that will be excavated and placed in an on-site repository in the consolidation area.

1.3 Report Organization

The remaining sections of this document include the following:

- Section 2.0 – Discusses the sampling objectives and related rationale
- Section 3.0 – Presents the field methods and procedures
- Section 4.0 – Presents the sample handling and analysis
- Section 5.0 – Discusses the quality assurance and control requirements
- Section 6.0 – Presents the reporting and data evaluation
- Section 7,0 – Summarizes the work to be completed
- Section 8.0 – Includes the references
- Appendices – includes:
    - Appendix A – Section 27 Site History Memorandum
    - Appendix B – Standing Operating Procedures

2 Sampling Objectives and Rationale

This section describes the sampling objectives and rationale for each of the activities planned to occur during the Supplemental Characterization.

2.1 Site Reconnaissance

Site reconnaissance will occur during a preliminary Site visit and will include a review of current Site conditions, documentation of erosion of current cover materials, and review of the background reference area for comparison to on-site conditions such as geology and vegetative cover. This information will be used for planning purposes, including evaluating access to the Site (for people and equipment) and the planned areas for characterization.

It is Stantec's understanding that cover materials placed during the 2010 construction activities have eroded in some places. Detailing the current condition of the cover materials will be important for planning modifications of the cover as part of the update to the *Supplemental Closeout Plan*.

Data gaps related to the previous background reference area used for the Site along with information on the background reference area are described in Section 2.4.1. A visit to the background reference area is needed to evaluate if the area is generally representative of pre-mining conditions at the Site, including similar physical, chemical, geological, and biological characteristics.

2.2 Resource Surveys

Updated ecological and cultural resource surveys are needed for the Site. A Site visit will be planned to review ecological conditions at the Site, to evaluate the presence of habitat, and to determine if there are protected species present that will be impacted during ground-disturbing activities. Methods for, and requirements of, the ecological survey are described further in Section 3.2.1.

The prior cultural resource and archaeological survey at the Site was limited to the mine permit boundary. Additional survey is needed in areas where ground-disturbance may occur outside of the permit boundary to identify, record, and evaluate archaeological sites and cultural properties so those areas may be avoided as needed during ground-disturbing activities. Methods and requirements of the cultural resource survey are described in Section 3.2.2.

2.3 Geotechnical Soil Characterization

Previous geotechnical evaluation conducted at the Site included modeling performed as part of the 2011 *Supplemental Closeout Plan* (MWH, 2011). Sampling of borrow source material to be used for backfill and cover and sampling of mine waste material will be conducted in connection with for the design of the repository in the consolidation area.

The samples will be collected on-site to characterize the geotechnical properties of borrow source material and mine waste materials that are planned for placement in the consolidation area. Upon completion of the field program, Stantec will review and select samples for laboratory testing to evaluate geotechnical properties of the materials. As these materials have not been characterized previously, this laboratory data is necessary for repository design. The mine Phillips Mill Cleanup Verification Estimated Ra-226 Concentrations in Grid Locations Near Section 27 Site waste material will be characterized for strength and compaction and will be used in the design of the onsite repository to determine the long-term stability as well as developing technical specifications for placement of the material. The characterization of the borrow material is necessary for the cover design including radon modeling to determine the thickness of the cover, compaction requirements for placement, and growth media requirements to apply vegetation to the cover.

This laboratory testing is anticipated to be completed in two phases. The index testing (sieve analysis, hydrometer, moisture content, and Atterberg limits) will be conducted first (Phase 1) to identify the types of materials present in the borrow area and within the mine waste materials. Up to 10 samples will be tested for the borrow area and up to 15 samples will be tested for the mining-disturbed materials. Sieve analyses will be used to categorize materials as coarse or fine and Atterberg limits results will be used to determine if fine-grained materials are plastic or non-plastic. Unified Soil Classification System (USCS) classifications will be used to group material types for Phase 2 laboratory testing. Following the initial index testing, Standard Proctor compaction test results will be completed on test pit samples to define the moisture and density that will be used to prepare samples for Phase 2 testing.

Phase 2 laboratory testing will include strength and permeability testing. If fine-grained materials (material passing a #200 sieve and less than 75 micron) are identified in Phase 1 testing, additional testing, including soil water characteristic curve (SWCC), consolidation/swell may be required. Approximately five consolidation/swell tests, three strength tests, five permeability tests, and five SWCC tests will be completed to define these properties. Additional information on geotechnical testing methods is provided in Section 4.1.1.

2.4 Supplemental Radiological Characterization

The objective of the supplemental radiological characterization is to delineate the lateral and vertical radiologic contamination boundaries corresponding to the Ra-226 RAL. Additionally, a Site-specific correlation will be performed to convert the results of the supplemental characterization field gamma radiation surveys in counts per minute (CPM) to Ra-226 soil concentration (pCi/g) for comparison to the results of laboratory analysis.

The Site is a former uranium mine and therefore the surface and subsurface soil is impacted by radionuclides associated with the uranium decay series, with Ra-226 being the primary constituent of concern. The Site is in a very remote, sparsely populated area that is difficult to access. Currently, the area surrounding the Site is used for ranching with no on-site residences and it is highly unlikely that land at the Site will be used for residential purposes in the future. Therefore, a RAL based on risk-based cleanup criteria for a ranching scenario would be appropriate for the Site.

Although the cleanup criteria specified in the *Joint Cleanup Guidance* (MMD and NMED, 2016) are based on a residential land use exposure scenario, it will nonetheless be used as the RAL for the current project to use a conservative approach at the Site, for which the potential exposure scenario is likely ranching. A Ra-226 RAL of 5.0 pCi/g above the background level in land averaged over 100 square meters in surface soil (top six inches) and 15.0 pCi/g above the background level in subsurface soil (soil below the top six-inch layer) will be used for the supplemental radiological characterization.

The static gamma survey points completed in 2010 and 2011 and estimated Ra-226 concentrations are shown on Figure 2. The static gamma survey extended to the proposed RAL in most areas around the Site. A supplemental gamma survey is needed outside the area of the current survey to bound potential radiological impacts at the Site. The proposed supplemental scan area is shown on Figures 3 and 4. The supplemental gamma scan area is estimated to encompass approximately 170 acres, as determined based on previous characterization, EPA ASPECT Survey (Figure 3), predominant wind direction, and land topography. Based on the prior cleanup of the Phillips Mill to a standard of 6.2 pCi/g Ra-226 (5 pCi/g plus Phillips Mill background of 1.2 pCi/g), no characterization is planned within the mill cleanup boundary (boundary is shown on Figure 4). Figure 5 shows approximate Ra-226 concentrations at the Phillips Mill near the Site where concentrations exceed the proposed background threshold value (BTV) of 1.5 pCi/g) proposed for Section 27. In addition, because UNC is presently negotiating investigation of former UNC mines in Section 34 with EPA, no characterization will be performed south of the boundary between Section 27 and Section 34. Radiological survey methods to be used are described in Section 3.3.

Soil sampling for radiological constituents was completed at the Site during the 2007 Site Characterization and the 2011 Supplemental Closeout Survey. Stantec proposes to include results from the samples collected during the 2011 Supplemental Closeout Survey as part of the Supplemental Characterization. Because the previous IL was greater than the RAL, Stantec proposes to collect additional soil data to delineate the horizontal and vertical limits of the radiological impacts above the RAL. Stantec proposes to collect surface soil samples (0 – 6 in depth) primarily near the RAL boundary to confirm gamma survey measurements. The number of samples will be determined after the gamma scan survey is completed and the RAL boundary and area are estimated. There may be as many as 20 surface samples collected. Additionally, the collected surface soil samples will be used to update the correlation of Ra-226 concentrations in pCi/g to direct gamma radiation measurements in CPM for the gamma scan survey. The soil samples will be analyzed for Ra-226, thorium-230 (Th-230), uranium, and a subset of up to 10 percent of soil samples will be selected randomly for analysis of target analyte list (TAL) metals.

As shown on Figures 2 and described in Appendix A, subsurface test pits and sampling were performed to estimate vertical contamination. However, the previous characterization IL was higher than the currently proposed RAL. In addition, the lateral extent of the area exceeding the RAL will be larger. Therefore, to evaluate the vertical extent of contamination, supplementary subsurface soil sampling is proposed at up to 20 locations within the lateral extent of contamination area.

During reclamation activities at the Phillips Mill, U.S. Department of Energy (DOE) evaluated the ratio of Ra-226 to uranium-238 in samples for tailings and waste rock and found that tailings had a signature distinguishing them from waste rock (DOE, 1990). During the Supplemental Characterization, several soil samples will be collected from the area near the western boundary of the Site to establish the source of contamination. These samples will be analyzed for uranium, Th-230 and Ra-226 to compare the uranium to Th-230/Ra-226 ratio and determine if the contamination derives from unprocessed uranium ore or from mill processed material (tailings).

Stantec proposes to collect characterization samples for TAL metals plus uranium analysis at the Site and to compare these results to NMED Soil Screening Levels for industrial/occupational soil (Target Cancer Morbidity Rate (TR) of 1E-05, Non-Cancer Total Hazard Quotient (THQ) of 1) (NMED, 2021). Considering the fact that future Site use is likely to include livestock grazing, it is important to note that the synthetic precipitation leaching procedure (SPLP) testing completed during the 2007 Site characterization found that leachable concentrations of relevant the metals were less than surface water standards for livestock watering, wildlife, and aquatic life and groundwater standards.

Details of radiological and metals sample collection and laboratory testing are included in Sections 3.5 and 4.1.2.

2.4.1 RADIOLOGICAL BACKGROUND EVALUATION

UNC identified a background reference area west of the Site during the 2007 Site Characterization and the range of background reference area values were used as confirmation values during the 2010 construction at the Site. Unshielded background gamma radiation exposure rates determined at the time (one-meter above ground surface) ranged from 20 µR/hr to 38 µR/hr. Review of the background reference area and its proximity to the Section 27 and Phillips Mill sites indicates that the background reference area may be potentially impacted and not representative of pre-mining conditions at the Site.

Accordingly, Stantec recommends that a background reference area identified as part of the Tronox Area Uranium Mines West Geographic Sub-Area (GSA) RSE instead be used as background for the Site. The West and Central GSA background location is approximately 4 miles from the Site as shown on Figure 6 and the areas of the GSAs, along with the geology of the area, are shown on Figure 7. The original figure was included in Appendix D of the *Removal Site Evaluation Report for Tronox Navajo Area Uranium Mines West Geographic Sub-Area (GSA) McKinley County, New Mexico* (Weston Solutions Inc. 2019a). For this proposed investigation at Section 27, using the background values from the West and Central GSAs appears more representative based on wind direction and land topography.

The selection of background reference areas and the evaluation of background concentrations for the West and Central GSAs are described in the *Background Investigation Report for Ambrosia Lake (East, West, and Central GSAs and the Section 10 Mine) and Section 32 and 33 Mine Navajo-Area Abandoned Uranium Mines (NAUM) McKinley County, New Mexico* (Weston Solutions 2019b). Gamma radiation measurements and soil samples were collected in the background reference areas. The gamma survey consisted of a walkover gamma survey performed with transects 1 meter apart and a meter held approximately 18 inches above the ground. The survey provided 100 percent coverage and the data were evaluated statistically for a normal distribution to determine suitability as a background reference area. Static 1-minute gamma measurements were collected at each of 20 sample points that were laid out on a grid of 4-by-5 sample points, separated by 50 feet. Additionally, a 5-minute gamma reading was collected at each of the points using a pressurized ion chamber (PIC) to determine dose rate measurements. At each sample point, a soil sample was collected from 0-6 inches below ground surface (bgs) and analyzed for Ra-226 using gamma spectroscopy analysis at an offsite laboratory.

Based on the data collected from the soil sampling, a background threshold value (BTV) was calculated for the West and Central GSAs background reference area at the 95 percent upper tolerance limit with 95 percent coverage (UTL95-95). The BTV represents the upper limit of the background data sets such that 95 percent of the background values are less than the BTV with 95 percent confidence. The Ra-226 BTV for the West and Central GSAs is 1.54 pCi/g and the BTV is 9,904 CPM for direct gamma radiation measurements. Stantec proposes to inspect the background reference area to confirm that it is representative of conditions (similar physical, chemical, geological, and biological characteristics) at the Site. If conditions are consistent, Stantec recommends using these values in the Supplemental Characterization and *Supplemental Closeout Plan*.

3 Field Methods and Procedures

This section describes the field methods and procedures to complete the supplemental characterization activities. The Site has uneven terrain and features, which poses a potential safety risk. Safety and radiation protection during excavation control are addressed in the Site-Specific Health and Safety Plan.

3.1 Site Access

The Site is located entirely on privately-owned land. Access gates are currently in place and prevent public access to the Site. The gates will remain in place as part of the final reclamation of the Site. The fence constructed during Phase 1 construction will be maintained and/or repaired, as needed.

UNC has executed an Access Agreement with the owner of the Site to perform the activities described in this Plan.

3.2 Resource Surveys

Ecological and biological resource surveys will be completed prior to any ground-disturbing activities.

3.2.1 ECOLOGICAL SURVEY

Cedar Creek Associates (Cedar Creek) conducted vegetation and wildlife evaluations and provided revegetation recommendations following a 2005 site assessment (Cedar Creek Associates, 2006). The assessment found that there were no threatened and/or endangered species in the vicinity of the Site; however, several species may occasionally migrate through the Site, including the peregrine falcon and bald eagle.

Prior to ground-disturbing activities, Cedar Creek will complete a desktop study to evaluate the potential for the presence of special status species. As part of the desktop study, Cedar Creek will implement a raptor data request from Natural Heritage New Mexico, which maintains a database of known raptor nests. Cedar Creek will conduct the desktop study and a qualified biologist will conduct the Site survey in accordance with the New Mexico Department of Game and Fish *Habitat Handbook – Baseline Wildlife Study Guidelines* (New Mexico Department of Game and Fish, 2010). If findings during the Site survey indicates the presence of protected species, mitigation measures will be implemented prior to, and during, ground-disturbing activities. Findings of the desktop study and Site survey will be included in the Supplemental Characterization Report.

Cedar Creek reviewed data collected during the 2005 study, results of agronomic analyses conducted during the 2007 Site Characterization, and the proposed scan area for the upcoming Supplemental Characterization (Figures 3 and 4) within the context of the current MMD guidance:

- *Guidance for Soil and Cover Material Handling and Suitability for Part 5 Existing Mines*, MMD 2022a
- *Guidance for Revegetation of Part 5 Existing Mines and Part 6 New Mines*, MMD 2022b

No data gaps were identified with respect to the suitability of cover materials or the revegetation plan at this time. Additional review will occur following radiological characterization at the Site and determination of the lateral extent of mine waste impacts.

3.2.2 CULTURAL SURVEY

A cultural resource survey was completed at the Site in 2005. The survey covered the area of the permit boundary at that time and included a review of records for other nearby cultural resource surveys and a records request from the New Mexico Historic Preservation Division (HPD) of the New Mexico Department of Cultural Affairs. New Mexico HPD provided comments pertaining to two archeological sites north of Non-Economic Storage Area #1 (letter dated April 13, 2004). HPD requested that an archeologist assess the condition of these two sites and any impacts from the proposed closeout operations. Lone Mountain Archeological Services, Inc. completed a cultural resources survey in 2005, and issued an assessment that indicated no cultural properties were identified in the Area of Potential Effect and concluded that there was no concern regarding the two, identified archaeological sites or the Site with respect to the *Closeout Plan* at that time (Lone Mountain Archaeological Services, 2005). Both archaeological sites were outside of the permit boundary and any area that was planned to be affected by the closeout activities.

The proposed Supplemental Characterization will require ground-disturbing activities outside of the permit boundary. For the additional projected area of disturbance outside of the current permit boundary, a qualified archaeologist permitted by the State of New Mexico will conduct a Class III cultural resource study that meets the requirements of the New Mexico HPD, Department of Cultural Affairs. Personnel will obtain a permit authorizing the survey, conduct a literature review and file search, complete the Class III survey, and present findings in a report to the Department of Cultural Affairs. If cultural resources are identified within the Area of Potential Effect, the Class III report will recommend mitigation measures to the Department of Cultural Affairs and request their concurrence. Following the receipt of concurrence, any mitigation measures will be enacted prior to ground-disturbing activities.

3.3 Radiological Survey Methods

The Site areas that will be characterized by field radiologic investigations under this Work Plan are shown on Figures 3 and 4. The field investigation will include gamma radiologic surveys, both gamma static measurements and differential global positioning systems (DGPS) based gamma scan surveys, along with ex-situ and in-situ soil screening, and soil sampling and analysis.

The method and procedures that will be used will be consistent with the applicable surveys and methods described in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM, EPA 2000a). The purpose of this supplemental radiological characterization is to augment the previous characterization data to delineate the radiologic contamination boundary based upon an appropriate investigation level, and to characterize the Site by performing radiological surveys and collecting soil samples at the Site. The following sections describe the strategy, methods, and procedures for the supplemental radiologic characterization of the Site.

A DGPS-based gamma radiation scan survey in CPM will be performed within the estimated 170-acre supplemental radiologic characterization area, as shown in Figures 3 and 4. The geo-located gamma scan data will be plotted on aerial maps to provide Ra-226 concentration level estimates in surface soil within the scanned areas. The gamma scan data, along with visual observations, will also be used to determine up to 20 locations for surface soil sampling to confirm the gamma scan for the lateral extent of the surface contamination boundary, and an additional, approximate 20 locations for subsurface soil sampling and ex-situ soil screening. Some of the subsurface soil sampling will be conducted in areas previously reclaimed and verified in 2010 and characterized in 2011, to better assess the vertical extent of contamination. The geo-located gamma scan data plotted on aerial maps will assist in determining the radiologic contamination boundary corresponding to the RAL. The number and locations of soil samples will be finalized following the completion of the scan gamma survey. With the exceptions noted below, if any portion of the gamma scan area exceeds the RAL, a step-out gamma scan will be performed until gamma radiation levels below the RAL are detected. Based on the prior cleanup of the Phillips Mill to a standard of 6.2 pCi/g Ra-226 (5 pCi/g plus Phillips Mill background of 1.2 pCi/g), no characterization is planned within the mill cleanup boundary (boundary is shown on Figure 4). In addition, because UNC is working with EPA to investigate former UNC mines in Section 34, no characterization will be performed south of the boundary between Section 27 and Section 34.

Depending on the type of soil matrix, ex-situ gamma radiation soil screening or in-situ gamma radiation level measurements will be performed at surface or subsurface soil investigation locations. The ex-situ gamma radiation soil screening or in-situ gamma radiation level measurements will provide real-time information to estimate subsurface contamination depth. A site-specific correlation of surface soil Ra-226 levels to gamma radiation levels in CPM was developed for a two-by-two sodium iodide (2x2 NaI) 0.5-inch-thick lead collimated detector during the 2011 post reclamation survey. Additionally, gamma static surveys and surface soil sampling will be performed at selected locations as needed to develop a Site-specific correlation of surface soil Ra-226 levels to gamma radiation levels in CPM for a 2x2 NaI 0.5-inch bare detector.

Direct gamma radiation surveys, gamma exposure rate surveys, ex-situ and in-situ gamma radiation soil screening, and soil sampling and analysis will be used in the supplemental radiological characterization of the Site. These methods are described in the following subsections.

3.3.1 GAMMA RADIATION SURVEYS

Gamma radiation surveys are an efficient tool for characterization of Ra-226 at uranium mine sites. Direct gamma radiation surveys will be used to detect Ra-226 in soils for the supplemental radiological characterization at the Site. Ra-226 is primarily an alpha-emitting radionuclide with a gamma radiation emission of 186 kiloelectron volt (keV) at about 4 percent intensity. Field measurement of alpha radiation from soils using radiation detection methods are an inadequate technique. Due to the low energy of its gamma radiation emission, field determination of Ra-226 is not practical. However, Ra-226 in soil can be determined by measuring gamma radiation levels of its decay products such as lead-214 (Pb-214) and bismuth-214 (Bi-214), which emit high energy gamma radiation at higher intensities and are easily detected and quantified by a NaI scintillation detector. This is a surrogate method consistent with MARSSIM guidance.

The RAL is presented in terms of Ra-226 mass activity concentration and is expressed in units of activity per unit mass of soil, pCi/g. The direct gamma radiation measurements, using a NaI scintillation detector, provide radiation levels in counts per unit time. The counts per unit time for a given radioactivity depend on the efficiency of the detector. Pb-214 and Bi-214 are decay products of Ra-226 through radon-222, a gaseous form, some of which emanates from soil. This process results in activity disequilibrium between Ra-226 and Bi-214 in the soil. The radon-222 (Rn-222) gas emanation fraction from the soil varies with different geometric characteristics of a particular soil. Therefore, a site-specific calibration is necessary. Typically, about 20 percent of the Rn-222 gas decayed from Ra-226 in soil emanates out of the surface soil, indicating that a significant percentage (about 80 percent) of this will decay into Pb-214 and Bi-214 in the soil matrix. If the soil geometry and other parameters such as moisture, radon emanation fraction, contamination distribution profile, gamma ray shine from nearby sources, and land topography are consistent, the ratio of Pb-214/Bi-214 to Ra-226 is constant. This results in a direct correlation between Pb-214/Bi-214 gross gamma radiation levels and Ra-226 concentrations in the soil. Therefore, a correlation between direct gamma radiation levels and Ra-226 soil concentrations in pCi/g at uranium mine site will be used to convert the CPM measurement to equivalent Ra-226 in soil.

The instrumentation configuration for direct gamma radiation level measurement during this characterization consists of a 2x2 NaI scintillation detector (such as Eberline SPA-3 and Ludlum 44-10) for detection of gamma radiation, connected to a scaler/rate meter (such as Ludlum 2221 or Ludlum 2241) for processing and counting the detected gamma radiation. This instrument configuration has been used widely for this type of application and is recommended by the MARSSIM. The SPA-3 and L44-10 scintillation detectors are sturdy, with the highest sensitivity gamma radiation detection for field application and this type of field survey. For radiation surveys at discrete points where significant shine interference is suspected from nearby areas, such as areas with deep excavation and areas with close proximity to waste piles, the 2x2 NaI scintillation detector will be installed in a 0.5-inch-thick lead collimator to mitigate any lateral gamma shine interference. During the gamma surveys, the detector will be held approximately 12 inches above ground level. The scaler/rate meter will be interfaced with a sub-meter accurate DGPS and a data logger controller for electronically correlating gamma radiation levels with their corresponding location coordinates for systematic gamma scan surveys. The instrumentation will be calibrated consistent with AVM Standard Operating Procedure (AVM SOP-1), included in Appendix B.

There is no site-specific correlation for a 2x2 NaI bare detector so a correlation will not be available during the field gamma scan survey to establish the IL in detector CPM. A site-specific correlation for a 2x2 NaI bare detector will be developed during this supplemental characterization by comparing the collected field gamma scan survey data to co-located Ra-226 concentrations in laboratory samples (see AVM SOP-2 in Appendix B). Therefore, correlations used at similar uranium mine sites will initially be used for determining the investigation level in CPM for use during the gamma scan survey. AVM performed site-specific correlations between co-located surface soil Ra-226 concentrations and direct gamma radiation levels for bare and 0.5-inch-thick lead collimated 2x2 NaI detectors for the nearby San Mateo Uranium Mine Site and St. Anthony Uranium Mine Site. All these correlations are essentially the same. For the same correlation and survey geometry and assumptions, the soil matrix is the only factor causing variation from site-to-site, which is due to radon progeny content and gamma radiation attenuation, which is likely to be less than 20 percent. The site-specific correlations developed for the St. Anthony Uranium Mine Site and the San Mateo Uranium Mine Site will be used in the interim for the initial determination of the investigation level in gamma radiation level CPM for 2x2 NaI detectors.

The St. Anthony Mine Site correlation yielded a correlation equation of Ra-226 pCi/g = (CPM x 0.0005) - 5.514 with a R^2 of 0.98. Based on this correlation equation, the gamma radiation level in CPM equivalent to 6.5 pCi/g Ra-226 in surface soil is 24,020 CPM for the bare 2x2 NaI detector. The San Mateo Mine Site correlation yielded a correlation equation of Ra-226 pCi/g = (CPM x 0.0006) - 7.45 with a R^2 of 0.98 for the bare NaI detector. Based on this correlation equation, the gamma radiation level in CPM equivalent to 6.5 pCi/g Ra-226 in surface soil is 23,259 CPM for the bare 2x2 NaI detector, which is comparable and essentially the same as the St. Anthony Mine Site. An average CPM of 23,640, equivalent to 6.5 pCi/g Ra-226 in surface soil, will initially be used for this supplemental radiological characterization gamma scan survey until development of a site-specific correlation.

3.3.2 GAMMA SCAN SURVEYS

A DGPS-based geo-located systematic gamma radiation scan survey will be performed within the area shown on Figures 3 and 4, which is estimated to be approximately 170 acres. The geo-located gamma scan surveys serve two purposes:

- Provide an estimate of Ra-226 concentration levels in the surface soil within the borrow source and mine waste material areas.
- Provide the data to determine the lateral radiologic contamination boundary at the RAL.

To determine the lateral contamination boundary to the RAL with an acceptable certainty, the gamma scan survey will extend until measurements indicate gamma levels are approximately below 75 percent of the RAL. If the gamma scan in the proposed scan area does not identify the lateral RAL contamination boundary at the Site, additional step-out gamma scans will be performed until the lateral RAL contamination boundary is delineated. Gamma scan surveys will be performed by scanning along transects at a spacing of 50 feet with a bare detector at 12 inches above the ground surface. Depending on the terrain at the Site, a walkover or an all-terrain vehicle (ATV)-assisted gamma scan survey may be performed. A scan rate of about three feet per second will be maintained depending on terrain but will not exceed four feet per second. The systematic gamma scan survey measurements will be electronically logged with a suitable sub-meter DGPS which provides real-time corrected location coordinates. Random gamma scan surveying without DGPS integration may also be performed in discrete areas if needed during the characterization.

Procedures are provided in the MARSSIM for calculating scan minimum detectable concentrations (MDCs) for particular survey and instrument parameters. More detail on signal detection theory and instrument response is provided in NUREG-1507 Rev. 1, *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions* (NRC, 2020). Based on scan rate, detector background counting rate, detector response factor, detector field of view and the desired sensitivity index, the selected instrumentation will meet the scan MDC at less than 50 percent of the 6.6 pCi/g Ra-226 soil RAL for the Site.

A typical example scan MDC calculation consistent with MARSSIM Section 6.7.2, scan MDC for Land Areas, based on similar survey and instrumentation parameters at a uranium mine site is described in AVM SOP-1. The scan MDC will be calculated using actual characterization instrumentation and survey parameters to demonstrate that it does not exceed the RAL based on operational and functional check data. Survey parameters for this instrumentation during previous surveys at other mine sites, a scan MDC for a 2x2 NaI bare detector, is estimated at less than 2.0 pCi/g, well below the RAL, for both bare and for a 0.5-inch lead collimated 2x2 NaI detector.

3.3.3 GAMMA STATIC SURVEYS

The gamma static surveys will be conducted using the same instrumentation described in Section 3.3.1. The detector may be fit with a 0.5-inch lead collimator, as needed, to mitigate any lateral gamma radiation shine interferences from nearby areas. Gamma static surveys will be performed at discrete locations for investigation/confirmation of the scan survey results at any point or location of interest during characterization (such as any questionable gamma scan measurements, scan measurements near the RAL at the boundary, and correlation sampling points). The detector will be held about 12 inches above the ground surface. The scaler/rate meter will be set in the count SCALER MODE and a one-minute count of gamma radiation levels will be conducted at each location for the gamma static radiation survey. Details of the gamma static survey are described in AVM SOP-3.

A typical example of a static measurement MDC calculation based on site-specific survey and instrumentation parameters is described in AVM SOP-1, which was calculated in accordance with MARSSIM Section 6.7.1. Based on operational and function check data, and survey parameters for this instrumentation during previous surveys at similar uranium mine sites, the static gamma measurement MDC for a 2x2 NaI detector is estimated at less than 1.0 pCi/g for the bare and collimated detector, well below 50 percent of the 6.6 pCi/g RAL. The gamma static surveys will be electronically logged with a suitable sub-meter accuracy DGPS which provides real-time corrected location coordinate data.

3.3.4 SITE-SPECIFIC GAMMA RADIATION LEVEL TO SURFACE SOIL RA-226 CONCENTRATION CORRELATION

A Site-specific correlation will be developed for the bare 2x2 NaI detector (see AVM SOP-2). Co-located gamma static measurements and soil samples analyzed for Ra-226 will be selected judgmentally to confirm that the full range of concentrations will be included. As such, approximately 10 to 15 sample locations from the Site will be used for the correlation. Surface soil samples collected for gamma scan survey confirmation may be used for the correlation if they meet the correlation assumptions. Using co-located gamma static measurements and soil sample Ra-226 analytical results from these locations, a linear regression will be developed for each detector type. The regression analysis results will be used for converting the static and scan gamma radiation levels in CPM to equivalent surface soil Ra-226 concentrations. Also, a cross-calibration of calibrated exposure rate meter and the 2x2 NaI detector at a known ore source, such as DOE calibration pad, will be performed to convert and normalize some of the previous characterization survey results in exposure rate (µR/hr) to equivalent direct gamma radiation level in CPM/Ra-226 surface soil concentration.

3.3.5 EX-SITU GAMMA RADIATION SOIL SCREENING

On-Site ex-situ gamma radiation soil screening will be performed for subsurface investigations in the characterization areas. Ex-situ soil screening provides real-time information regarding Ra-226 concentrations in soil samples. Ex-situ soil screening may also be performed as necessary to confirm direct gamma radiation surveys from areas with suspected subsurface gamma shine. The on-Site ex-situ soil screening method consists of selectively measuring the 609 KeV region gamma radiations of Bi-214, a decay product of Ra-226 (see AVM SOP-4 in Appendix B). This method, which is more reliable than the in-situ direct gamma survey, was successfully implemented at the various uranium mine sites for expedited estimates of Ra-226 in soil. A single channel analyzer, such as Ludlum L2221 integrated with a Ludlum 44-20 3x3 NaI scintillation detector, will be used to measure the 609 keV energy peak region of Bi-214. The soil sample is placed around the plastic-lined detector in a heavily shielded counting chamber. The shielded counting chamber lowers the system background counts, improving the system MDC. Based on data from previous use of this system at the Site, the MDC is expected to be less than 50 percent of the 6.5 pCi/g Ra-226 RAL. A typical MDC calculated from the previous ex-situ analysis at the Site is provided in AVM SOP-4. For an expedited estimate of Ra-226 in soil, a reference soil with a known Ra-226 concentration near the RAL will be prepared and used. The 609 KeV gamma radiation counts will be obtained and compared to the sample soil for field screening during excavation control.

3.4 Test Pit Excavation

Test pits will be excavated in both the borrow source and mine waste material to collect samples of varying depth for the materials characterization. Test pits will be advanced per Stantec SOP-1 – Trenching and Test Pitting. The same test pits will be used for geotechnical, and radiological samples. Each borrow source test pit will be excavated to approximately 5 to 10 feet bgs, depending on professional judgment and test pit excavation refusal. The depths of test pits within the mine waste material areas will be based on results of the gamma surveys but are anticipated to be approximately 2 to 4 feet bgs. A track excavator will be used to excavate a trench at each test pit location for subsurface soil sample collection. At each 1-foot depth interval, or less if a significant change in material type is observed, a soil sample will be collected. Prior to leaving any test pit location, the test pit will be backfilled with the excavated material, leveled, location will be surveyed with the DGPS, and then marked with labeled pin flags.

Observations during test pitting will be documented on test pit logs like the one included in the Stantec SOP-1 for Trenching and Test Pitting.

3.5 Sample Collection

3.5.1 GEOTECHNICAL SAMPLES

Geotechnical samples will be collected from the test pits by filling two 5-gallon buckets and two 1-gallon zip-lock plastic storage bags for each sample. Geotechnical samples will be logged and visually classified in the field during collection using modified ASTM 2488 methods. Geotechnical samples will be targeted to be collected in areas where radiological constituents are less than the 0.1 millirem per hr (mrem/hr) laboratory handling limit. Sample bags will be stored in rigid-bodied containers (e.g., bucket or cooler). Geotechnical samples will be stored on-site prior to delivery by field personnel to a laboratory in Albuquerque, NM. If geotechnical samples are collected in winter months, care will be taken to store the samples in a temperature-controlled environment so that they will not freeze.

3.5.2 RADIOLOGICAL SAMPLES

Surface soil samples, generally described as the top six inches of ground surface, will be collected from some areas such as the areas near contamination boundaries for confirmation of gamma survey results. Surface soil sample results will also be collected for the correlation. Additionally, several soil samples will be collected from the area near the western boundary of the Site to establish the source of contamination. These samples will be analyzed for uranium, Th-230 and Ra-226 to compare uranium to the Th-230/Ra-226 ratio to determine if the contamination is from unprocessed uranium ore or from mill processed material (tailings). Surface soil samples will be collected using a stainless-steel scoop or spoon and will be homogenized in a stainless-steel bowl and placed in a sample bag (see AVM SOP-5 in Appendix B).

Subsurface soil sampling for on-site ex-situ gamma soil screening will be performed for subsurface soil radiologic contamination characterization at up to 20 locations. The majority of the subsurface sample locations will be selected upon the completion of the supplemental characterization gamma scan survey. Some of the subsurface sample locations will be selected within the permit boundary in the Phase 1 reclamation Ball Mill Reject Pile, Ore Storage and Shaft #2 excavation areas. At these locations, the initial subsurface soil sample will be collected at one foot depth bgs. Where gamma measurements exceed the investigation level in the initial sample, an additional sample will be collected at 1 foot depth intervals until gamma levels are below the investigation level. At subsurface soil sample locations expected to have gamma levels below the RAL at six inches bgs based on the gamma scan survey, a subsurface soil sample will be collected initially at a depth of six inches. If ex-situ soil screening measurements exceed the RAL in this initial sample, an additional sample will be collected at a depth of 1-foot bgs. If the gamma levels continue to exceed the RAL, additional samples will be collected at 1-foot intervals until gamma levels are below the RAL The subsurface soil samples will be collected by excavating test pits using a backhoe (see AVM SOP-5) depending on Ra-226 levels, type of subsurface soil material and sampling depth.

The subsurface soil samples will be analyzed by on-site ex-situ gamma radiation soil screening (AVM SOP-4) to estimate Ra-226 concentrations. Surface soil samples and confirmatory subsurface soil samples in labeled sample bags with a completed chain of custody (COC), will be packaged in rigid-body containers, such as a cooler, for shipment to an off-site vendor laboratory for analysis. The external surface of the sample package is expected to have gamma radiation levels of less than 0.5 mrem/hr. The sample package will be transported to the laboratory as an excepted package (UN-2910 in accordance with 49 CFR 173.421). The off-Site vendor laboratory will document the condition of the environmental samples upon receipt. Samples collected during the project will be shipped within the sample holding time specified by the analytical method. Samples will be stored in a secure area between sample collection and shipment to the laboratory.

3.6 Field Decontamination

Field sampling equipment, such as stainless-steel scoops, bowls, and spoons, used for soil sampling will be decontaminated between sample locations. The soil sampling equipment decontamination will be conducted by removing loose visible soil by brushing it off, washing equipment with detergent water, and rinsing with distilled water. Other equipment used during investigation sampling activities that directly contact sample materials (such as the backhoe bucket) will be cleaned to remove loose visible soil contamination. Soil generated from excavation of test pits for subsurface investigation and excess soil samples will be put back into the hole that it came from. Equipment decontamination water/rinsate will be poured on top of excess soil and excess samples placed back into the test holes and pits. Personal protection equipment (PPE), such as gloves and Tyvek® coveralls will be brushed off and scanned for residual contamination and will be disposed of as solid waste.

Wastes generated because of Site activities will be handled in accordance with applicable environmental regulations. Generation of investigation-derived wastes such as equipment decontamination wastewater, soil cuttings, sample containers, and personal protective equipment will be minimal. Field personnel will characterize (as necessary) and dispose of decontamination wastewater and PPE in accordance with state and federal regulations. Used PPE and disposable sampling equipment are not considered hazardous and can be sent to a municipal landfill. Field personnel will use disposable PPE or dedicated equipment until it becomes unusable. Unless, specifically stated, personnel are to treat decontamination wastes as part of the investigation derived wastes. If in doubt about what to do, ask the On-site Safety Officer.

4 Sample Handling and Analysis

This section presents methods for sample handling and analysis based on the sampling objectives outlined in Section 2.

4.1 Soil Sample Analysis

Soil samples for the various investigations will be analyzed for the analytes listed below.

4.1.1 GEOTECHNICAL CHARACTERIZATION

Soil samples will be analyzed for geotechnical properties in two phases. Phase 1 includes the following:

- Sieve Analysis and Hydrometer (ASTM D7928) – particle size distribution
- Moisture Content (ASTM D2974) – soil moisture content of samples
- Atterberg Limits (ASTM D4318) – used to evaluate the shrink-swell potential of clays and clayey soil and its propensity to develop desiccation cracks during cyclical wetting and drying.
- Standard Proctor (ASTM D698) – used to define maximum dry density and optimum moisture content of the soil for specifying the percent compaction and in-place density of the soil.

Phase 2 testing will occur following the review of the results of Phase 1. SWCC and consolidation/swell testing will be limited to samples that contain fine-grained materials (passing a #200 sieve and less than 75 micron) are present. Phase 2 testing includes the following test methods:

- Consolidation/swell (D4186/4546) – on-dimensional swell or settlement potential of cohesive soils
- Strength (Direct Shear) (ASTM D6528) – remolded and recompacted to determine the shear strength of a soil or rock samples for estimates of strength parameters.
- Permeability Falling Head (ASTM D5084) – used to determine the hydraulic conductivity of saturated porous soil material.
- Soil Water Characteristic Curve Testing (ASTM D6836) – 8-point test used to determine the hydrological characteristics of unsaturated soil. A minimum of one sample location per borrow source area will be selected for this testing.

4.1.2 RADIOLOGICAL CHARACTERIZATION

All surface and subsurface samples for the source of contamination will be analyzed for Ra-226 with a reporting limit of 1.0 pCi/g using EPA method 901.1 modified for soil media. The soil samples for source of contamination (mine waste vs tailings) will be analyzed for uranium using EPA method E200.8/SW6020 and Th-230 by EPA method E908.0. The laboratory method, instruments and sensitivities will be in accordance with EPA protocols for environmental analysis. The laboratory used for environmental sample analysis will have appropriate Environmental Laboratory Approval Program certification or equivalent. Laboratory instrumentation will be calibrated by using National Institute of Standards and Technology (NIST) traceable standards.

4.1.2.1 Metals

A subset of samples will be analyzed for TAL metals plus uranium as follows:

- EPA method E200.8/SW6020 – aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, nickel, selenium, silver, thallium, uranium, vanadium, and zinc
- EPA method E200.7/SW6010 – calcium, magnesium, manganese, potassium, and sodium
- EPA method M7471A/7470A – mercury

4.2 Sample Labeling and Handling

4.2.1 SAMPLE LABELING

All samples will be labeled in a clear, precise way for proper identification in the field and for tracking in the laboratory. The samples will have identifiable and unique numbers. The labels for laboratory analyses contain the following information:

- Sample identification number
- Sample depth (as appropriate)
- Date/Time of collection
- Initials or name of person(s) collecting sample

Previous test pit and surface samples were named based on nearby Site features (e.g., a sample from the topsoil stockpile would start with TS). Because many of the mine features have been covered or moved during the 2010 construction, sample identification names will be more generic during the supplemental characterization.

4.2.2 CHAIN OF CUSTODY

Each sample will be properly documented to facilitate timely, accurate, and complete analytical analysis. The documentation system is used to identify, track, and monitor each sample from the point of collection through final data reporting. Where practicable, this documentation system may be electronic. COC protocols will be implemented and followed for samples submitted to off-site laboratories. A sample is considered to be in a person’s custody if it is: 1) in a person’s physical possession, 2) in view of the person after taking possession, or 3) secured by that person so that no one can tamper with it.

COC forms will be used for sending or shipping samples to an off-site laboratory to help verify that the integrity of samples is maintained. Each form will include the following information:

- Sample number
- Date/time of collection
- Sample depth
- Testing requirements
- Number of sample containers
- Recipient laboratories
- Signatures of parties relinquishing and receiving the sample at each transfer point

Whenever a change of custody takes place from the sampler to the laboratory, both parties will sign and date the COC form, with the relinquishing person retaining a copy of the form. For samples shipped by a courier, the laboratory that accepts the samples will inspect the COC form and all accompanying documentation to confirm that the information is complete and accurate before signing the COC form upon receipt of the samples. Any discrepancies will be noted on the COC form.

4.2.3 PACKAGING AND SHIPPING

After collection, samples will be properly stored to prevent degradation of the integrity of the sample prior to its analysis. Sampling personnel will inventory the sample containers at the Site prior to shipment to make sure all samples listed on the COC form are present.

All samples designated for off-site laboratory analysis will be packaged and either delivered or shipped in accordance with applicable U.S. Department of Transportation (DOT) regulations. Samples will be sealed in the appropriate sampling container. Samples will be containerized depending on media to include laboratory-supplied bottles/jars, plastic bags, or five-gallon buckets, as appropriate.

The originals of the analysis request and chain-of-custody forms will be sealed in a waterproof plastic bag and placed inside the shipping container prior to sealing the container. The shipping containers will be taped shut using strapping tape over the hinges and custody seals placed across the top and sides of the container. Custody seals will be used to preserve the integrity of each shipping container from the time the sample is collected until it is opened by the laboratory. Clear tape will be placed over the custody seals to prevent inadvertent damage during shipping. The tape should not allow the seals to be lifted off with the tape and reaffixed without breaking the seal.

5 Quality Assurance and Quality Control Measures

Quality Assurance/Quality Control (QA/QC) measures will be employed throughout the Supplemental Characterization to confirm that decisions are made based on data of acceptable quality.

Field QA/QC duplicates will be collected at a frequency of 10 percent of the total soil samples collected and will be sent to an offsite vendor laboratory for analysis.

The instrument QA/QC measures will include annual instrument calibrations, meeting specified scan MDC requirements, daily instrument operational function checks, and replicate field measurements. Instruments and equipment used will be operated, calibrated, and maintained according to AVM SOP-1 and/or the manufacturer's guidelines and recommendations. Equipment that fails calibration or becomes otherwise inoperable will be removed from service and segregated to prevent inadvertent use. Such equipment will be tagged to indicate that it should not be used until the problem is corrected. Equipment requiring repair or recalibration must be approved for use by AVM before being placed back into service. Equipment that cannot be repaired or recalibrated will be replaced. These measures are described in appropriate AVM SOP-1.

6 Reporting and Data Evaluation

The resource surveys, radiological scan data, radiological and metal sample data, geotechnical sample data, and field observations collected as part of this Work Plan will be used to evaluate if the testing objectives are met as listed in Section 2.0.

A *Supplemental Site Characterization Report* will be submitted to MMD and NMED within 120 days following the completion of the field program. This timeframe relies on four-week turnarounds for laboratory data analysis and laboratory data validation. The report will include:

- Summaries of ecological and cultural resource survey findings
- Geotechnical sampling results
- Radiological survey and sampling results and an evaluation of the lateral and vertical extent of mining-related materials at the site along with the volume of those materials outside of the current NESA-1 and NESA-2 repositories

Data collected and observations made during the supplemental characterization activities will support the update of the *Supplemental Closeout Plan*.

7 Summary

Stantec prepared this Work Plan at the request of UNC to summarize previous characterization and removal activities that occurred at the Section 27 Site and to provide a work plan for the upcoming supplemental characterization to be completed to update the *Supplemental Closeout Plan* for the Site.

Previous activities at the Site consist of the following:

- Site characterization, including ecological studies, cultural resource studies, radiological surveys, and sample collection for analysis of radiological, metals, metals leaching, and agronomic properties
- Construction activities that consolidated radiological material into two stockpiles that were covered with materials from a nearby borrow area and backfilling of some areas on-site
- Post construction radiological surveys.

Additional data needs to be addressed in the supplemental characterization at the Site include the following:

- Site reconnaissance to evaluate the proposed background reference area
- Ecological survey to identify if special status species are present prior to ground-disturbing activities
- Cultural resource survey outside of the permit boundary to protect and avoid cultural resources
- Supplemental characterization of radiological constituents and metals to delineate the lateral and vertical extents of materials that exceed the RAL and compare metals to state standards
- Geotechnical sampling to evaluate the geotechnical properties of borrow materials to be used for backfill and cover and mining-related materials to be placed in an on-site repository.

Stantec will develop a *Supplemental Site Characterization Report* describing Site observations and the results of Site surveys and sampling. The report will be submitted to MMD.

8 References

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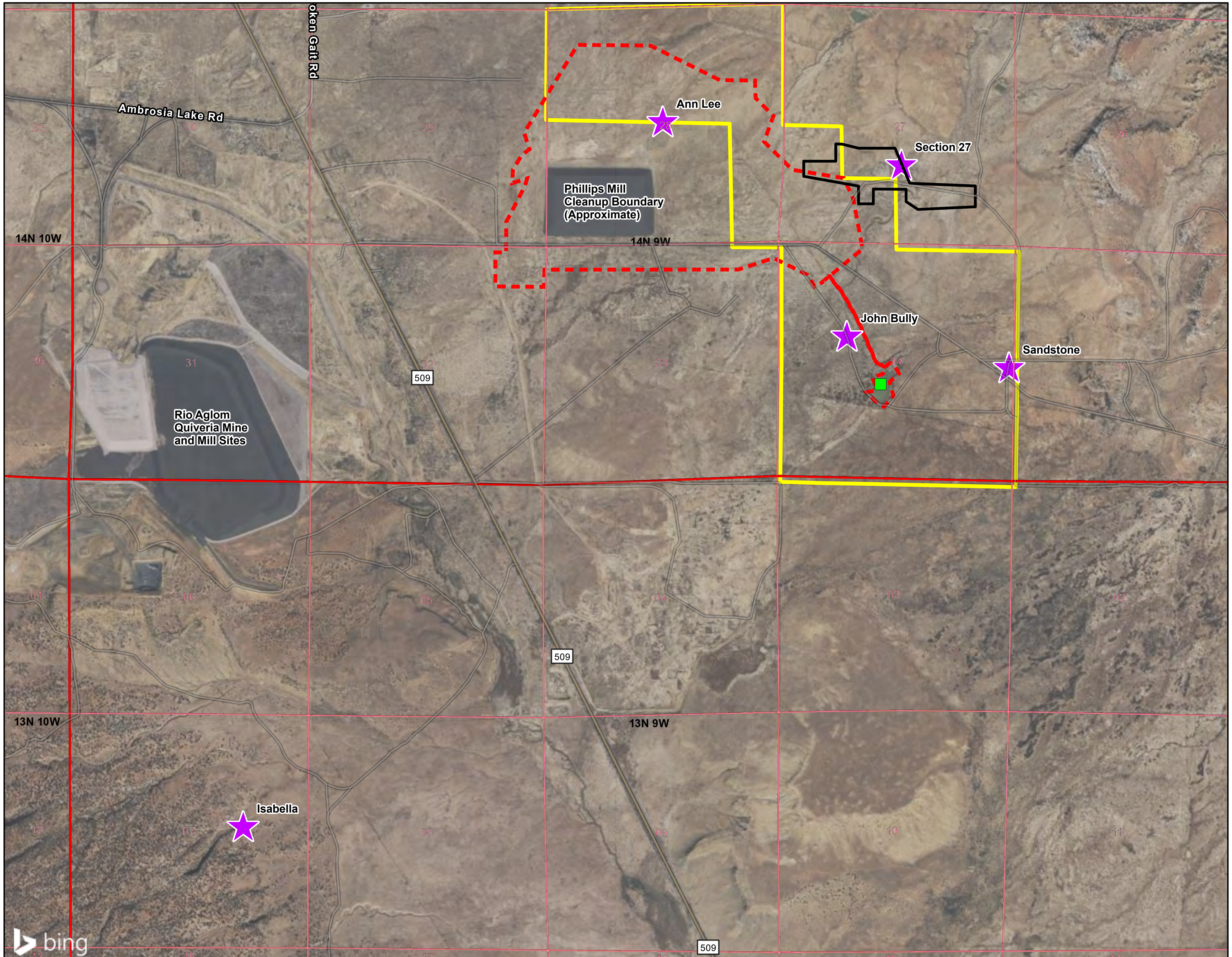
FIGURES



Stantec

- Former UNC Mines (Approximate)
- Voght Tank
- Phillips Mill Limit of Excavation (Approximate)
- Section 27 Permit Boundary
- GE/UNC Property Boundary (Approximate)
- Approximate Section Boundary & Number

Notes
1. Coordinate System: NAD 1983 StatePlane New Mexico West FIPS 3003 Feet
2. Data Sources: Stantec
3. Background: Georeferenced image

N

0 1,200 2,400 Feet

(At original document size of 11x17)
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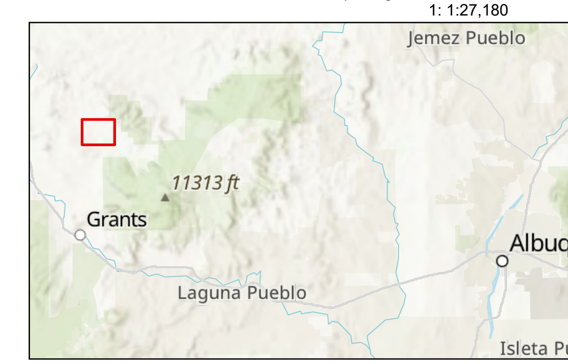

Project Location
Chinle County, NM

Prepared by JBA on 2023-10-06
TR by EDZ on 2023-10-06
IR by KJ on 2023-10-06

Client/Project 182922679

Client: General Electric Company
Project: Section 27 Supp. Characterization

Figure No.
1

DRAFT

Title
Section 27 Site Map

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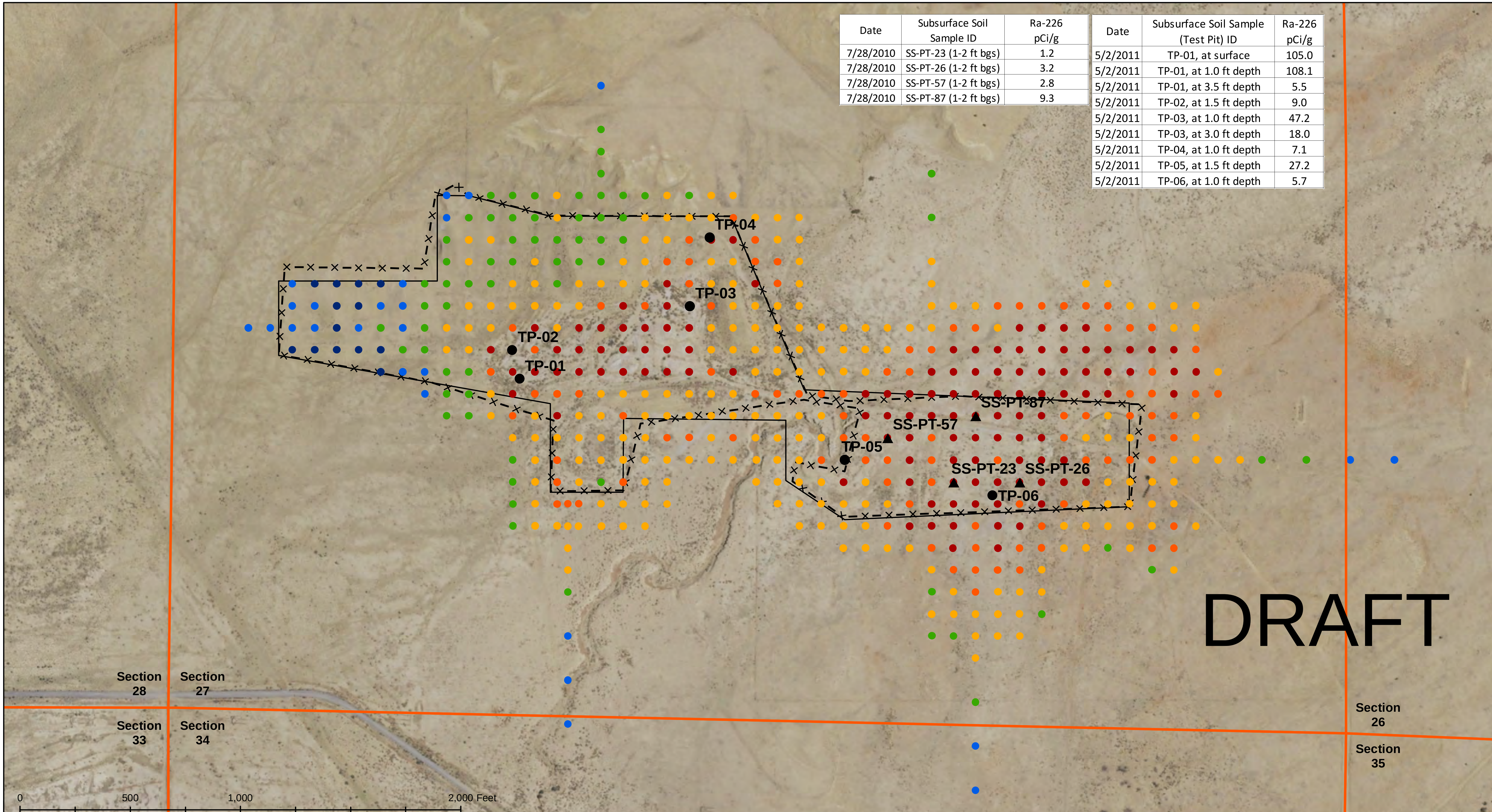


Date	Subsurface Soil Sample ID	Ra-226 pCi/g
7/28/2010	SS-PT-23 (1-2 ft bgs)	1.2
7/28/2010	SS-PT-26 (1-2 ft bgs)	3.2
7/28/2010	SS-PT-57 (1-2 ft bgs)	2.8
7/28/2010	SS-PT-87 (1-2 ft bgs)	9.3

Date	Subsurface Soil Sample (Test Pit) ID	Ra-226 pCi/g
5/2/2011	TP-01, at surface	105.0
5/2/2011	TP-01, at 1.0 ft depth	108.1
5/2/2011	TP-01, at 3.5 ft depth	5.5
5/2/2011	TP-02, at 1.5 ft depth	9.0
5/2/2011	TP-03, at 1.0 ft depth	47.2
5/2/2011	TP-03, at 3.0 ft depth	18.0
5/2/2011	TP-04, at 1.0 ft depth	7.1
5/2/2011	TP-05, at 1.5 ft depth	27.2
5/2/2011	TP-06, at 1.0 ft depth	5.7

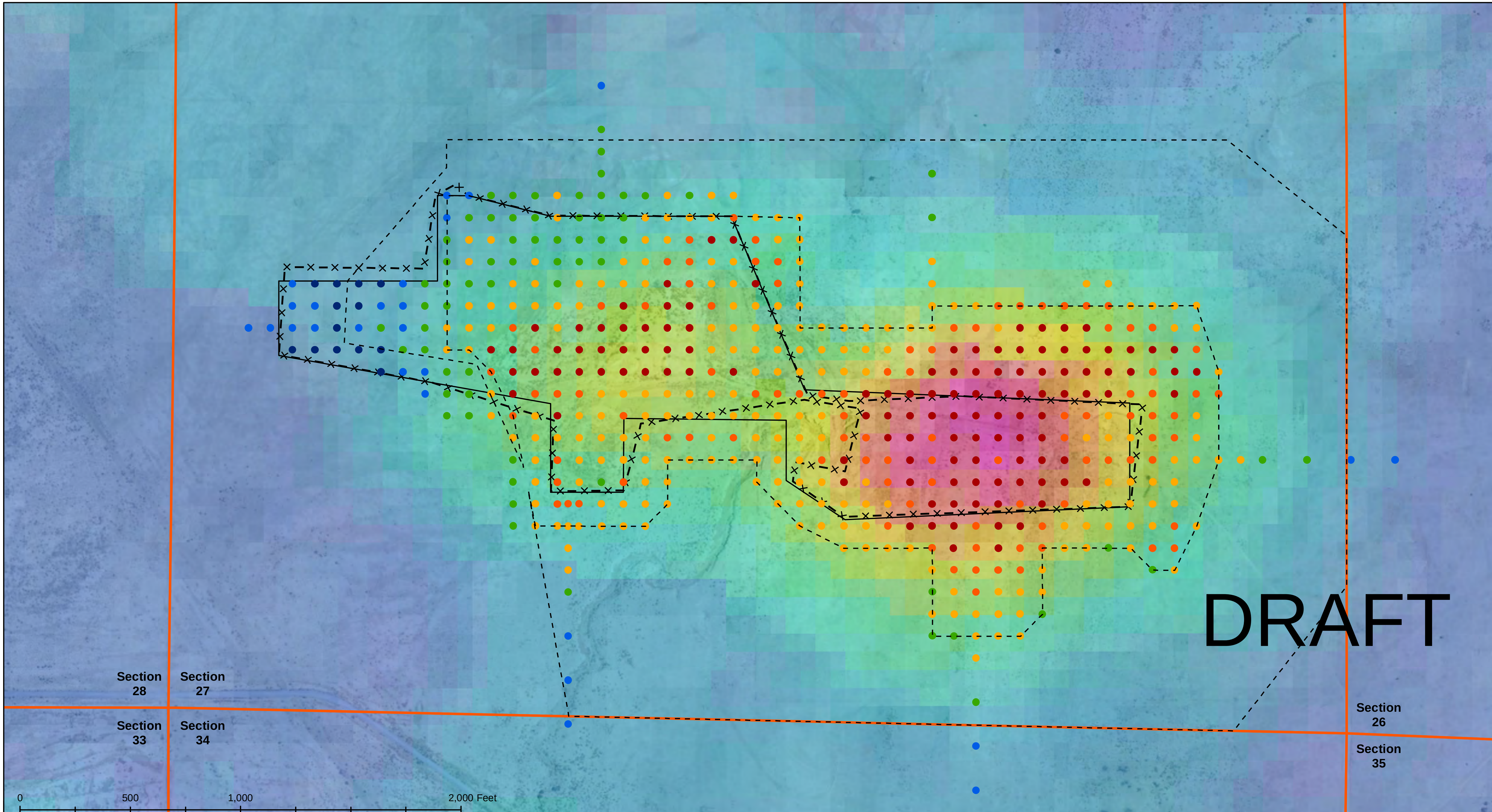
AVM Environmental Services, Inc.

Figure 2
Section 27 Mine Site
2010/2011 Static Gamma Survey and Subsurface Soil Sample & Test Pit Locations and Data

Legend

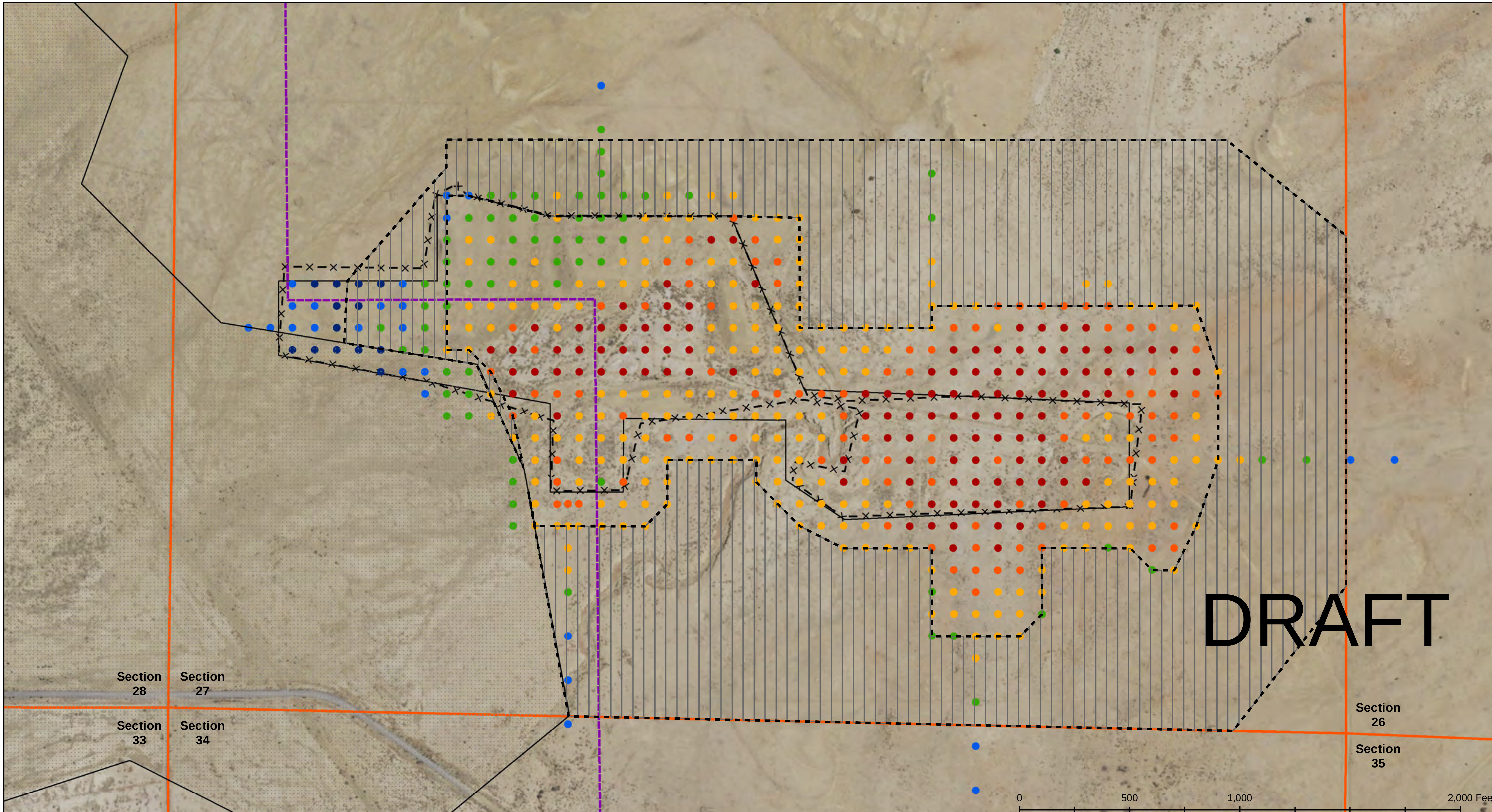
Estimated Ra-226 pCi/g

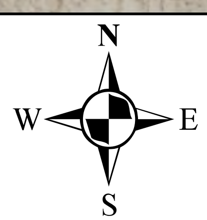
- <4.0 pCi/g
- 4.1 - 6.5 pCi/g
- 6.6 - 10.0 pCi/g
- 10.1 - 25.0 pCi/g
- 25.1 - 50.0 pCi/g
- >50 pCi/g
- Section 27 Fence
- Section 27 Permit Work Boundary
- 2011 Test Pit (TP) Location
- 2010 Subsurface Soil Sample (SS-PT) Location
- Approx. Section Boundary



AVM Environmental Services, Inc.

Figure 3
Section 27 Mine Site
2010/2011 Static Gamma Survey and EPA ASPECT Survey





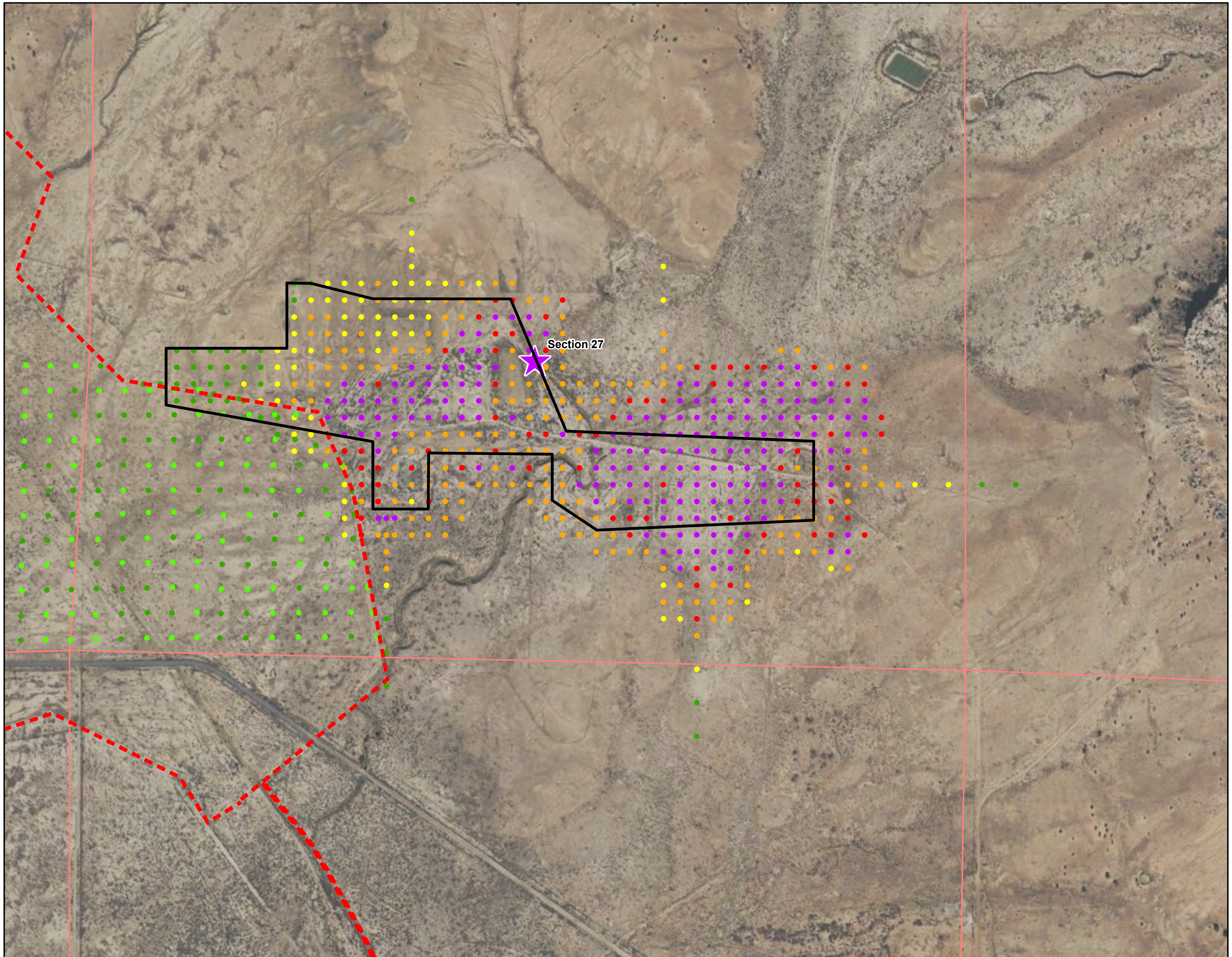
AVM Environmental Services, Inc.

Figure 4
Section 27 Mine Site
2010/2011 Static Gamma Survey and
Proposed Supplemental Scan Area with 50ft Scan Transects

Legend

Estimated Ra-226 pCi/g

- <4.0 pCi/g
- 4.1 - 6.5 pCi/g
- 6.6 - 10.0 pCi/g
- 10.1 - 25.0 pCi/g
- 25.1 - 50.0 pCi/g
- >50 pCi/g
- Section 27 Fence
- Proposed Supplemental Scan Area
- Phillips Cleanup Boundary
- Phillips Soil Verification Boundary
- Approx. Section Boundary



Stantec

- ★ Former UNC Mines (Approximate)
- Phillips Mill Limit of Excavation (Approximate)
- Section 27 Permit Boundary

Theoretical Gamma Scan Results
In Picocuries Per Gram (pC/g)

- 0 - 1.5 (Background Threshold Value)
- 1.6 - 6.4 (removal Action Level)
- 6.5 - 10
- 10.1 - 20
- 20.1 - 30
- 30+

Notes
1. Coordinate System: NAD 1983 StatePlane New Mexico West FIPS 3003 Feet
2. Data Sources: Stantec
3. Background: Georeferenced image

N

0 300 600 Feet
(At original document size of 11x17)
1:7,200

Project Location
Chinle County, NM

Prepared by JBA on 2023-05-24
TR by EDZ on 2023-05-18
IR by KJ on 2023-05-18

Client/Project 182922679

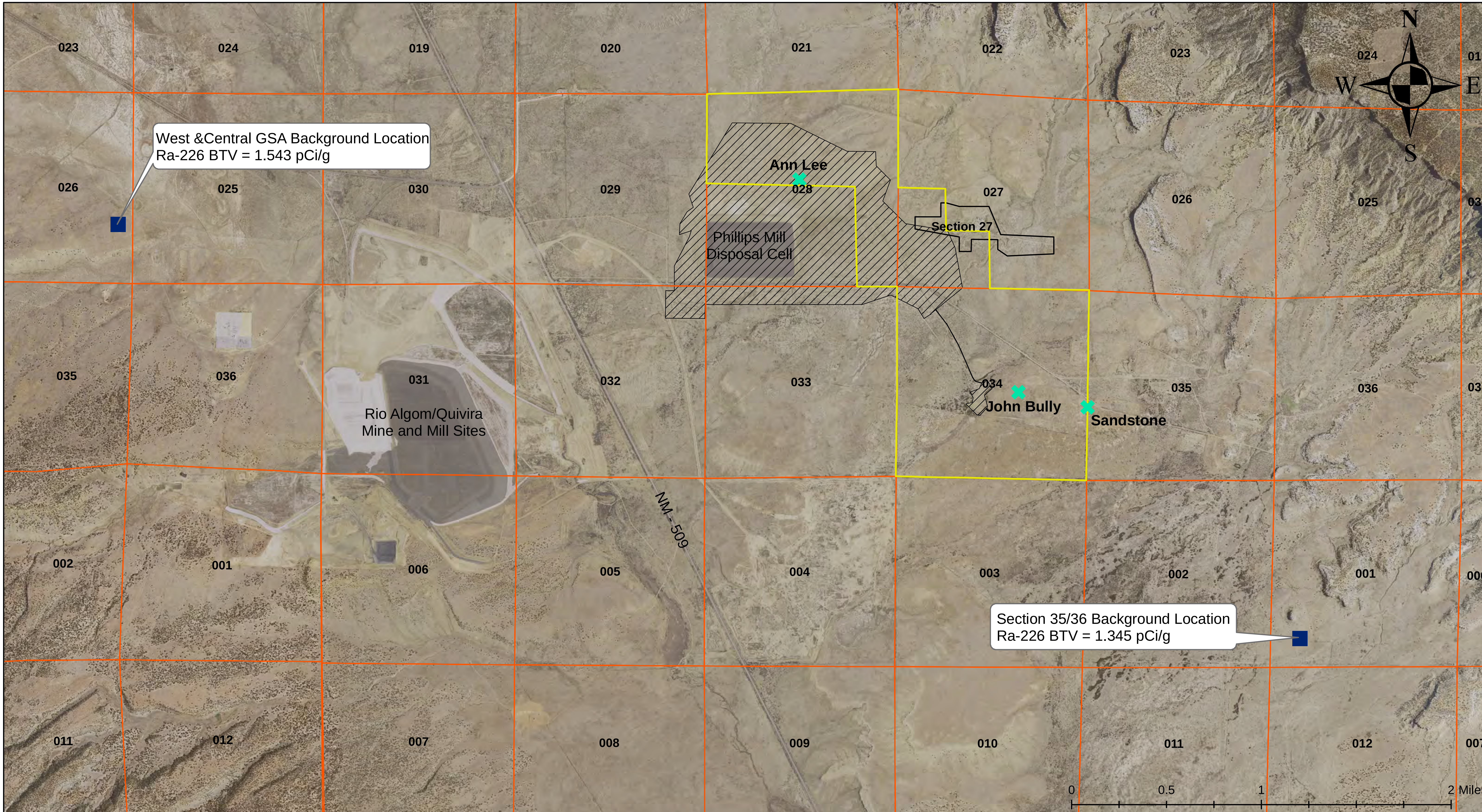
Client: General Electric Company
Project: Section 27 Supp. Characterization

Figure No.
5

DRAFT

Title
Section 27 and Philips Mill Radiological Surveys

U:\182922679_ArcPro\MyProject\New_Mexico_Gamma_Radiationt.aprx Project_Scoping_Section27_Zoom_in_WorldIMG20230524 Revised: 2023-05-24 By: jallred



AVM Environmental Services, Inc.

Figure 6
San Mateo Creek Basin
GSA Background Locations

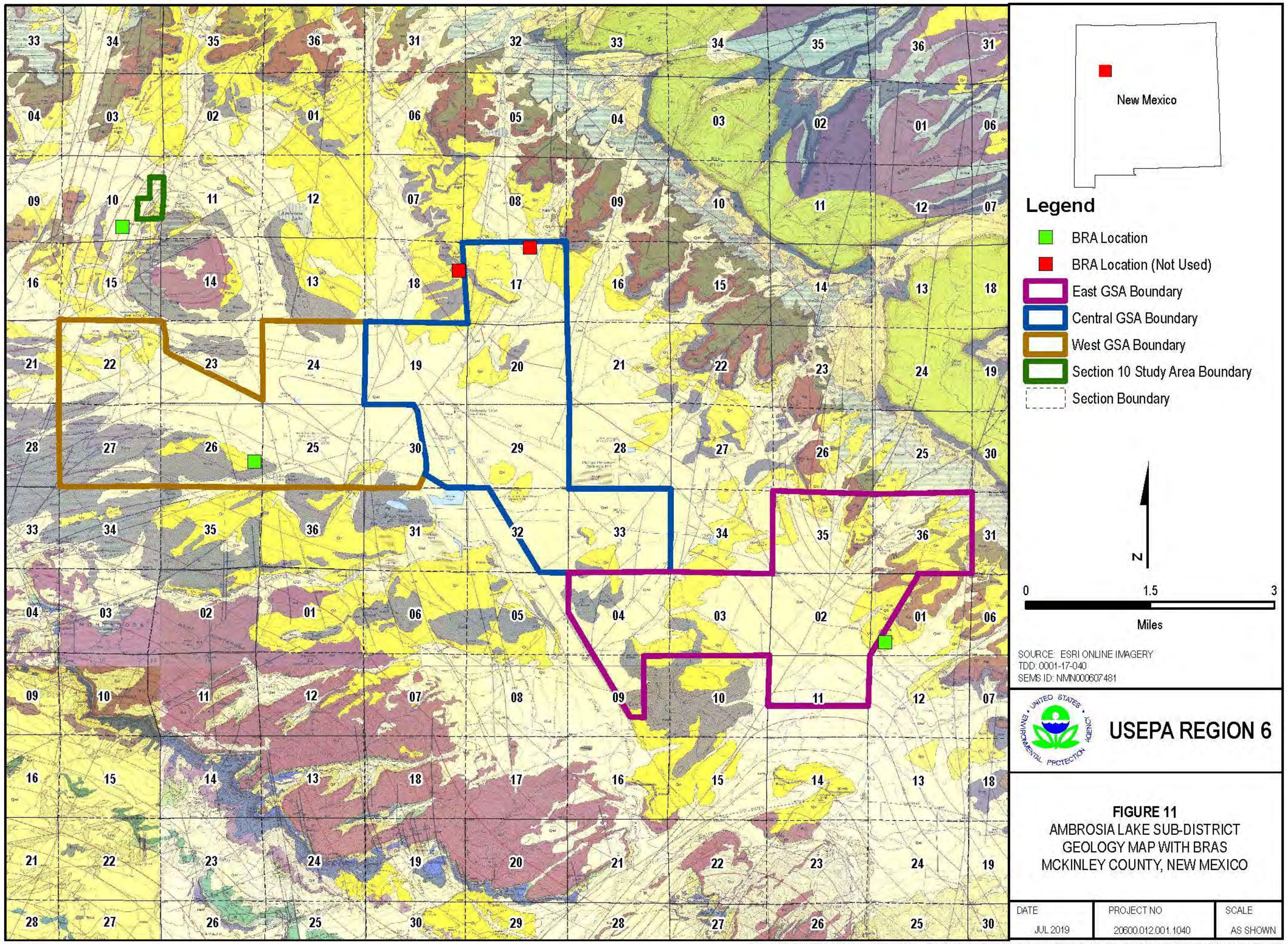
August 2021

Legend

- Approximate Site Locations
- West/Central GSA & 35/36 Background Location
- Approximate UNC Property Boundary
- Section 27 Mine Permit Work Boundary
- Approximate Phillips Mill Limit of Excavation
- 033 Approximate Section Boundary & Number

Figure 7: Geology in Areas of Section 27 Mine Site and Background Reference Area (BRA) Used for West and Central GSAs. Background Reference Area is in Section 26 in Western Area of Map

Figure from Weston Solutions. 2019. Removal Site Evaluation Report for Tronox Navajo Area Uranium Mines West Geographic Sub-Area (GSA) McKinley County, New Mexico



APPENDICES

Appendix A Section 27 Site History

Table of Contents

LIST OF FIGURES

Acronyms / Abbreviations

ALSA	Ambrosia Lake Study Area
DOE	Department of Energy
EPA	U.S. Environmental Protection Agency
HPD	New Mexico Historic Preservation Division
MMD	New Mexico Mining and Minerals Division
NESA	Non-economic Storage Area
NMED	New Mexico Environmental Department
RSE	Enter Full Name
SOW	Statement of Work
SPLP	Synthetic Precipitation Leachate Procedure
Stantec	Stantec Consulting Services Inc.
UNC	United Nuclear Corporation

1 Introduction

In a letter dated October 14, 2022, the New Mexico Mining and Minerals Division (MMD) requested that United Nuclear Corporation (UNC) revise the *Supplemental Closeout Plan, Section 27 Mine Site, New Mexico, Permit No. MK005RE* (*Supplemental Closeout Plan*) dated June 27, 2011. The United States Environmental Protection Agency (EPA) also provided UNC a draft Statement of Work (SOW) for a Removal Site Evaluation (RSE) at former UNC mine sites in the Ambrosia Lake Study Area (ALSA), McKinley County, New Mexico on May 17, 2021, including the Section 27 mine site (Site). During UNC telephone communication with EPA (Region 6) on March 31, 2023, the EPA indicated that UNC should proceed with work at Section 27 under state oversight and surface investigation of other UNC mines in the ALSA under EPA oversight.

UNC contracted Stantec Consulting Services Inc. (Stantec) to update the *Supplemental Closeout Plan*, including conducting supplemental characterization activities, at the Site. This memorandum summarizes past data collection and cleanup efforts at the Site.

2 Summary of Previous Work at Site

The mineral lease for Section 27 covered approximately 200 acres in the southern half of the section. The Section 27 mine site is inactive, and the mining features cover an area of approximately 14 acres. Site assessment and reclamation at the Site has been ongoing since the 1980s when UNC completed work to remove buildings, equipment, and debris as well as sealing off shafts and vent holes. Prominent materials characterization at the site occurred in 2007 and 2008 followed by site cleanup activities including consolidating and capping of waste materials onsite in 2010. Data developed during previous activities at the site and data developed during upcoming supplemental characterization activities will support the update to the Supplemental Closeout Plan.

2.1 Resource Surveys

Ecological and cultural resource surveys were completed at the Site prior to ground-disturbing activities. Cedar Creek Associates (Cedar Creek) conducted vegetation and wildlife evaluations and provided revegetation recommendations following a 2005 site assessment (Cedar Creek Associates, 2006). The assessment found that there were no threatened and/or endangered species in the vicinity of the Site; however, several species may occasionally migrate through the Site, including the peregrine falcon and bald eagle.

A cultural resource survey was completed at the Site in 2005. The survey covered the area of the permit boundary at that time along with review of records for other nearby cultural resource surveys and a records request from the New Mexico Historic Preservation Division (HPD) of the New Mexico Department of Cultural Affairs. New Mexico HPD provided comments on the Site pertaining to two archeological sites north of Non-economic Storage Area #1 (letter dated April 13, 2004). HPD requested that an archeologist assess the condition of these two sites and any impacts from the proposed closeout activities. Lone Mountain Archeological Services, Inc. completed a cultural resources survey in 2005, and issued an assessment that indicated no cultural properties were identified in the Area of Potential Effect and there was no concern regarding the two archaeological sites or the Site with respect to the proposed closeout activities at that time (Lone Mountain Archaeological Services, April 2005). Both archaeological sites were outside of the permit boundary and any area that was planned to be affected by the closeout activities.

2.2 Material Characterization Report

In 2007, the Materials Characterization Work Plan (MWH, 2007a) was prepared in response to an MMD request for additional characterization of the non-economic material piles and the topsoil sources. Additionally, UNC sampled the ore stockpiles, earthen material in the ball mill rejects piles, and a background reference area.

The 2007 Material Characterization Report (MWH, 2007b) provides details and results of the radiological survey and soil sampling conducted in 2007. The radiological survey was designed to identify gamma exposure rates in each survey area. Gamma exposure rate surveys were conducted as follows:

- Exposure rates were measured in the background reference area, topsoil stockpiles, non-economic material piles, and ore stockpile
- Measurements were collected on a grid with an interval that averaged 50 feet
- Three measurements were made at each location: (1) shielded contact with the ground; (2) shielded one-meter above ground; and (3) unshielded one-meter above ground.
- Unshielded background gamma radiation exposure rates determined at the time (one-meter above ground surface) ranged from 20 microRoentgen per hour (µR/hr) to 38 µR/hr.

Soil analyses included the following:

- Radiochemical analyses (radium-226 [Ra-226], thorium-230, uranium, and gross alpha) – 46 surface and subsurface samples at 20 test pit locations, including four test pit locations in a background reference area west of the site.
- Metals analyses – synthetic precipitation leachate procedure (SPLP) analyses were completed to evaluate potential contribution of soil and sediment to groundwater and surface water (SPLP analytes included major cations, major anions, metals, and radiochemical analyses). SPLP was completed on samples collected from the background reference area, topsoil stockpiles, non-economic material piles, and ore stockpiles. It is important to note that when comparing the SPLP results to New Mexico surface water standards, the only constituent with concentrations greater than the surface water standards for livestock watering, wildlife, and aquatic life was gross alpha and no constituent concentrations exceeded the New Mexico groundwater standards for irrigation use.

- Agronomic analyses of surface and subsurface samples from the background reference area, topsoil stockpiles, non-economic material storage areas, and ore stockpiles were completed to identify potential hazards to plants established based on the concentrations of constituents present. The following constituents were tested and were found to be significantly lower concentrations than toxicity levels: arsenic, cadmium, calcium, chlorine, chromium, lead, mercury, nickel, selenium, uranium, and zinc. The sodium adsorption ratio (soluble salts) concentrations in the ore stockpile exceeded the recommended range. Ra-226, thorium-230, and possibly sulfate concentrations were elevated in the non-economic storage area (NESA), ore stockpiles, and ball mill rejects piles. Materials from the ore stockpiles and ball mill rejects piles were later transferred to trenches in the NESA during the 2010 site closeout, and covered by 36 inches of borrow material and, therefore, are unlikely to impact revegetation.

2.3 2010 Site Closeout

In 2010, UNC began work outlined in the MMD-approved Closeout Plan and Reclamation Permit. This plan included reclamation of disturbed areas and demolition of site features as well as a post-construction radiological survey. Activities were performed in accordance with the Section 27 Mine Closeout Plan (MWH, 2008) between May 24 and August 13, 2010. Major activities completed during construction included:

- Regrading of non-economic storage areas
- Removal, consolidation, and on-site capping of the ore stockpiles, ball mill rejects piles, and other piles of potential non-economic materials
- Removal, consolidation, and on-site capping of the remaining foundations on-site
- Sealing all shafts and vent holes
- Revegetating all disturbed areas

The Non-Economical Storage Area 1 (NESA-1) was regraded to meet slope requirements. During excavation at NESA-1, non-economical material from reclamation activities throughout the site were placed within NESA-1, including material from the area of the North Shaft #2, the Ball Mill Reject Pile, East and West Ore Stockpiles, and concrete foundation materials. The Construction Completion Report (MWH, 2010a) identifies that the volume of material in NESA-1, including a 3-foot-thick cover of clean material, was 39,967 cubic yards.

Non-economic Storage Area 2 (NESA-2) was regraded and during the excavation, additional debris from reclamation activities throughout the Site were placed within NESA-2, including telephone poles, angular metal frames, and the largest pieces of demolished concrete foundations. Topsoil was then placed in a 6-to-8-inch lifts on NESA-2 to reach a total design thickness of 36 inches. The Construction Completion Report identifies that the volume of material in NESA-2, including the topsoil lift, was 10,360 cubic yards of material.

Scan gamma radiation exposure rate surveying (gamma survey) was conducted during construction to guide excavation of mine spoil materials within the disturbed areas and to verify that materials with radionuclide levels greater than the range of background levels were removed. The aim of this radiological survey was to verify gamma readings from the reclaimed ball mill reject piles and ore stockpiles were less than gamma readings collected in the background reference area. Figures 1 through 3 show excavation control measurements collected in 2010 and 2011. The estimated Ra-226 concentrations shown in the figures range from <6.4 pCi/g to greater than 30 pCi/g. Additional test pits will be required in some areas to estimate the vertical extent of material exceeding the Reclamation Action Levels (RALs) described below.

A gamma survey was completed with an unshielded detector in May 2010 to supplement the background gamma survey conducted in 2007. Twenty-eight locations on a regular grid were scanned, with 80-foot node spacing within the same background reference area. Background gamma radiation exposure rates ranged from 21 µR/hr to 39 µR/hr, similar to the 2007 background survey.

To confirm that a 36-inch cover would attenuate the gamma radiation levels to background range, a 50-foot grid exposure rate survey was performed on the graded surface of the NESA-1 and NESA-2 piles after consolidation of excavated soil and grading and prior to placing a 3-foot cover system on top. Survey measurements indicated that a 36-inch cover would attenuate the gamma radiation.

A post-reclamation verification gamma survey was conducted after completion of the closeout construction activities over the disturbed areas. The areas surveyed included the NESA covers and excavated areas (Ball Mill Reject Piles, Ore Stockpiles, miscellaneous piles, and Shaft 2 Area). Survey locations and results are shown on Figure 4. The results of the collimated/shielded gamma survey (with measurement height of one meter above the ground surface) indicate:

- Background reference area: 5 to 12 µR/hr
- Primary areas (Ball Mill Reject, Ore Stockpiles, and NESA covers): 6 to 11 µR/hr
- Miscellaneous piles/areas: 6 to 13 µR/hr

The post-reclamation exposure rates exceeded the background range in two areas: southwest and northeast of Vent 3 where rates were up to 13 µR/hr (Figure 4). All other collimated exposure rate measurements were within the range of background levels.

2.4 2011 Supplemental Closeout Plan

At the New Mexico Environmental Department's (NMED) request, a supplemental gamma characterization survey was conducted to determine: 1) the vertical extent of soils with gamma radiation exposure rate levels exceeding 150 µR /hr at selected areas within the work permit area boundary, and 2) the lateral extent of gamma radiation exposure rate levels exceeding 250 µR/hr outside the work permit boundary (MWH, 2011). Field personnel conducted the excavation of test pits at six different locations within the permit boundary. These pits were used to collect soil samples and determine the vertical extent of contamination. Samples were collected from a depth of 1 foot or shallower depending on the location of native soils. Soil samples were screened to determine Ra-226 content based on a correlation between count rate for the gamma meter and soil content developed using three different soils with known concentrations, with the target concentration approximately 30 pCi/g. The 2011 survey also included a gamma exposure rate survey that was conducted following 100-foot node spacing. This survey was conducted outside the mine permit boundary and included the use of a Ludlum Model 19 µR similar to the 2010 survey. Results of the 2010 and 2011 surveys were converted to estimated Ra-226 concentrations utilizing a correlation of exposure rates to laboratory Ra-226 concentrations and are shown on Figure 5. Estimated Ra-226 concentrations shown on Figure 5 are greatest in the central areas of the site and indicate elevated Ra-226 concentrations extend beyond the permit boundary.

Modeling of geotechnical slope stability was completed for the reclaimed configurations of the NESA-1 and NESA-2 piles as part of the Supplemental Closeout Plan (MWH, 2011). The models indicated that the regraded configurations resulted in factors of safety greater than 2.5. Long-term stability generally requires a factor of safety of 1.5, the configurations of the piles well exceeded 1.5, indicating that they were safe.

3 Summary of Previous Work Near the Site

The site of the former Phillips Uranium Mill (Phillips Mill) is west of the Section 27 site. The Phillips Mill operated between 1957 and 1963 and processed approximately 3 million tons of ore during that period. Figure 6 includes a 1973 aerial photograph of the mill operations area and the proximity to the Site. Results of a 1981 aerial radiological survey are shown on Figure 7. The survey indicated elevated exposure rates were present at and surrounding the Phillips Mill with windblown material extending east and northeast of the Phillips Mill to the Site. As described below, cleanup efforts at the Phillips Mill extended to an area just inside of the current Section 27 permit boundary.

The Department of Energy (DOE) evaluated the Phillips Mill for cleanup in the 1980s and 1990s. The DOE established a background Ra-226 concentration of 1.2 pCi/g for the Phillips Mill site and identified cleanup criteria for mill related impacts of 5 pCi/g plus background for the surface and 15 pCi/g plus background for subsurface. The DOE evaluation established a boundary of windblown mill-related contamination, and the boundary was set at 5 pCi/g based on surface gamma measurements that were correlated to laboratory Ra-226 measurements and potentially only in the area where DOE's prior assessment attributed impacts to the mill. The boundary is shown on Figure 8 along with planned excavation depths throughout the Phillips Mill site. The planning document for the cleanup (Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings at Ambrosia Lake, New Mexico (DOE, 1990)) discusses DOE's prior assessment to attempt to separate impacts from the mill site from impacts from the nearby mine sites (including Section 27) using a ratio of Ra-226 to uranium-238 (U-238) to differentiate between ore and tailings materials (ore has a different ratio than tailings). Statements in the Ambrosia Lake, New Mexico Final Completion Report (DOE, 1996) are not clear on whether the ratio was used to evaluate mill vs mine impacts during tailings and waste rock delineation and cleanup.

DOE conducted the site cleanup at Phillips Mill between 1988 and 1994, including the removal of over 1.9 million cubic yards of mill-related materials from 570 acres. Figure 9 shows the limit of the excavation. The cleanup extended into the current permit boundary of Section 27. Mill-related surface/windblown material near the Site was generally assumed to be 6 inches deep, and a scraper was used to remove material in those shallow areas. Following the removal, verification gamma surveys and limited verification sampling were completed in 100 square meter grids within the limit of the excavation. Figure 10 shows the estimated Ra-226 concentrations in the grid areas near the Site; verification Ra-226 concentrations averaged 1.7 pCi/g and the highest concentration was 5.0 pCi/g.

4 Conclusion

Stantec prepared this summary of previous characterization and removal activities that occurred at the Site to support the Supplemental Characterization Work Plan.

Previous activities at the site consist of the following:

- Site characterization including ecological studies, cultural resource studies, radiological surveys, and sample collection for analysis of radiological, metals, metals leaching, and agronomic properties
- Construction activities that consolidated radiological material into two stockpiles that were covered with materials from a nearby borrow area and backfilling of some areas on site
- Post construction radiological surveys.

5 References

Cedar Creek Associates, 2006. Vegetation & Wildlife Evaluations / Revegetation Recommendations

Department of Energy (DOE), 1990. Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico. September

Department of Energy (DOE), 1996. Ambrosia Lake, New Mexico Final Completion Report. V. 4. August

Energy, Minerals & Natural Resources Department – Mining and Minerals Division (MMD) & New Mexico Environmental Department (NMED), 2016. Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico. March

Lone Mountain Archaeological Services, 2005. An Intensive Cultural Resource Survey of 13.36 ha (33 ac) for the Proposed Remediation of the Section 27 Uranium Mine Near Ambrosia Lake in McKinley County, New Mexico

MWH, 2003. Section 27 Mine Site Assessment

MWH, 2007a. Section 27 Materials Characterization Work Plan

MWH, 2007b. Section 27 Materials Characterization Report

MWH, 2008. Section 27 Closeout Plan

MWH, 2010a. Section 27 Construction Completion Report

MWH, 2010b. Post-Reclamation Risk Evaluation, Section 27 Mine, New Mexico

MWH, 2011. Section 27 Supplemental Closeout Plan

FIGURES

Figure 1: Section 27 Mine Site Excavation Control Estimated Subsurface Ra-226 Measurements During 2010 Construction Activities

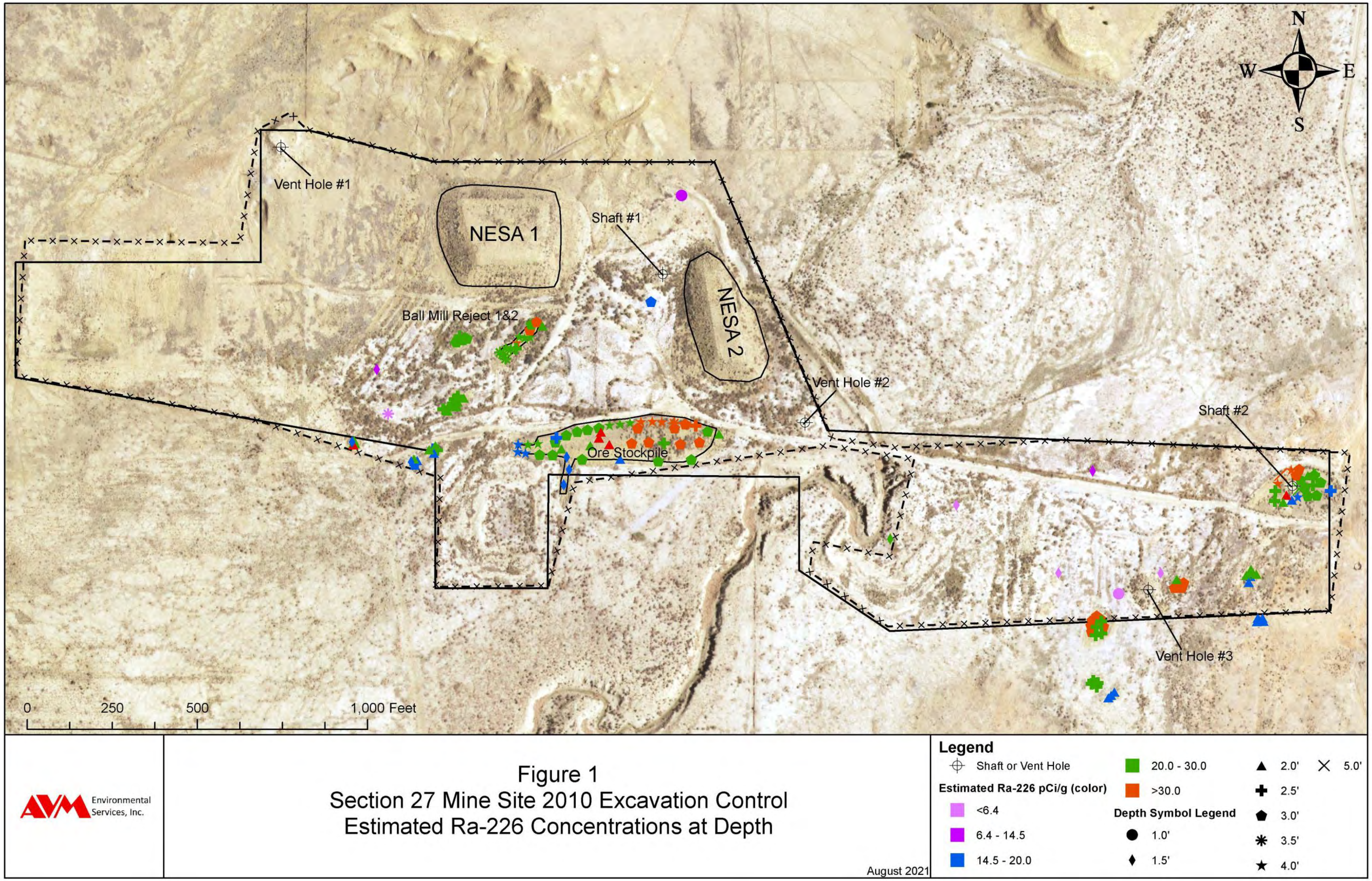


Figure 2: Section 27 Mine Site Excavation Control Estimated Subsurface Ra-226 Measurements During 2010 Construction Activities in Western Area of Site

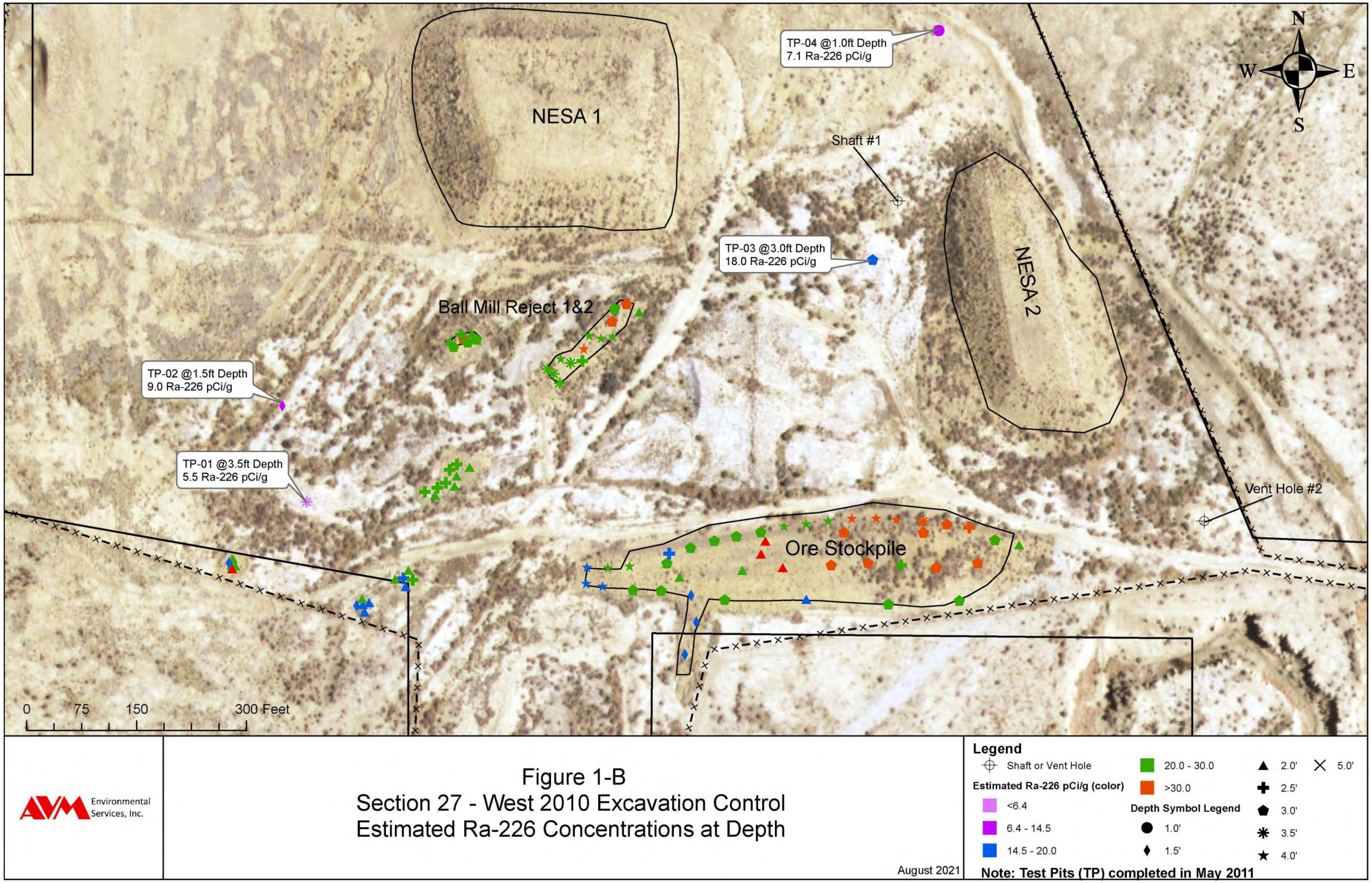


Figure 3: Section 27 Mine Site Excavation Control Estimated Subsurface Ra-226 Measurements During 2010 Construction Activities in Eastern Area of Site

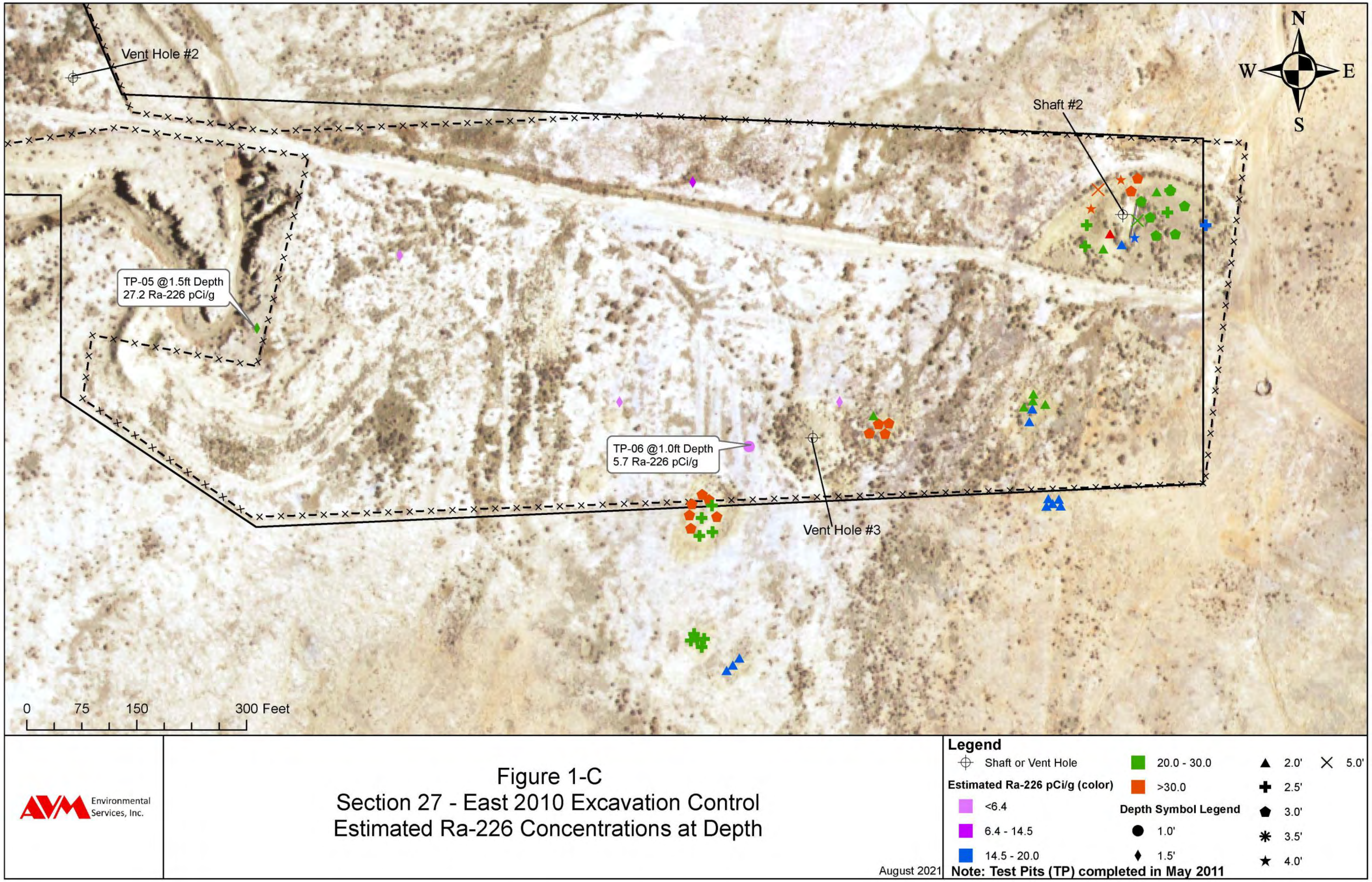


Figure 4: Section 27 post 2010 Construction Surface Verification Survey Measurements. Image from Section 27 Supplemental Closeout Plan (MWH, 2011)

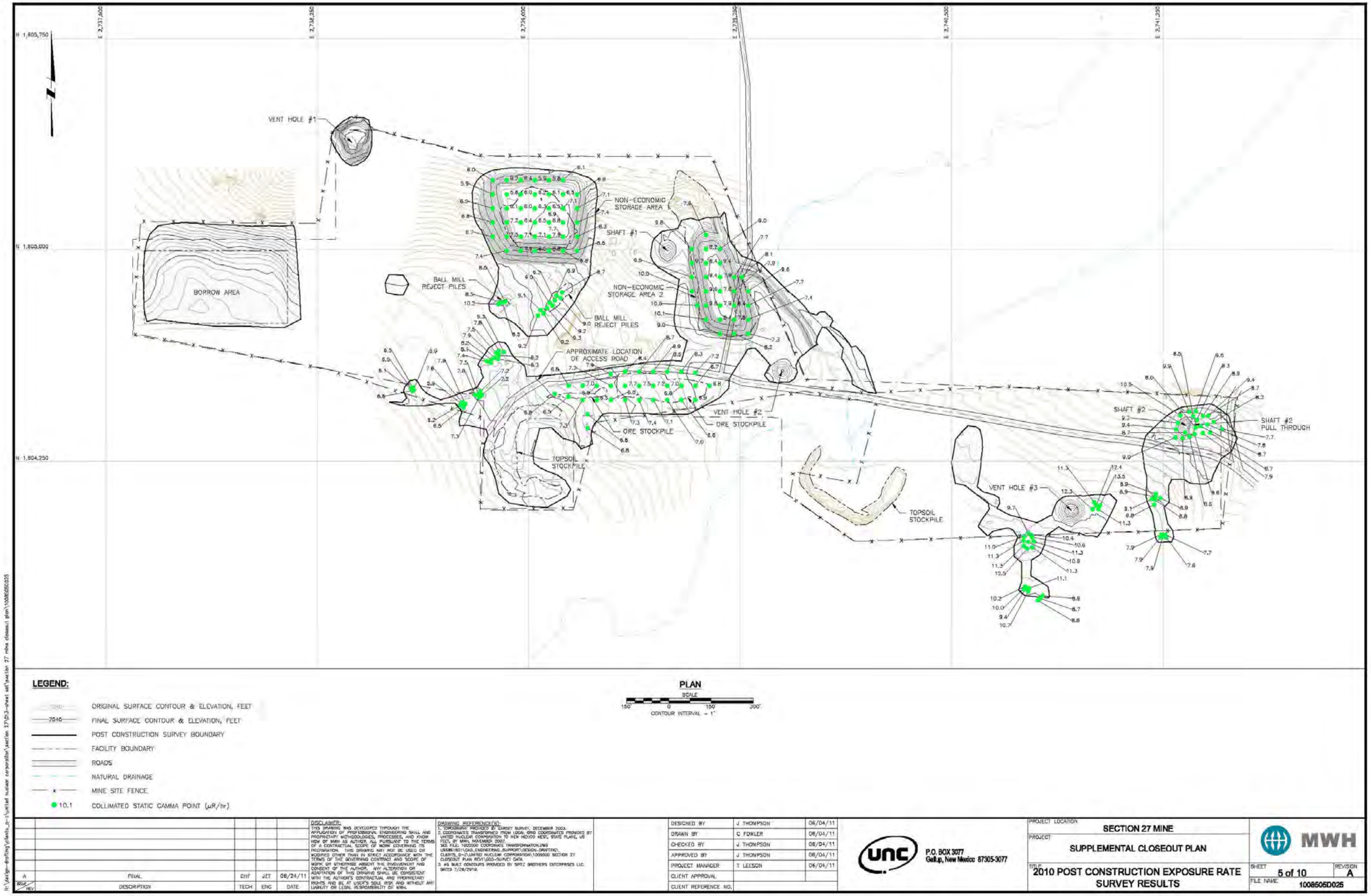
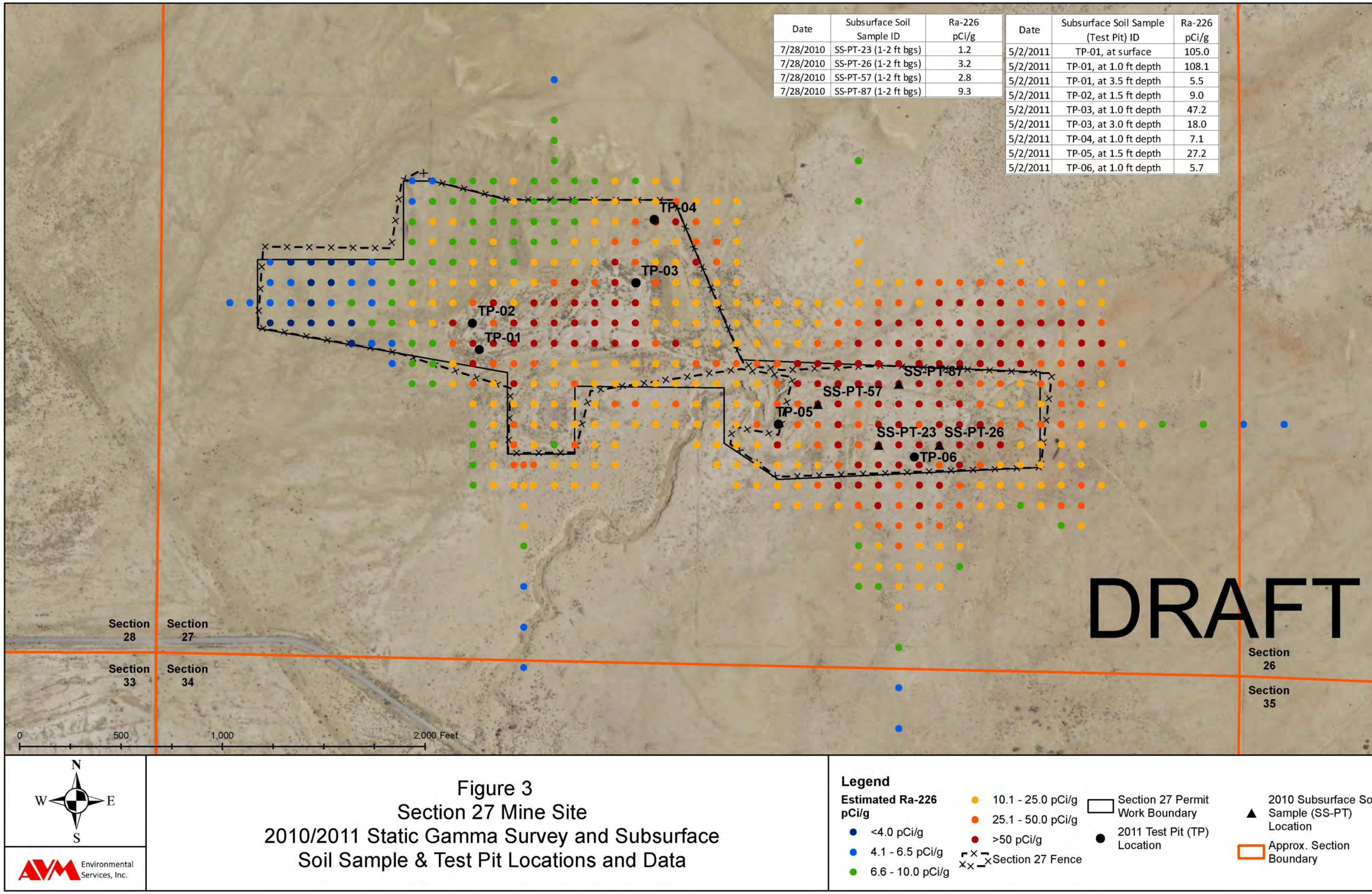


Figure 5: Section 27 2010/2011 Static Gamma Survey Locations, Estimated Ra-225 Concentrations, and Subsurface Test Pit Locations



Date	Subsurface Soil Sample ID	Ra-226 pCi/g
7/28/2010	SS-PT-23 (1-2 ft bgs)	1.2
7/28/2010	SS-PT-26 (1-2 ft bgs)	3.2
7/28/2010	SS-PT-57 (1-2 ft bgs)	2.8
7/28/2010	SS-PT-87 (1-2 ft bgs)	9.3

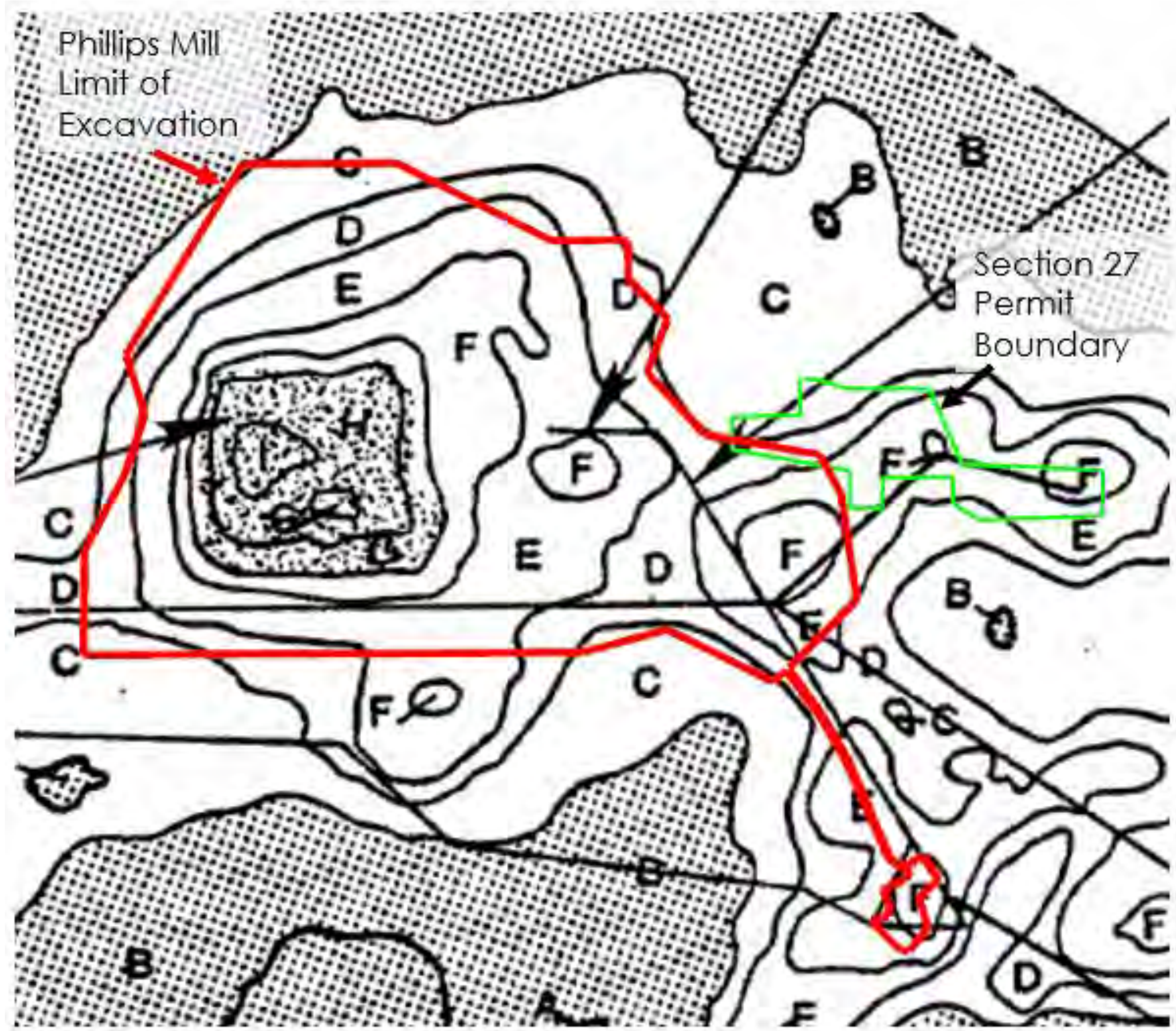
Date	Subsurface Soil Sample (Test Pit) ID	Ra-226 pCi/g
5/2/2011	TP-01, at surface	105.0
5/2/2011	TP-01, at 1.0 ft depth	108.1
5/2/2011	TP-01, at 3.5 ft depth	5.5
5/2/2011	TP-02, at 1.5 ft depth	9.0
5/2/2011	TP-03, at 1.0 ft depth	47.2
5/2/2011	TP-03, at 3.0 ft depth	18.0
5/2/2011	TP-04, at 1.0 ft depth	7.1
5/2/2011	TP-05, at 1.5 ft depth	27.2
5/2/2011	TP-06, at 1.0 ft depth	5.7

Figure 3
Section 27 Mine Site
2010/2011 Static Gamma Survey and Subsurface Soil Sample & Test Pit Locations and Data

Figure 6: Phillips Mill Facilities in 1973 and Eventual Phillips Mill Limit of Excavation

Image downloaded from USGS EarthExplorer

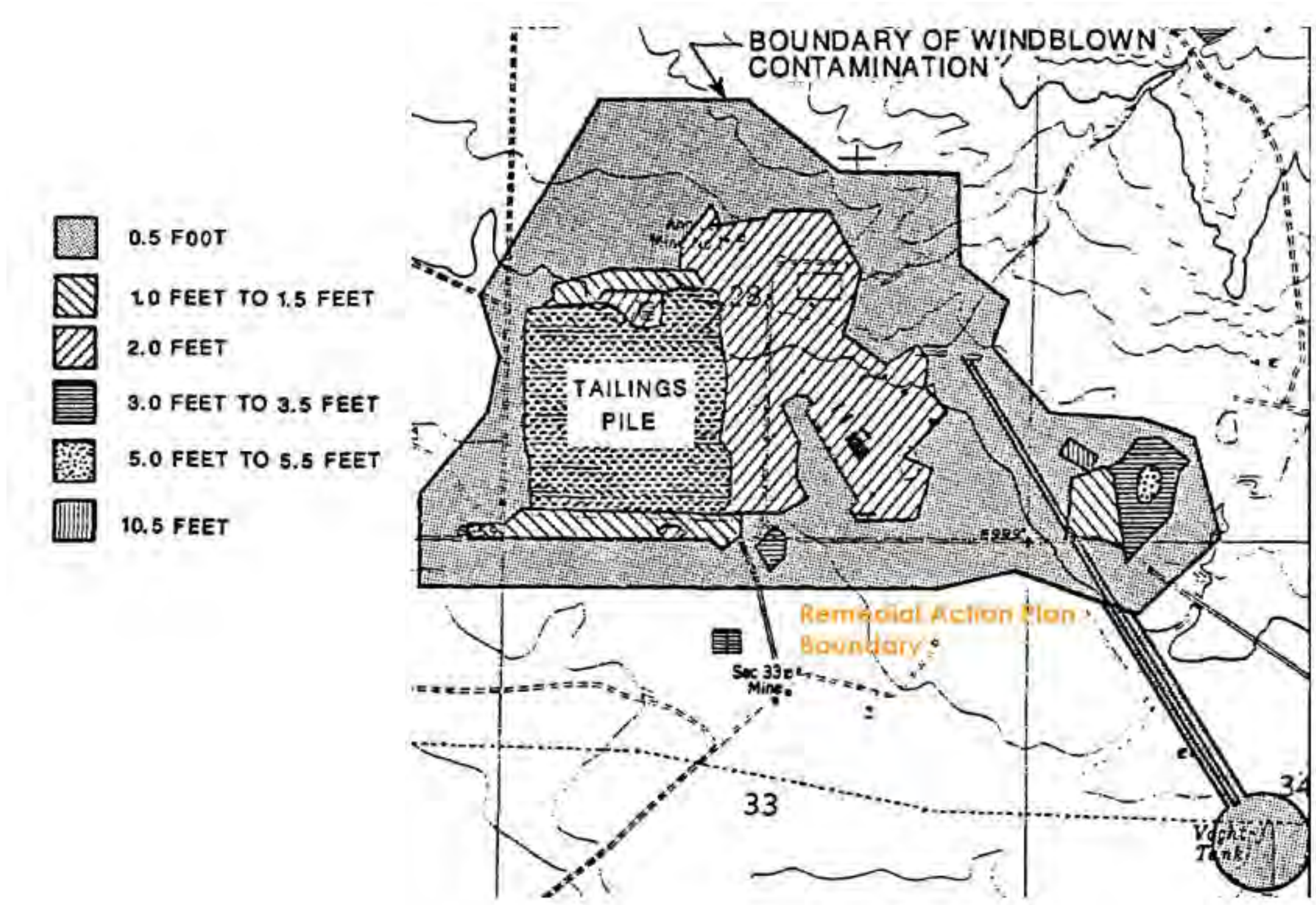
Figure 7: 1981 Aerial Radiological Survey and Estimated Exposure Rates of Phillips Mill and Section 27 Mine Site Areas



Letter	Exposure Rate (uR/h)
A	9-14
B	14-19
C	19-30
D	30-50
E	50-150
F	150-350

Image modified from Appendix D of the U.S. Department of Energy Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico. September 1990.

Figure 8: Phillips Mill Boundary of Windblown Contamination

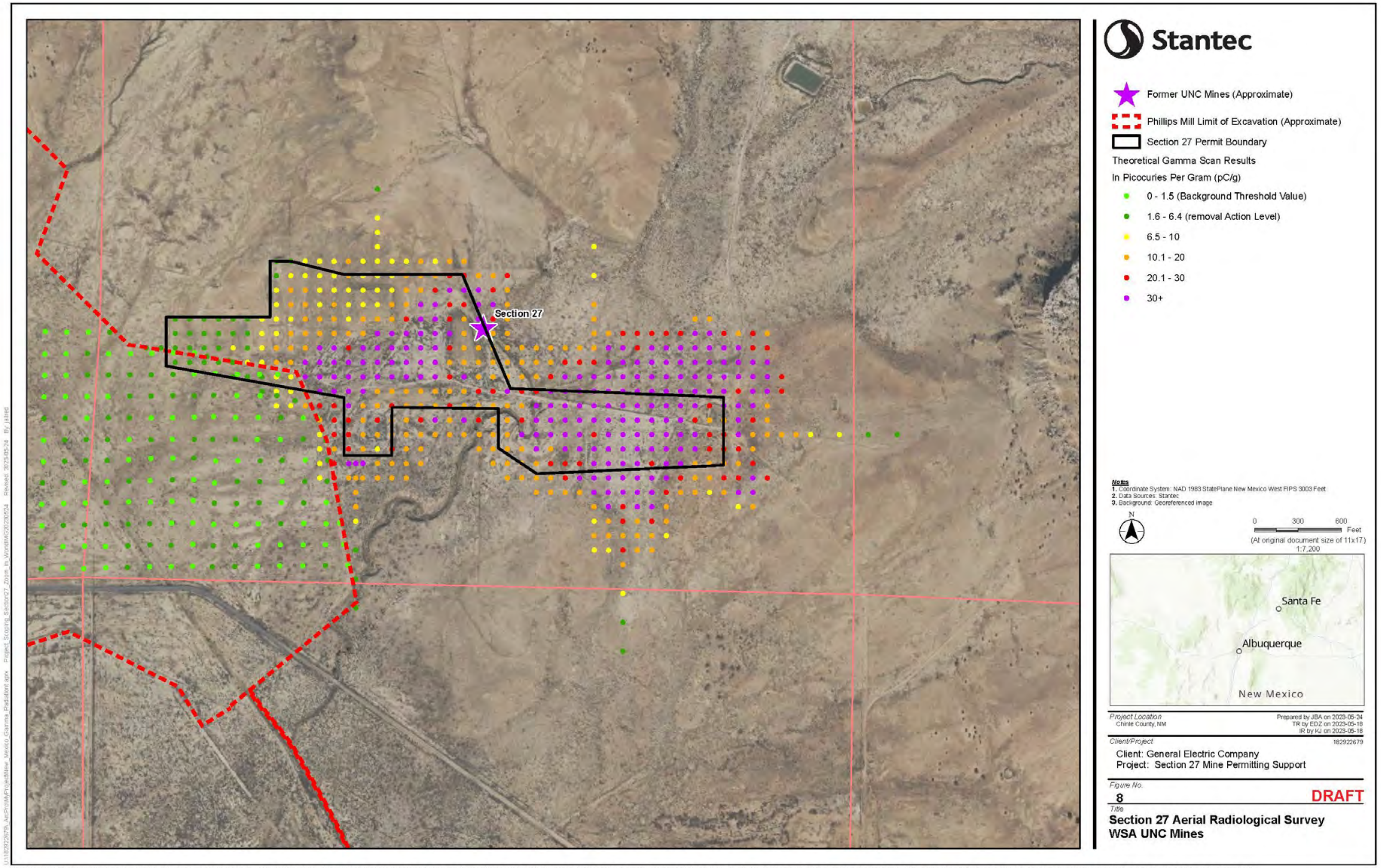


Boundary of windblown contamination developed where estimated Ra-226 concentrations were greater than 5 pCi/g. Provided vertical depths are planned excavation depth estimates. Image modified from Appendix D of the U.S. Department of Energy Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Ambrosia Lake, New Mexico. September 1990.

Figure 9: Aerial Photo Showing Phillips Mill Limit of Excavation and Extent of Cleanup

Department of Energy contractors generally removed windblown surface material near Section 27 site to 5 pCi/g + background concentrations. Image from U.S. Department of Energy Ambrosia Lake, New Mexico Final Completion Report. V. 4. August 1996.

Figure 10: Phillips Mill Cleanup Verification Estimated Ra-226 Concentrations in Grid Locations Near Section 27 Site



Appendix B Standard Operating Procedures

SOP-1
AVM Environmental Services, Inc.
Calibration of Gamma Radiation Survey Instruments
UNC's Section 27 Mine Site Supplemental Radiologic Characterization

1. SCOPE

1.1 Purpose

To provide a standard procedure for calibration of the Ludlum Scaler/Ratemeter, model 2221 with a 2"x2" sodium iodine (NaI) Scintillation Detector (the Ludlum 44-10 or Eberline SPA-3) for gamma radiation surveys during the Section 27 Mine Site Supplemental Radiologic Characterization (SRC).

The Ludlum 2221 is a portable, battery operated, self-contained counting instrument designed for operation with scintillation, proportional or G-M detectors. When combined with a 2"x2" NaI scintillation detector, the Ludlum 2221 is used for detection and measurement of gamma radiations. This instrument configuration is used for surrogate detection of the soil Ra-226 gamma radioactivity.

1.2 Applicability

This instrument will be calibrated every twelve months, after repairs, or when the instrument function check fails. This method can be used with any Scaler/Ratemeter with a 2"x2" NaI scintillation detector configuration.

2. REFERENCES

2.1 Technical Manual for Scaler Ratemeter, Model 2221

3. REQUIREMENTS

3.1 Tools, Material, Equipment

3.1.1 Small flat head screwdriver.

3.1.2 Ludlum Model 500 Pulser or equivalent.

3.1.3 A source of sufficient gamma radiation activity to allow a response For high voltage plateau and function check. A 1% uranium ore in a sealed can is used.

3.1.4 Detector response factor for Ra-226 gamma survey is performed as described in Section 7

3.2 Precautions, Limit

3.2.1 The detector to Scaler/Ratemeter connector cable could easily be damaged if the weight of the 2"x2" NaI detector is suspended with it.

3.2.2 The NaI scintillation crystal is fragile. Shock to the crystal could cause a fracture or a crack, which could impact operation.

3.2.3 Do not leave the reading lamp on for any length of time as it will rapidly drain the battery voltage.

3.2.4 The meter firmware affects the measurements outputted via the RS-232 communication port. Based on the selected integrated count output for specific scan survey, verify appropriate firmware version installed for the Model L2221. The L2221 should have firmware version 261-02-N11 for one second integrated count output, and the firmware version 26106n03 two second integrated count output. The firmware version will appear on the L2221 display after turning it ON.

3.3 Acceptance Criteria

The instrument response to the calibration source should be within ± 20%.

4. LUDLUM 2221 OPERATION CALIBRATION

If the Ludlum 2221 has been calibrated by the vendor within 12 months, skip this procedure in this section and start with detector calibration in Section 5. Record Scaler/Ratemeter information (model and serial number, and calibration date) on the Scaler/Ratemeter Calibration Form. Record information about the calibration source (Pulser and/or source, 1% uranium ore standard).

4.1 Check the battery condition by pressing the “BAT” button with instrument switched on. If the meter does not indicate the battery charge above 5.3 volts, replace the four (4) D-cell batteries.

4.2 Set the threshold value as follows:

4.2.1 With the instrument turned on, press the threshold button. Read the displayed reading. If necessary, adjust the **“**THR**”** adjustment screw until the threshold reads 100.

NOTE: The "THR” adjustment screw is located under the calibration cover

4.3 Set the WIN (window) IN/OUT to OUT.

4.4 Connect the Ludlum 500 Pulser to the 2221.

4.5 Switch SCALER/DIG RATEMETER switch to DIG RATEMETER.

4.6 Select 400 CPM on the Pulser (multiplier switch to 1 and count rate adjusted to 400 cpm).

4.7 Adjust the pulser amplitude above the set threshold (100 mV) until a steady count rate is observed.

4.8 Record the meter rate count response in AS FOUND column on the calibration form. If the meter response is not within 10% of the Pulser set count rate of 400 cpm, adjust the R40 Meter Cal (Labeled MCAL) on the processor board for 400 cpm on the meter.

4.9 Repeat steps 4.6 to 4.8 for 4000, 40,000 and 400,000 cpm pulses.

4.10 Switch the SCALER/DIG RATEMETER switch to SCALER. Select Count Time to 1 Minute.

4.11 Select 400 counts on the pulser (multiplier switch to 1 and count rate adjusted to 400)

4.12 Count the pulses on the meter for one minute by pressing COUNT switch.

4.13 Record the meter response counts in AS FOUND column on the calibration form. If the meter count is not within 10% of the pulser set counts of 400 cpm, adjust the R40 Meter Cal (Labeled MCAL) on the processor board and repeat step 5.12 until a count of 400 is observed on the meter.

4.14 Repeat steps 4.11 to 4.13 for 4000, 40,000 and 400,000 pulses.

If the meter reading could not be set within 10% of the pulses generated by the pulser, the meter requires repair and calibration prior to use.

The Ludlum 2221 is ready for detector calibration and operation.

5. DETECTOR HIGH VOLTAGE AND BACKGROUND CALIBRATION

Record Scaler/Ratemeter (Ludlum 2221) and 2”x2” NaI detector (Eberline SPA-3 or Ludlum 44-10) information (model and serial number, and calibration date) on the Scaler/Detector Calibration Form. Record information about the radiation source (1% uranium ore standard).

5.1 Connect the calibrated Ludlum 2221 to the 2”x2” NaI detector.

5.2 Turn the Ludlum 2221 ON. Set WIN ON/OFF to OFF.

5.3 Check Threshold setting. Should be at 100 mV.

5.4 Switch SCALER/DIG RATEMETER switch to SCALER. Select Count Time to 1 Minute.

5.5 Set HV to 500 VDC.

5.6 Expose the detector to the 1% uranium ore can by placing directly under the detector.

5.7 Obtain one-minute counts with the detector exposed to the source at every 50-volt increment until voltage plateau is passed and sudden increase in the counts is observed. (Usually for the 2”x2” NaI detector, the high voltage plateau maximum voltage is about 1300 to 1400 VDC.). Record the counts under the READING CPM SOURCE in the calibration form.

5.8 Return HV setting back to 500 VDC.

5.9 Remove the calibration source away from the detector. Obtain one-minute background counts with the detector shielded from the source at every 50-volt increment until similar voltage to the source high voltage plateau reading. Record the counts under the

READING CPM BACKGROUND in the calibration form.

5.10 Plot voltage versus cpm reading for both the source and background high voltage data.
From the plot, select the optimum operating high voltage, which is usually at least about 50 volts above the knee of the source response plateau curve for greater counting stability. The optimum high voltage should be also within 50 volts of the background plateau curve for background counting stability.

5.11 Set the Ludlum HV at the optimum operating voltage determined above.

5.12 Record the HV voltage setting on the Scaler/Detector Calibration Form.

The Ludlum 2221 and the 2”x2” NaI detector configuration are ready for determining the detector response factor and establishing the operating background and source function check.

6. OPERATING BACKGROUND AND SOURCE FUNCTION CHECK DETERMINATION

6.1 Set the Ludlum 2221 to Scaler mode, Count Time at 1 minute, with WIN OUT and THR at 100.

6.2 Remove any type of sources of radioactivity from the detector. Obtain five one-minute background counts. Record the background counts in the calibration form. Average the five one-minute background counts. Record the average background counts in the calibration form. The daily function check background counts should be within 20% of this average.

6.3 Expose the 1% uranium ore source (in the sealed can). Note the exact location of the source to the detector. Obtain five one-minute background counts with the detector exposed to the source. Record the source counts in the calibration form. Average the five one-minute source counts. Record the average source counts in the calibration form. The source position to the detector for the function check should be exactly the same as this calibration, and the source counts for the daily source function check counts should be within 20% of this average.

7. DETECTOR RESPONSE FACTOR AND FIELD OF VISION

7.1 Filed Vision

A detector field of vision (FOV) is used for determining observation interval of gamma scan survey for scan MDC calculations, and for transects spacing calculations for scan gamma survey coverage. Detection range of a photon from a particular source by a detector is related to FOV for that detector. The detection range is dependent on the energy of radiation (photon) being detected since it is a characteristic of photon energy, not a detector. Detection range will be longer for a photon with higher energy than a photon of lower energy. FOV is a circular area with the detection range as radius. A minimum FOV of 6.0 feet for bare and 3.0 feet for collimated 2x2 NaI detectors for Ra-226 (uranium ore) photons will be used for observation interval for MDC calculations. If a different FOV is used, it will be verified by conducting a FOV test.

7.2 Detector Response Factor

For the calculation of minimum detectable concentrations (MDCs), the detector response factor, AKA detector efficiency, which is a conversion constant in units of cpm per pCi/g is required. There are several methods for determining the detector response factor, such as using calibration pads, source modeling or a concentration to gamma radiation level correlation study. Since final gamma radiation level to Ra-226 surface soil concentration correlations for bare and collimated detectors have been established for the site, the appropriate detector response factor from these correlations will be initially used for MDC calculations for gamma surveys during the St. Anthony mine site field gamma survey activities. The correlations were developed for the ground surface assumptions similar to what is expected at the St. Anthony mine site, i.e., fairly homogeneous and distribution of Ra-226 concentration in surface soils by using sampling data from appropriate conditions. These correlations meet the statistical acceptance criteria and the project data quality objectives.

The slope of the regression represents the relationship between the field gamma measurement in cpm and the Ra-226 surface soil concentration in pCi/g. Thus, the slope is in units of pCi/g/cpm. The derivations of the correlations are described in the Attachment 1 to the Attachment C.1 to Appendix C of the Closure Plan, Excavation Control Plan. The final correlations yielded a regression slope of 0.0005 pCi/gm/cpm (or 2000 cpm/pCi/g) for bare 2x2 NaI Detectors, and 0.0013 pCi/gm/cpm (or 970 cpm/pCi/g) for 0.5-inch lead collimated 2x2 NaI detectors.

Response factor for all 2x2 NaI scintillation detectors are fairly comparable. However, if a detector is repaired, replaced or new one is used, the comparability of the response factor should be verified by cross measurement against the original calibrated detector using a constant uranium ore source with sufficient activity, or preferably at the DOE uranium ore calibration pad. The response should be within ±20%.

8. DETECTOR MINIMUM DETECTABLE CONCENTRATION CALCULATION

8.1 MDC for Static Gamma Radiation Measurement (for 0.05 probability for both false positive and false negative errors)

The calculation below is an example for illustrative purposes and the static MDC will be calculated in the field based on actual field background measurements from function checks. It is important to note that these MDC calculations necessarily depend on several assumptions of consistent conditions in the field such as homogeneous distributions of contamination in soil, infinite plane geometry, consistent thickness of the contaminated layer of material, and consistent detector to soil surface relationship. Those conditions will not be ideal when field measurements are performed and the MDC will likely be greater than the value calculated below.

$$MDC = C \times [3 + 4.65\sqrt{B}]$$

Where:
C = Detector response factor, cpm/pCi/g
B = Background count rate in cpm.

Example:

- For the bare 2x2 NaI detector, estimated background count rate of 10,000 cpm from previous function checks at the site, detector response of 0.0005 pCi/g/cpm from Section 7.2 above, then the MDC for a one minute static measurement would be:

$$MDC = 0.0005 \text{ pCi/g/cpm} \times [3 + 4.65\sqrt{(10{,}000 \text{ cpm}}] = 0.23 \text{ pCi/gm}$$

- For the 0.5-inch lead collimated 2x2 detector, estimated background count rate of 3,000 cpm from previous function checks at the site, detector response of 0.0013 pCi/g/cpm from Section 7.2 above, then the MDC for a one minute static measurement would be:

MDC = 0.0015 pCi/g/cpm x [3 + 4.65√ (3,000 cpm] = 0.63 pCi/gm

The integration count time for static measurement may be changed to attain MDCs to required levels. Tolerable maximum instrument background count rate to attain a specified MDC can be calculated by solving the above equation using other accepted parameters (integration time and detector response factor). A daily function check must be performed prior to use.

The total propagated uncertainty will be calculated for the static survey measurement and reported with the static MDC values in all reports, tables, and figures.

8.2 MDC for Scan Gamma Radiation survey

The scan MDC is assumed for a scan rate of about 3 feet per second and a 2 second interval. For a single component scan, such as GPS based gamma scan for St. Anthony mine site soil excavation action, the scan CPM is recorded using DGPS and Data logger for later evaluation of data with no pausing for stationary survey investigation needed in the field during the scan, and variability in the actual scan speed due to human inconsistencies in scan rate and detector height, a surveyor efficiency (p) of 0.8 is appropriate. For a dual component where a surveyor may pause during a scan survey for investigation, a surveyor efficiency of 0.5 will be used. The calculation below is an example for illustrative purposes and the scan MDC will be calculated in the field based on actual field conditions (based on the actual detector response factor, surveyor efficiency, field of view, scan rate to meet the scan MDC requirements, and background; d' is fixed as indicated below).

First calculate the Minimum Detectable Count Rate (MDCR) as follows:

MDCR = (d' x √bi) x (60/i)

Where:

d' = value for true positive and false positive proportion. A value of 1.38 (MARSSIM Table 6.5) will be used for 95% true and 60% false positive proportion.

bi = number of background counts in the interval i [(background rate in cpm/60 sec/min) x 2 for two second interval].

Example: For the bare 2x2 NaI detector background count of 10,000 cpm estimated from previous function checks at the site, the MDCR for two second observation interval (6.0 feet FOV/3.0 feet per second scan rate) would be:

bi (2 sec) = (10,000 cpm) x (1 min/60 sec) x (2 sec) = 333 counts

MDCR cpm = (1.38) x √[333 counts] x (60 sec/min)/(2 sec) = 756 cpm.

The MDCR $_{surveyor}$ using surveyor efficiency (p) of 0.8 would be:

MDCR $_{surveyor}$ = MDCR/√p = 756 cpm/√0.8 = 845 cpm.

From the MDCR $_{surveyor}$, calculate the scan MDC using the following:

Scan MDC = MDCR $_{surveyor}$, cpm x C, cpm/pCi/gm

Where: C = Detector response factor, 0.0005 pCi/g/cpm (from Section 7.2 above)

Scan MDC = 756 cpm x 0.0005 pCi/g/cpm = 0.42 pCi/gm

For the 0.5-inch lead collimated detector with a background of 3,000 cpm, C of 0.0015 pCi/g/cpm, observation interval of one second (3.0 feet FOV/3.0 feet per second scan rate), the scan MDC would be 0.98 pCi/g.

A daily function check must be performed prior to use. The scan rate for radiation scan survey may be changed to attain MDCs to required levels. The tolerable maximum instrument background count rate to attain a specified scan MDC can be calculated by solving the above equation using the other approved instrument and survey parameter values, such as survey sensitivity (d'); detector response factor; scan rate; observation interval; and surveyor efficiency. Likewise, maximum scan rate for scan survey to attain a specified scan MDCs can be calculated by solving the above equation with using other instrument and survey parameter values, such as survey sensitivity (d'); instrument background count rate; detector response factor; detector FOV for Ra-226; and surveyor efficiency factor.

Attachment A

Scaler/Ratemeter Calibration Form

Model___________________________ S/N ___________________

Calibration Source____

Threshold (input sensitivity), Found at_______________ mV Left or Set at _________ mV

Window, In/Out_________ Window _______________ mV

Pulser Amplitude Set @___________________________mV

Range/Mode	Calibration Point (Pulser Setting) cpm x multiplier	As Found Reading	Left or Set Reading

HV Set @_______________ VDC

Date ________________________ Calibrated By ______________________________________

Attachment B

AVM Environmental Services Inc.
Scaler/Ratemeter - Detector Calibration Form

Scaler/Ratemeter : Ludlum 2221, SR #
Detector: 0.5 Inch Lead Collimated SPA-3, #

Source: ______________________________ Strength: _________________

Scaler/Ratemeter Threshhold set @ 100 (10mV); Window IN/OUT: OUT; Window: N/A mV

HV	Reading, CPM (Source)	Reading, CPM (Background)
500		
550		
600		
650		
700		
750		
800		
850		
900		
950		
1000		
1050		
1100		
1150		
1200		
1250		
1300		
1350		
1400		

at designated function check location in office.

Count #	Reading (CPM)
1	
2	
3	
4	
5	
Average	

Count Readings with 1 percent U_3O_8 can directly under collimated detector on designated function check location in office.

Count #	Reading (CPM)
1	
2	
3	
4	
5	
Average	

HV Set @________________________ VDC (Instrument) ___________________ VDC (DVM Fluke 8020B)

Input Sensitivity (THR), mV _________________

Function Check with 1 percent U_3O_8 ore in can. Can Directly under the detector.
Acceptable Function check range is: _______________________ to ____________________ CPM

Count Readings for Calibration Pad GPL (87.78 pCi/gm Ra-226)

#1 _______________ cpm
#2 _______________ cpm Average _______________ cpm
#3 _______________ cpm
#4 _______________ cpm Efficiency _______________ cpm/pCi/gm
#5 _______________ cpm Efficiency _______________ pCi/gm/cpm (1/cpm/pCi/gm)

Date ______________________________ By ____

SOP -2
AVM Environnemental Services, Inc.
Direct Gamma Radiation Level to Ra-226 Soil Concentration Correlation Update
UNC's Section 27 Mine Site Supplemental Radiologic Characterization

1.0 Purpose

The purpose of this procedure is to develop and update the Site-specific Ra-226 concentrations in surface soil to direct gamma radiation level correlations Section 27 mine site (Site). Site-specific correlations were initially developed for 0.5 inch thick lead collimated 2x2 NaI detectors during the 2011 during the Phase 1 post reclamation surveys. Although the Site-specific correlations meet or exceed the appropriate acceptable statistical criteria (correlation coefficient, p-value and low MSEs), the correlations may be updated to improve the statistical parameters. A correlation for the bare detector will be developed during this Supplemental Radiologic Characterization (SRC).

2.0 Scope

The Ra-226 levels in soil could be measured as a surrogate by measuring Pb-214 and Bi-214 gamma radiation levels, as to the measurement described in Section 4.3.2 of the MARSSIM. Pb-214 and Bi-214 are decay products of Ra-226 through radon-222 (Rn-222), a gaseous form, some of which emanates from soil. This process results in activity disequilibrium between Ra-226 and PB-214/Bi-214 in the soil. The Rn-222 gas emanation fraction from the soil varies with different characteristics of a particular soil. Therefore, a site-specific calibration of the detector is necessary. Studies at the Site have shown that about 20 percent of the Rn-222 gas decayed from Ra-226 in soil emanates out of the surface soil, indicating that a significant percentage (about 80 percent) of Ra-226 will decay into Pb-214 and Bi-214 in the soil matrix. If the soil characteristics and other parameters (such as moisture, radon emanation fraction, contamination distribution profile, gamma ray shine from nearby sources, and land topography) are consistent, the ratio of Pb-214/Bi-214 to Ra-226 will be consistent. This results in a direct correlation between Pb-214/Bi-214 gross gamma radiation levels and Ra-226 concentrations in the soil. The gamma radiation from other naturally occurring isotopes in soil, such as Th-232 decay products and K^{40}, may contribute to gross gamma radiation intensity. In addition, background gamma radiation from cosmic rays also contributes to gross gamma radiation intensity. However, the gamma radiation level from such naturally occurring isotopes and sources are generally at a constant level. A linear regression would identify such a constant to correct for and minimize interference with the gamma radiation level and Ra-226 soil concentration correlation.

The Site-specific correlation for collimated 2x2 NaI detectors was developed with primary assumption of contamination distribution in surface soil (0 to 6 inches). Any lateral gamma radiation shine from the nearby elevated areas would skew gamma radiation level. A collimator detector mitigates the lateral shine interference. The collimated detector correlation was updated with sampling data from locations that fit this assumption during post reclamation surveys. A correlation with this assumption is most appropriate for excavation control and final status surveys during removal actions because the contamination distribution is expected to be fairly homogeneous and primarily in surface soils following the removal action. Only gamma radiation level measurements and soil sample Ra-226 data from corresponding locations with this correlation assumption will be used to develop and update the correlations.

3.0 Instrumentation

Instrumentation to collect gamma radiation level measurements will be the same as used during the development of previous correlations. A 2"x2" NaI Scintillation detector (an Eberline SPA-3 or Ludlum 44-10 detector) and a Scaler/Ratemeter, (Ludlum Model 2221 or 2241) will be used for field gamma radiation level measurements and to select sampling locations. A 2x2 NaI detector with 0.5-inch thick lead collimator will also be used for gamma radiation level measurement for the collimated detector correlation update. The Scaler/Ratemeter will be calibrated consistent with SOP-1 to assure that it properly counts the electronic pulses generated and sent by the 2x2 NaI detector. An optimum operating high voltage for the detector will be established by performing a high voltage plateau on the detector using SOP -1a. The input sensitivity (threshold) of the Scaler/Ratemeter will be set @ 100 mV to avoid interference from low level background radiation. The pulses generated by the detector for Ra-226 gamma radiations (primarily from the Pb-124 and Bi-214 decay products) are significantly higher than 100 mV, as verified by using 1% uranium ore standard.

4.0 Gamma Radiation Level Measurements and Soil Sample Collection for Updating Correlation

If any surface soil sampling is performed during the SRC with a co-located gamma radiation level measurement, the data may be used for correlation. One minute static gamma radiation level measurements will be performed consistent SOP-1. The co-located surface soil sample will be collected consistent with SOP-5, and will be analyzed for Ra-226 by an offsite vendor laboratory using EPA Method 901.1. Gamma radiation level measurements and surface soil sampling for the correlation will not be conducted within several days following rain or on wet ground surface.

5.0 Linear Regression Analysis

The relationship between gamma radiations from Ra-226 to detector response is linear. To determine the correlation between gamma radiation level counts and corresponding Ra-226 concentration in surface soil, i.e. to determine a calibration equation, a liner regression analysis will be performed on the sample Ra-226 concentration in pCi/gm, Y, and the associated gamma radiation level count rate, cpm at X, from all the sample locations using a least-square liner regression and plotting the results. A linear regression is the only statistical approach determined to be appropriate because the 2x2 NaI detector response to gamma radiation detection is linear, specifically at the levels emanating from uranium ore and tailings impacted soil. The liner regression will be performed by augmenting the appropriate correlation data for the collimated detector. Prior to developing or updating the correlation, review the data to make sure that the data meets appropriate QA/QC requirements and the collected data fits the correlation assumption, i.e. fairly homogeneous Ra-226 distribution in only surface soil for bare detector, and in area with any lateral shine is mitigated with collimated detector.

Linear regression data will be summarized by the generalized equation:

$$Y = mX + b$$

Where:

Y = soil concentration in pCi/gm,
m = slope, pCi/gm/cpm
X = count rate (the mean) in cpm
b = constant, y intercept

This correlation will provide a site specific calibration factor (m) in pCi/gm/cpm for the 2”x2” NaI detector, with a constant (b) to correct for any interference, specifically at lower range. The purpose of the update is to increase correlation sample numbers to improve statistical parameters (correlation coefficient, confidence level, p-value and low MSEs). If the update does not improve the statistical parameters, investigate the data to see if they meet the correlation assumptions or are outliers.

SOP-3
AVM Environnemental Services, Inc.
Field Gamma Radiation Survey for Ra-226 Concentration in Soil
UNC's Section 27 Mine Site Supplemental Radiologic Characterization

1.0 SCOPE

1.1 Purpose

This procedure will be used for direct gamma radiation surveys to detect Ra-226 in surface soil for performing characterization surveys and investigation surveys, excavation control (Remedial Action Support) surveys, and as a component of the Verification Survey (VS) at uranium mine sites.

2.0 EQUIPMENT AND MATERIALS

2.1 A Ludlum model 2221 or 2241 Scaler/Ratemeter coupled with a Ludlum 44-10 or an Eberline SPA-3 2"x2" NaI crystal scintillation detector for direct gamma radiation detection. (SPA-3 and Ludlum 44-10 are both similar 2"x2" NaI crystal scintillation detectors).

2.2 A global positioning system (GPS) with real time differential correction and data logging capability

2.3 A 0.5 inch lead Collimator for use with 2"x2" NaI detectors, if needed to mitigate nearby lateral gamma-ray shine interference and focus on the area of interest under detector. The 0.5-inch thick collimator, which surrounds the NaI crystal, is contained within a protective marlex housing.

2.4 A vendor calibrated Exposure Rate (uR/hr) meter.

2.5 Map of survey areas with marked points, grid nodes and transects. Ink pen and appropriate Field Survey Forms to record survey readings and notes.

2.6 Measuring tape, pin flags, area markers and marking paint.

3.0 INSTRUMENT CONFIGURATION & OPERATIONS

Prior to any instrument function check or operation, the technician will read the Technical Manual for the instrument operations (Ludlum 2221) and the correlation Method (SOP-2) for the rationale behind the gamma radiation surveys.

The field gamma radiation level surveys for Ra-226 in surface soil will be performed using a Ludlum 2221 Scaler/Ratemeter connected to a 2"x2" NaI crystal scintillation detector (SPA-3 or Ludlum 44-10) which detects gamma radiation emitted from radium-226 decay products (primarily Pb-214 and Bi-214) in the soil. The detector will be held at approximately 12 inches from the ground surface. The bare (uncollimated) detector should be sensitive to an area at least six feet in diameter under the detector. The Model 2221 Scaler/Ratemeter with external RS232 or a Bluetooth connector can be coupled to a DGPS/data logger where the gamma radiation count rate in CPM would be logged with its corresponding location coordinates.

For gamma radiation surveys where significant shine interference is present from nearby areas, the 2”x2” NaI crystal scintillation detector will be installed in a 0.5 inch thick lead collimator to reduce lateral gamma radiation shine interference. During the survey, the detector will be held approximately 12 inches above ground level, which should focus and be most sensitive to an approximate 36 inch diameter area under the detector.

The instrumentation must be calibrated consistent with SOP-1 prior to use.

3.1 Instrument Function Check

An operational function check will be performed on the Scaler/Ratemeter (L2221) and the detector (SPA-3 or Ludlum 44-10) configuration each day prior to any field surveys. The operator will verify calibration validity for the Scaler/Ratemeter and the detector. The calibration date for the instruments must be within one year. If not, the instrument must be removed from service and calibrated with a certificate in file. The function check will be performed in the field office. The following function check procedures will be used and the pertinent information recorded on the Scaler/Ratemeter-Detector Function Check Form (Attachment A).

3.1.1 Visual Inspection

Perform a visual inspection checking for signs of any damage on the instrument, cables, detector and the shield. Test for possible electrical shorts in the cable with the instrument in the audio on mode, move the cable and note for any sudden increase in audible “clicks” and also and sudden increase in counts on the Scaler/Ratemeter display.

3.1.2 Calibration Due

Verify calibration validity for the Scaler/Ratemeter and the detector. Calibration date for the instruments must be within one year and have a current Calibration Certificate on file.

3.1.3 Battery Charge

Assure that the Scaler/Ratemeter battery is functional. For ESP Scaler/Ratemeter it should not be indicating a “Low BAT” signal. For Ludlum 2221, the battery voltage digital readout must be at least 5.3 volts.

3.1.4 High Voltage

The detector high voltage must match that determined during high voltage calibration (HV Plateau) for that detector.

3.1.5 Threshold (input sensitivity)

Check and make sure that the Scaler/Ratemeter threshold is set at 10.0 mV. If not, set the threshold to 10.0 as all gross gamma measurements are performed with 10 mV (equivalent to 100 setting on instrument) threshold. Ludlum 2221 Threshold can be set by the instrument digital read out display.

3.1.6 Window

If Ludlum 2221 Scaler/Ratemeter is used for instrument configuration, the WIN (window) toggle switch must be in the OUT position for gross gamma measurements.

3.1.7 Background Counts

The background counts will be determined for the same time interval as the field static survey count time, generally one minute. The background counts will be performed at the designated location in the field office. A location will be designated in the field office for obtaining the required daily background counts. Keep all beta/gamma radiation sources away from the detector while performing the background check. The background function check counts at the field office must be within 20% or lower than the background counts obtained during the detector high voltage calibration.

3.1.8 Source Function Counts

Obtain the gamma radiation function check source, (1% U_3O_8 ore standard sealed in a can marked "Function Check Source”). The 1% ore standard was used to determine the acceptable count range for the detector following calibration. Place the source at the same location on the detector used to obtain the source function check counts during calibration. Count the source for one minute and note the counts in CPM. The source function check counts must be within 20% of the source counts obtained during the detector and Scaler/Ratemeter calibration.

3.1.9 Instrument Tolerance

The Scaler/Ratemeter and detector counting and detecting tolerance are expressed as percent deviation from the mean of the acceptable count range. The background counts and the source function check counts must be within 20% of the mean established following instrument calibration. If the source count is outside this range, pull the instrument from service. The instrument must be repaired and/or re-calibrated prior to use.

3.1.10 Technician

After completing the function check, initial in the column marked TECH of the function check form.

3.2 Instrument Minimum Detectable Concentration Calculation

When required, calculate Minimum Detectable Concentration (MDC) for the instrumentation using the function check background readings as described in SOP-1 (Instrument MDC Calculation). Acceptable MDCs are below the specified investigation or Action Levels. The acceptable Ra-226 MDC limit for the SRC for static and scan gamma surveys is 3.3 pCi/g (50% of the 6.5 pCi/g investigation level). Calculate MDC for appropriate survey, i.e. Direct Measurement MDC for static (stationary) gamma radiation survey and scan MDC for scan or walkthrough gamma radiation survey instrument background information. Record in the Function Check Form (Attachment A) if the instrument MDC is less than the acceptable limit.

The integration count time for static measurement and the scan rate for scan survey may be changed to attain MDCs at acceptable levels

4.0 FIELD GAMMA RADIATION SURVEYS

The direct gamma radiation level survey for Ra-226 in surface soil will be conducted as either scan survey (walkthrough) or static survey (stationary) measurements.

4.1 Scan Gamma Radiation Survey

Scan gamma radiation surveys (walkthrough surveys) will be performed by walking with the detector at about 12 inches from the ground surface with the scaler/Ratemeter in count RATE MODE. Scan surveys will be performed to identify and locate any hot spots and contaminated area boundaries for characterizations and investigations during the SRC. A 0.5 inch lead collimator for 2"x2" NaI detectors will be used if needed to reduce lateral gamma-ray shine interference and focus on an area of interest under the detector. The scan rate and walking speed depends on the desired scan MDC for the survey. For this instrument configuration, a scan walking rate of 3 feet per second (fps) results in a Ra-226 scan MDC of about 1.5 pCi/g. For a different scan MDC, the scan walking rate may be modified.

A GPS based gamma radiation scan survey can be performed to log a gamma radiation rate with corresponding point location coordinates in a data logger. A GPS based scan survey paired with a scaler/ratemeter and a bare 2"x2" detector will be used for the SRC surveys. This scan survey can be performed by walking along the specified transects in the areas using a 2x2 NaI detector with a ratemeter coupled with a DGPS/data logger unit. The GPS-gamma scan survey system will consist of a Ludlum 2221 Scaler/Ratemeter/ with SPA-3 2x2 NaI Detector coupled to a DGPS/data logger system. Where terrain allows, the scan survey may also be performed using an all terrain vehicle (ATV) mounted scan survey system. The Ludlum 2221 will be operated in Ratemeter mode, allowing a gamma count rate (cpm) to be logged with its corresponding coordinates in one or two second intervals. Appropriate walk-over transect spacing based on the scan coverage rate and the detector FOV for Ra-226 will be used for this survey, as discussed in SOP-1.

The logging process can be partially automated by logging points by interval. You can log points after a specified time period has elapsed. The procedure for using the Log By Interval function in SoloField mapping software is described below:

1. Select **Log** > **Log by Interval**, or tap the **Log by Interval** button in the Mode Toolbar. This will open the **Select Feature to Log** screen.
2. You will be prompted to select a feature and to complete the attribute entry. When you tap on the **OK** button in the **Attributes** screen, the **Log by Interval** screen will be displayed.
3. Select between **Log by TIME interval.**
4. Enter the **2.00 Seconds** log interval in the **Log every** field.
5. Tap the **Start** button to begin logging by interval.

The first point will be logged at your current position. Once you have waited the specified time another point will be logged. This will continue until you tap the **Pause** button or close the screen. At the end of each survey day, the field data will be downloaded into a computer and processed for tabulārization and mapping. Download the survey file as follow:

Select **File** > **More** > **Export** to open the **File Export** screen.

You may select the **Export Format** by tapping on the down arrow to the right of the selection box. choose Text, All exported files are stored in \My\Documents\SOLO\Export by default, otherwise. **If Prompt for filename** is selected, you can customize the names as each file is created.

Depending upon the export format selected, you may choose to export your features in two ways; a unique file for each feature layer, or one file.

With **Text *.txt** selected as the **Export Format**, tap **Options** to display the text options. You may turn these options on/off using the checkbox next to each option.

When you are satisfied with your selections, tap the **Export** button to create the file(s) in the selected format

4.2 Static Gamma Radiation Survey

Static gamma radiation surveys will be performed at any point or location of interest during surface soil characterization and investigation surveys at specified locations. The detector will be held at about 12 inches from the ground surface. The Scaler/Ratemeter will be set in the count SCALER MODE. A one-minute integrated count (CPM) of gamma radiation level will be obtained at each location for a static gamma radiation survey. A DGPS integrated with a data logger may be used to log the gamma counts and location for static surveys. A 0.5 inch lead collimator for the 2"x2" NaI detectors may be used if needed to reduce lateral gamma-ray shine interference and focus on the area of interest under detector. For this instrument configuration, a one-minute integrated count results into a Ra-226 MDC of about 0.4 pCi/g for bare detectors and 0.5 pCi/g for collimated detectors. For a different MDC, the integrated count period may be modified.

4.3 Remedial Action Support (Excavation Control) Survey

Excavation control surveys will be performed to guide the excavation of contaminated soil exceeding the Ra-226 RAL of 6.6 pCi/g during the site soil excavation action. Obtain field action level in CPM (for either bare or collimated detector) for the site Soil Action Level (SAL) concentration (pCi/g) based on the site specific correlation. This direct radiation level CPM may change as soil excavation progresses and the correlation is updated; therefore, contact the Radiation Safety Officer (RSO) to obtain the current direct radiation level CPM. Excavation control surveys will be performed using a combination of scan gamma radiation surveys and static radiation level measurements as follow:

IT IS IMPORTANT TO COORDINATE WITH THE EXCAVATION CREW THE EXCAVATION AND SURVEY SEQUENCE FOR YOUR SAFETY. ESTABLISH NECESSARY SAFETY COORDINATION WITH THE EXCAVATION CREW. ALWAYS WEAR AN ORANGE SAFETY VEST WHILE PERFORMING SURVEY IN THE FIELD.

1. Perform the function check as indicated in Section 4.1 of this procedure. In area where gamma radiation shine is expected, use the collimated detector.

2. Ensure that the Scaler/Ratemeter is set in RATE mode. Turn the Scaler/Ratemeter audio speaker to the ON position. For Ludlum 2221 Scaler/Ratemeter, set the RESP (response) toggle switch to F (fast) position. Set the audio rate toggle switch to x1, x10 or x100 position based on radiation level of the area and familiarize yourself to the audio rate at the action level

count rate. The audio toggle rate set at x10 or x100 is appropriate for the field survey.

3. Using appropriate maps, area boundary location coordinates and a DGPS if needed, field locate and mark any area exceeding the SAL with pin flags. Radiation scanning may be necessary to delineate the contaminated area boundaries. Coordinate the marked area with the excavation crew. The area may be divided into smaller subareas such as about 100 square meter areas, or 10 feet strips to help efficiently control excavation based on the type of excavation equipment used for excavation. The excavation fleet will remove the contaminated soil in necessary thickness lifts initially based on vertical extent of contamination.

4. Following the initial excavation lift, assure that the excavation equipment is out of the way and the area is clear and safe, perform a radiation scan with the detector at approximately 12 inches from the ground surface by walking in a serpentine pattern along a transect or within the subdivided areas with the audio speaker ON to identify any locations that exceed the site action level count rate by audio response and digital count rate display. The scan survey for the excavation control will be performed for 100% coverage within the area. Note that the collimated detector at about 12 inches from ground is most sensitive within an area of about three feet diameter under the detector, and about six feet diameter under the bare detector. The scan gamma radiation survey form (Attachment B) may be used to note any comments.

   If no point or a location exceeding the action level is identified within the area by the scan, the removal action in the area would be considered complete, and the area will be ready for the final status survey.

5. If the radiation scan following the initial soil excavation lift shows portions the area above the SAL, or any static measurement point is above the SAL, mark out those areas with pin flags or marking paint and coordinate with the excavation crew for the additional excavation of contaminated soil as necessary until the scan survey shows no points or locations above the SAL, and repeat step 5 at those locations.

6. If the radiation scan following the initial soil excavation lift still shows most or all of the area above the SAL, the contamination in entire area is deeper than the initial lift. Coordinate with the excavation crew for additional soil excavation and repeat steps 5 and 6 until the area is clean.

4.4 Investigation and Characterization Surveys

Gamma radiation surveys for Ra-226 contamination investigations will be used to identify hot spots and investigation level contamination boundaries. Static gamma radiation surveys will be conducted at any points of interest that are above the appropriate investigation level of an area. Obtain appropriate investigation level in CPM. Follow the scan and static survey procedure as described in Section 4.1 and 4.2 above. Scan gamma radiation surveys will be performed by walking around with the detector at about 12 inches from the ground surface with the scaler/ratemeter in count RATE MODE. Investigation scan surveys will be performed at necessary coverage rates, as specified in the Work Plan, within areas of interest in a serpentine shape along transects. The characterization scan surveys will be performed along transects as specified in the Work Plan. The transects will be loaded in the data logger and can be viewed during the scan. The investigation scan and static gamma survey data may be recorded in the DGPS/data logger and/or in field forms that are included in Attachments B and C.

5.0 ATTACHMENTS

Attachment A	Scaler/Ratemeter-Detector Function Check Form
Attachment B	Scan/Walkthrough Gamma Radiation Survey Field Form
Attachment C	Static Gamma Radiation Survey Field Form

Attachment A, SOP-03
Scaler/Ratemeter - 2" x 2" NaI Detector Function Check

Scaler/Ratemeter ID:_________________________________ Function Check Source ID: 1% U_3O_8 Ore in Sealed can

2" x 2" Detector ID:___________________________________ Acceptable background Count (cpm) Range (20%) ____________________ to ____________________

Acceptable Source Count (cpm) Range (20%) ____________________ to ______________________

Date	Physical Check	Cal Due	Battery[1] Volts or OK	HV Volts	Threshhold mV [2]	Window In or OUT[3]	C.C.[4]	BKG Counts cpm	Source Counrts cpm	Within Acceptable Range Y or N	MDC pCi/gm	Tech

Note: (1) Battery Voltage for Ludlum 2221 must be >5.3 volts; (2) Threshhold must be at 100 mV; (3) Window Position must be OUT; (4)

Attachment B, SOP-03
Scan/Walkthrough Gamma Radiation Survey Field Form

Instrumentation : Scaler/Ratemeter_________________________________, Detector____

Instrument Calibration Date: ______________________________, Instrument Daily Function Check Performed: __________

2"x2" NaI Detector Collimated ______ Yes or ______ No.

Survey Area/Unit Decsription ____

Survey Date/Time	Survey Area-Transect ID/Description	Gamma Radiation Reading Range CPM	Comments/Notes

Technician Signature __________________________________, Reviewed by _____________________________________

Attachment C, SOP-03

Static Gamma Radiation Survey Field Form

Instrumentation : Scaler/Ratemeter___________________________, Detector _______________________________________

Instrument Calibration Date: ______________________________, Instrument Daily Function Check Performed: __________

2"x2" NaI Detector Collimated ______ Yes or ______ No.

Survey Area/Unit Decsription ____

Survey Date/Time	Survey Point ID/Description	Survey Point Coordinate		Gamma Radiation Reading, CPM	Comments/Notes
		Northing	Easting		

Technician Signature ___________________________________, Reviewed by ______________________________________

AVM SOP-4
AVM Environmental Services, Inc.
Field Soil Gamma Radiation Screening Procedure
UNC's Section 27 Mine Site Supplemental Radiologic Characterization

1.0 Introduction

This field soil screening procedure for Ra-226 consists of measuring 609 KeV gamma radiations of Bi-214, a decay product of Ra-226 through Rn-222. The 609 KeV gamma radiation counts of the sample soil is compared to a reference soil from the site with a known Ra-226 concentration for field screening. Although the Rn-222 is a gas and the soil is not sealed, the soil retains over 80 % of Rn-222 gas within the soil matrix, resulting in a significant amount of Bi-214 decay product and its gamma radiations. Bi-214 609 KeV gamma radiation is at fairly high intensity (46%) and isolated, which mitigates interference from other energy gamma radiations. A single channel analyzer (SCA), such as Ludlum L2221 integrated with a Ludlum 44-20 3x3 NaI scintillation detector will be used to measure gamma radiation at an energy of 609 KeV, the gamma radiation energy of Bi-214. The heavily shielded counting chamber lowers the background counts without lowering the counting efficiency for that geometry and sample size, thus lowers the detectable concentration. For a quick estimate of Ra-226 in soil, a reference soil with a known Ra-226 concentration (similar to screening level), which is not previously sealed, the 609 KeV gamma radiation level of Bi-214 can be measured (pulse height analysis) for field screening. The soil sample in a plastic bag is placed around the detector in a counting chamber (1.5 inch thick x 7.5 Inch ID x 12 inch tall lead ring collimator with a 1.5 inch thick lead bottom shield) and 609 KeV gamma radiation counts are obtained and compared to the reference soil and sample soil for field screening. The soil screening results are estimated for confirmation of gamma survey results during the SRC and are not used for compliance at specified limits. If the soil screening result is used for confirmation and indicate that the sample concentration is at or below the investigation level, the sample must be sent off site vendor laboratory analysis for confirmation.

2.0 L2221/44-20 Window Operation and Energy Calibration Procedure

The following procedure calibrates threshold directly in keV.

1. Setup the counting chamber shield system with L 44-20 detector inside the chamber and connected to L2221 scaler/ratemeter. The L44-20 3x3 NaI detector is situated in the shielded counting chamber with the detector crystal facing up.

2. Place RATEMETER multiplier switch to LOG position.

3. Unscrew and remove instrument calibration cover.

4. Press HV pushbutton. The HV should read out on the display directly in volts. While depressing the HV pushbutton, turn HV potentiometer maximum counterclockwise. The HV should be less than 50 volts.

5. Depress the THR pushbutton. Turn the THR potentiometer clockwise until 652 displays.

6. With WIN IN/OUT switch IN, depress the WIN pushbutton. Turn the WIN potentiometer until 20 appears on the display.

7. Switch WIN IN/OUT to OUT.

8. Connect the detector (Ludlum 44-20) and expose to Cs-137 source.

9. Increase HV (if HV potentiometer is at minimum, it will take approximately 3 turns before any change is indicated). While increasing the HV, observe the log scale of the ratemeter. Increase HV until ratemeter indication occurs.

10. Switch WIN IN/OUT switch to IN.

11. Turn the HV control until maximum reading occurs on the log scale. Increase HV until reading starts to drop off, and then decrease the HV for maximum reading.

12. Turn RATEMETER selector switch to the X1K position.

13. Press ZERO pushbutton and release. If meter does not read, switch to a lower range until a reading occurs.

14. Carefully adjust HV potentiometer until maximum reading is achieved on the range scale. The instrument is now peaked for Cs137 on both the LOG and Linear scales. Record HV for energy calibration.

    NOTE: When the THR control is adjusted, the effective window width remains constant. As an example, if the THR is set at 559, the WIN at 100, a 609 KeV peak +559 (100 divided by 2) will be centered in the window. Then the threshold point is equivalent to 559 KeV with a 100 KeV window and calibrated for 100 KeV per turn. Now if the thresh hold is reduced to 250, the threshold is equivalent to 250 KeV, but the window (100) is still equal to 100 KeV. Proportionally, this represents a broader window.

15. Set THR at 559 and window at 100 for Bi-214 609 KeV (559 to 669 KeV ROI) gamma radiation measurement. Expose the detector with a 1% Uranium ore function check source and obtain a one minute counts. Remove the function check source and obtain a one minute background counts.

16. Record the energy calibration data in the L2221SCA/L44-20 Energy Calibration Form (Attachment A).

3.0 Minimum Detectable Concentration

The calculation below is an example for illustrative purposes for minimum detectable concentration (MDC), and the actual MDC will be calculated in the field based on actual field background measurements from function checks. The MDC, for 0.05 probability for both false positive and false negative errors, is calculated using equation 6-7 in Section 6.7.1 of the MARSSIM Guidance,

$$MDC = C \times [3 + 4.65.\sqrt{B}]$$

Where:
C = Detector response factor, pCi/g/cpm
B = Background count rate in cpm.

Example:

For the 3x3 NaI detector of the soil screening system, estimated background count rate of 80 cpm from previous function checks and the detector response during 2018 Characterization of about 86 cpm/pCi/gm (570 net cpm for 3,000 gm reference soil @ 6.6 pCi/g of Ra-226) sample, then the Ra-226 MDC for a 3,000 gm screening sample for a one minute measurement is calculated to be:

$$MDC = (0.0116\ \text{pCi/g/cpm}) \times [3 + 4.65.\sqrt{(80\ \text{cpm}]} = 0.79\ \text{pCi/gm}$$

The required MDC for the St. Anthony Mine Closeout is <3.3 pCi/g (50% of the 6.6 pCi/g SAL). The soil screening counting system will meet the required MDC limit of with one minute background counts of less than about 1000 cpm

Note: The MDC calculation assumes the weight of reference soil and screening soil to be same, 3000 grams, and the background and sample counting time be the same, least one minute. The measurement (integration) time of background and sample may be changed to attain desired MDC.

4.0 Field Soil Screening Procedure

1. Setup the L2221 parameters (HV, Threshold and Window) obtained during energy calibration above and connect the 44-20 detector. Make sure the window toggle switch is in the IN position.

2. Setup the counting chamber shield system in back of pick-up truck.

3. The L44-20 3x3 NaI detector is situated in the shielded counting chamber with the detector crystal facing up.

4. Perform background and source (1% Uranium ore) function checks and record in the Function Check Form (Attachment B).

5. Insert a clean plastic bag in the counting chamber for lining detector and counting chamber to avoid cross contamination. Obtain 3,000 grams of appropriate reference soil, not previously sealed, and place in the plastic bag so that the sample is around the detector without any void, similar to the Marinelli Beaker geometry to provide the best counting efficiency. Cover the chamber opening with lead lid.

6. Obtain an integrated count for specified time period, generally one minute, with L2221 in Scaler mode and record in the soil screening Field Form (Attachment C). The reference soil counts may be used for efficiency calculation (pCi/g/com) for MDC calculation.

7. Remove the plastic bag with soil. Insert new plastic bag in the chamber for liner. Homogenize sample in stainless steel bowl and weigh 3000 grams of sample. Repeat step 5 and 6 for next soil sample. Change counting chamber liner between every sample.

8. Compare the reference soil counts to the sample soil counts to determine the sample Ra-226 concentration at above or below the reference soil concentration.

9. Following completion of soil screening, split a sample aliquot if needed for confirmatory analysis using EPA Method 901.1 by vendor laboratory. Return the unused sample at the location collected from.

QA/QC Procedure

1. The instrumentation, L2221 must be calibrated at least annually. Although the operating HV for the 3x3 NaI detector for soil screening is established during energy calibration discussed above, an HV plateau should be performed at least annually to verify proper detector operation throughout the HV range.
2. The background and source (with uranium ore check source to verify 609 KeV ROI calibration) function checks must be performed daily prior to use.
3. The reference soil material concentration must be determined from vendor laboratory analysis, or prepared using a certified reference material.
4. Duplicate measurement will be performed for 5% of the samples.
5. For verification survey soil screening, any soil sample screening result less than SAL will be sent to a vendor laboratory for confirmation.

Attachment A

AVM Environmental Services Inc.
L2221 SCA/L44-20 Energy Calibration Form

SCA: L2221, SR #68782 Detector: Ludlum 44-20 (3x3 NaI Scintillator)

Calibration Source: Cs-137 Check Source, 5 uCi (August 2008) For 662 KeV Peak Cal

Threshold (input sensitiv **652**

Window, In/Ou__**IN**__ Window ____**20**____

HV Initial ___________, At Peak _____________

Maximum CPM: ________________________ Background CPM: _________________

HV Set @______________VDC

For Bi-214 609.2 KeV Peak (559 - 659 KeV ROI), Set Threshold @ 559, Window @ 100

CBi-214 609 KeV ROI Calibration Check: 1% U3O8 Ore Check Source: _______________ CPM
Background count (empty chamber) ____________ CPM

Date _______________________ Calibrated By ____________________________________

Attachment B

AVM Environmental Services, Inc.
Ludlum SCA L2221 - 44-20 3x3 NaI Detector Function Check
559 - 659 KeV Gamma Radiation Soil Screening

L2221 #68782

Function Check Source ID: 1% U_3O_8 Ore in Sealed can

Ludlum 44-20 3x3 NaI Detector, #PR295573

Acceptable background Count (cpm) Range (20%) ______________________ to ____________________

Acceptable Source Count (cpm) Range (20%) ______________________ to _______________________

Date	Physical Check	Cal Date	Battery(1) Volts or OK	HV Volts	Threshhold mV (2)	Window mV	Window In/Out	BKG Counts cpm	Source Counrts cpm	Within Acceptable Range Y or N	MDC pCi/gm	Tech

Note: (1) Battery Voltage for Ludlum 2221 must be >5.3 volts; (2) Threshhold must be at 220 mV; (3) Window @ 440, must be IN

Attachment C

AVM Environmental Services, Inc.

Field Soil Sample Gamma Radiation Screening Form

Instrumentation : Scaler/Ratemeter________________________, Detector __________________________________

Instrument Calibration Date: ___________________________, Instrument Function Check Performed: _________

Survey Area/Unit Decsription ____

Date/Time	Soil Sample ID	Sample Weight Grams	609 (559-669) Kev Gross Counts	Weight Corrected Counts	CPM	Estimated Ra-226 pCi/g	Comments

Technician Signature ______________________________, Reviewed by _________________________________

AVM SOP-5
AVM Environnemental Services, Inc.
Surface Soil Sampling
UNC's Section 27 Mine Site Supplemental Radiologic Characterization

1.0 Introduction

This standard operating procedure (SOP) describes methods and equipment commonly used for collecting environmental surface soil samples for radiologic analyses during the supplemental radiologic characterization (SRC) at the Section 27 Mine Site (Site). The information presented in this SOP is generally applicable to the collection of all surface soil samples, except where the analyte(s) may interact with the sampling equipment. This SOP defines sample collection procedures using hand augers and shovels/trowels samplers. This document focuses on methods and equipment that are readily available and typically applied in collecting surface soil samples. It is not intended to provide an all-inclusive discussion of sample collection methods.

The objective of surface soil sampling is to characterize radiologic and chemical properties of the soil. Details pertaining to sample locations, number of samples, and type of analyses required, are presented in the Work Plan.

2.0 Scope

This SOP describes procedures for surface soil sampling using hand tools for Ra-226, total uranium and metals analysis as required for the SRC

3.0 Sample Type

Surface soil samples are typically collected from the ground surface to 6 inches below ground surface. Samples collected from greater than 6 inches below ground surface are referred to as subsurface soil samples. Soil sampling includes samples for confirmation of in-situ gamma radiation level and ex-situ gamma radiation soil screening, and for site-specific correlation Surface soil samples may be collected as grab samples or as composite samples. The sample method is determined based on the physical characteristics of the sample location and soil matrix.

- Grab sample: A sample taken from a particular location. Grab samples are useful in determining discrete concentrations, but also provide spatial variability when multiple samples are collected. Grab samples will be collected from sampling locations for the SRC.

- Composite sample: A number of samples that are individually collected then combined (homogenized) into a single sample for subsequent analysis. Composite samples are useful when averaged or normalized concentration estimates of a waste stream or an area are desired. Also, multi-point composite samples may be collected for correlation sampling location.

4.0 Sampling Equipment and Technique

The following materials will be available, as required, during soil sampling activities:

- Personal protective equipment (PPE), as specified by the site HASP
- Stainless steel bowls
- Stainless steel spoons
- Stainless steel spatulas
- Stainless steel trowel
- Stainless steel spades
- Stainless steel hand augers
- Rock pick
- Permanent Indelible ink pens
- Tape measure or a ruler
- Sealable plastic bags (e.g., Ziploc®)
- Appropriate sample location coordinates and/or area maps or figures
- Equipment decontamination materials
- Transport container such as cooler (if sampling for laboratory analysis)
- Appropriate Field Sampling Data forms

A grab surface soil sample may consist of a single scoop or core, or the sample may be a composite of several individual samples. Surface soil samples shall be obtained using hand augers, shovels/trowels, or soil core samplers.

Hand Auger: A hand auger consists of a stainless steel tube with two sharpened spiral wings at the tip. The auger typically cuts a 2-inch to 3-inch diameter boring and works better in consolidated or slightly moist soils. Because the auger is hand-driven, penetration in dense or rocky/gravelly soil may be difficult. For surface soil sample collection, the procedures outlined below shall be followed.

1. Advance the auger by hand into the soil, to the desired depth (6 inches or less for surface soil samples), by turning in a clockwise direction with down force applied.

2. Retrieve the auger by pulling straight up until completely out of the hole, preferably without any rotation.

3. Fill the sample container, generally a Ziploc bag for Ra-226 and/or other container, using clean stainless steel spatulas or spoons. Repeat step 1 and 2 until a sufficient amount of sample is collected for specified analysis. For Ra-226 analysis by Method 901.1, about 400 grams in a quart size Ziploc bag is sufficient. For on-site ex-situ soil screening, about 3000 grams in a gallon size Ziploc bag will be required. Affix label on the sample container with appropriate sample information.

Shovel/Trowel: Various shovel/trowel designs and sizes are commercially available for a variety of sampling applications. These devices are hand-driven and are typically used for sampling relatively soft, unconsolidated surface soils. Some designs (e.g., the sharpshooterTM) can be driven into hard, rocky soil by opening a deep, narrow hole. All shovels or trowels used for soil sampling shall be made of stainless steel. The procedures outlined below shall be followed while collecting samples with shovels or trowels.

1. Drive the shovel/trowel into the soil six inches deep.

2. Retrieve the shovel/trowel being careful to not spill sample.

3. Fill the sample container, generally a Ziploc bag for Ra-226 and/or other type sample container for metals using clean stainless steel spatulas or spoons. Repeat step 1 and 2 until sufficient amount of sample is collected for specified analysis. For Ra-226 analysis by Method 901.1, about 400 grams in a quart size Ziploc bag is sufficient. For on-site ex-situ soil screening, about 3000 grams in a gallon size Ziploc bag will be required. Affix label on the sample container with appropriate sample information.

This procedure can also be used for collecting soil samples collected for ex-situ gamma radiation soil screening for subsurface soil investigation from the base of shallow test holes, pits or trenches excavated by hand tool such as a shovel or by a backhoe. Any soil sample collected for on-site ex-situ gamma screening may require sending to off-site vendor laboratory for Ra-226 analysis based on the ex-situ soil screening results. Split an aliquot for the off-site vendor laboratory from the ex-situ sample, which would have been already homogenized and of ample quantity.

5.0 Sample Equipment Decontamination

All sampling tool and equipment used for soil sampling will be clean prior to any soil sample collection. Sampling tools and equipment that are reusable will be decontaminated in between sample collection at different locations to avoid sample cross contamination. Hand tools, such as trowels, shovels, spoons, mixing bowls, etc. will be decontaminated at the sample locations. Any large equipment may be decontaminated at the designated decontamination area at the Site to for appropriate disposal of residual soil and rinsate. Since the sampling involves soil that may be potentially impacted by the COCs, Ra-226, uranium, and the COPC metals from uranium ore, which are mostly insoluble, the following procedure will be used to decontaminate soil sampling tools and equipment:

1. Brush off any loose soil from the sampling tool.
2. Wash the sampling tool with water and a residue free detergent, such as Alconox, in a bucket using a brush.
3. Rinse the sampling tool in a bucket with fresh water.
4. Rinse the sample tool with de-ionized water.

6.0 Investigation Derived Waste

The surface soil sampling is not expected to generate any Investigation Derived Waste (IDW) other than PPE (disposable gloves) and paper towels. Any excess soil from soil sample will be backfilled into the hole created from sample collection. Sampling tool decontamination rinse water will be poured on top of the backfilled sample hole for compaction. This method does not create any additional contamination or waste.

7.0 Sampling Data Recording, Handling and

Field sampling documentation will be completed to provide sample information. Fill out sample information in the Field Soil Sample Log Form, included in Attachment A. Any additional information may be included in the log book. Sample handling requirements, such as storage, shipping and chain of custody, are specified in the Work Plan. The soil samples collected for the COCs and CPOC metals do not require any specific preservatives. Complete sample chain of custody provided by laboratory. The field supervisor will retain all site documentation while in the field and add to project files when the field mobilization is complete.

8.0 QA/QC Requirements

Quality assurance quality control (QA/QC) includes following the SOP as discussed above, which includes proper decontamination to avoid cross contamination and sampling data recording and handling. Field QA/QC samples will be collected at the frequency specified in the work plan as listed below:

- Sampling equipment rinsate sample as discussed above in the section 5.0.
- Field QA/QC soil sample duplicate at a frequency of 10% of the samples collected.

Other applicable QA/QC requirements for laboratory, such as blanks, duplicate analyses, matrix spike are specified in the Work Plan.

Attachment A
Field Soil Sample Log Form

Sample ID	Sample Date and Time	Sample Location (Coordinates)	Sample collection method/container/preservative	Analyses	Sample Type/Description	Comments/Notes	Sample Tech

Please include other applicable information, such as sampling activity/event, COC#, sampling depth, soil description, sample sub-location, etc in sample description or comments/notes

STANDARD OPERATING PROCEDURES

SOP-1
TRENCHING AND TEST PITTING

Stantec

STANDARD OPERATING PROCEDURES

SOP
TRENCHING AND TEST PITTING

TABLE OF CONTENTS

DISCLAIMER

THE FOLLOWING STANDARD OPERATING PROCEDURE PROVIDE A GENERAL GUIDANCE ON INTERNAL PROCEDURES OF STANTEC, INC. ("STANTEC") RELATING TO TECHNICAL ISSUES TO BE ADDRESSED INVOLVING EXCAVATION AND SAMPLING OF ENVIRONMENTAL TEST PITS. IT IS NOTED, HOWEVER, THAT EACH PROJECT AND SITE IS UNIQUE AND THAT THESE GUIDELINES ARE NOT A SUBSTITUTE FOR COMMON SENSE AND GOOD MANAGEMENT PRACTICES BASED ON PROFESSIONAL TRAINING AND EXPERIENCE. IN ADDITION, INDIVIDUAL CONTRACT TERMS MAY AFFECT THE IMPLEMENTATION OF THESE STANDARD OPERATING PROCEDURES. MANAGEMENT RESERVES THE UNRESTRICTED RIGHT TO CHANGE, MODIFY OR NOT APPLY THESE GUIDELINES IN ITS SOLE, COMPLETE AND UNRESTRICTED DISCRETION TO MEET CERTAIN CIRCUMSTANCES, CONTRACTUAL REQUIREMENTS, SITE CONDITIONS OR JOB REQUIREMENTS.

1.0 INTRODUCTION

This standard operating procedure establishes guidelines for conducting test pit and trench excavations at hazardous waste sites.

Shallow test pits accomplish the following:

- Permit the in-situ condition of the ground to be examined in detail both laterally and vertically
- Provide access for taking samples and for performing in-situ tests
- Provide a means of determining the orientation of discontinuities in the ground

Periodically, a portion of a site investigation will focus on abandoned subsurface structures or an area that may contain, or was at one time a dumping ground for, various types of hazardous and nonhazardous waste. Before drilling soil borings in these areas, excavation of a trench or test pit may be necessary to clear drilling areas of debris and identify sources or geophysical anomalies. Excavations can be readily extended to locate the boundaries of abandoned foundations, landfills, or trenches. At appropriate locations, trenches or test pits may be used to uncover unexploded ordnance by qualified explosive ordnance detection teams prior to commencing any intrusive activities. In suitable ground, shallow excavations may provide an efficient and economic method to evaluate the shallow subsurface environment of a site.

2.0 DEFINITIONS

Trench or Test Pit	Linear excavation, of varying width, usually used as an exploratory method to locate landfill boundaries or buried structures, or to characterize the soil/fill sequence at a site.
Ground Crew	Composed of excavating support crew and sampling crew.

3.0 RESPONSIBILITIES

The **Project Manager** selects site-specific soil sampling methods with input from the Site Geologist/Field Team Leader and oversees preparation of heavy equipment/explosive ordnance detection subcontract.

The **Site Geologist/Field Team Leader** selects excavation options, implements the trenching/test pit program, assists in the preparation of technical provisions, and prepares subcontracts.

The **Sampling Crew** performs sampling procedures.

4.0 TRENCH AND TEST PIT CONSTRUCTION

4.1 GENERAL

Trench and test pit excavation is carried out either manually or by using standard equipment such as backhoes, trenching machines, track dozers, track loaders, excavators, and scrapers. Operators of excavating equipment must be skilled and experienced in its safe use for digging test pits and trenches. A typical excavator with an extending backhoe arm can excavate to a depth of approximately 15 feet. If investigations are required to penetrate beyond 15 feet, soil borings may be a more feasible method.

A tailgate safety meeting is conducted by a designated on-site safety officer before commencing excavation.

Prior to all excavations, the Field Team Leader must confirm that underground utilities (electric, gas, telephone, water, etc.) within the proposed areas of excavation have been cleared or marked off. Certain underground services may not be picked up by detectors. Careful excavation, use of probing rods, and the ground crew watching for early signs can help prevent damaging or puncturing underground services.

Prior to commencing excavation, standard signals shall be developed and reviewed for rapid and efficient communication between the backhoe operator and the ground crew. Before approaching areas with operating equipment, the sampling and support crew must verify that the operator has noted their presence.

Upon locating the area for excavation, the backhoe operator determines wind direction and positions the machine upwind of the area of excavation. The backhoe operator outlines the area of investigation by extending the bucket arm to its maximum length and traces a 180-degree outline around the area to be excavated. The support crew cordons off the exclusion zone with a wooden lath and brightly colored "caution" tape, or other appropriate temporary fencing.

Once the excavation equipment has been positioned and stabilized, excavation can commence. If the area of investigation is beneath vegetative cover or surface debris, the backhoe operator removes the surface material to allow a clear and safe working area. Excavated soil is stockpiled away from the immediate edge to one side of the trench to prevent excavated soil from re-entering the trench or test pit and to reduce pressure on the sidewalls. When possible, the soil is deposited downwind of the ground crew and the machine operator. Shifting winds may cause the machine and its operator and the ground crew to periodically move in order to remain upwind. Under some conditions where remaining upwind is not possible, it may be necessary to curtail further activities. The support crew should regularly check the machine operator who, if in a partially enclosed cabin, may be susceptible to fumes/gases.

4.1.1 Safety Procedures

Entry of personnel into pits or trenches is strictly prohibited unless specifically approved and strict adherence to state and federal Occupational Safety and Health Administration guidelines is observed.

Unless full lateral support of the side walls is provided, personnel should never trench deeper than 4 feet (chest height) when personnel will be working in the trench. Any personnel entering the trench may be exposed to toxic or explosive gases and an oxygen-deficient environment. Air monitoring is required before and during entry and appropriate respiratory gear, protective clothing, and egress/rescue equipment is mandatory. Caution should be exercised at all times. For example, in combustible fills, temperature measurements may be necessary. On waste tips, burning material below ground may give rise to toxic or flammable fumes from the hole; tip fires may also create voids that may collapse under the weight of an investigation rig or backhoe machine. Lagoons within waste tips may be areas of very soft ground.

At least two people must be present at the immediate site. Ladder access/egress out of the pit must be installed before entry. Two ladders for worker access/egress must be provided for every 25 feet of lateral distance of a trench and, at a minimum, ladders shall be positioned at opposite ends of trenches less than 25 feet in length.

Care should be taken to ensure that personnel do not stand too close to the edge of the trench especially during sampling or depth measurements; the combination of depositing soil adjacent to the pit and the risk of caving or toppling of the side walls in unstable soils can lead to unsafe conditions.

4.1.2 Stability

Depending on the desired depth of excavation, the trench may require shoring to prevent the sides from collapsing. Lateral support may be provided by a support frame system, or by benching or sloping the sides of the excavation or trench to an appropriate angle. Any timbering or support systems must be installed by qualified personnel.

Groundwater may be pumped out of the pit to stabilize the sidewalls and to keep the excavation dry, allowing a greater depth to be reached especially in granular materials that are below the water table.

Near-vertical slopes can stand for seconds or months, depending on the types of material involved and various other factors affecting the stability. Although personnel should not be entering the excavation, it is prudent to know the possible behavior of the various soil types and conditions that may be encountered. Excavations into fill are generally much more unstable than those in natural soil.

Excavations in very soft, normally consolidated clay may stand vertically without support for short periods. Long-term stability is dependent on a combination of factors: the type of soils, pore pressures, and other forces acting within the soil, and adverse weather effects. Fissured clays can fail along well-defined shear planes; therefore, their long-term stability is not dependent on their shear strength and is difficult to predict.

Dry sands and gravels can stand at slopes equal to their natural angle of repose no matter what the depth of the excavation (angles can range from approximately 28 to 46 degrees depending on the angularity of grains and relative density).

Damp sands and gravels possess some cohesion and can stand vertically for short periods. Water-bearing sands, however, are very difficult in open excavations. If they are cut steeply, as in trench excavation, seepage of water from the face will result in erosion at the toe followed by collapse of the upper part of the face until a stable angle of approximately 15 to 20 degrees is obtained.

Dry silts may stand unsupported vertically, especially if slightly cemented. Wet silt is the most troublesome material to excavate. Seepage leads to slumping and undermining with subsequent collapse, eventually reaching a very shallow angle of repose.

It should not be taken for granted that excavations in rock will stand with vertical slopes unsupported. Their stability depends on the soundness, angle of bedding planes, and the degree of shattering. Unstable conditions can occur if bedding planes slope steeply towards the excavation, especially if groundwater is present to act as lubrication.

4.2 FIELD RECORDING AND SAMPLING TECHNIQUES

The field record should include a plan giving the location, dimensions, and orientation of the pit, together with dimensioned sections of the sidewalls, description of the strata encountered, and details of any sampling or testing carried out. A photographic record of the test pit, with an appropriate scale, would be ideal.

Any groundwater encountered should be noted with regard to its depth and approximate rate of seepage. If possible, the groundwater level within the test pit should be monitored for 20 minutes, with readings taken at 5-minute intervals.

Working from the ground surface the technician can prepare a visual log of the strata/soil profile and decide the interval of sampling. Samples from excavations can be either disturbed or undisturbed.

Disturbed samples are taken from the excavator bucket or from the spoil. To obtain a representative sample of the material at a certain depth, care must be taken not to include scrapings from the sidewalls.

Undisturbed samples may be block samples, cut from in situ material; tube samplers may be driven into the floor of the pit using a jarring link and drill rods and extracted using the backhoe of the excavator.

Samples of groundwater or leachate may be taken using telescoping poles or a small bailer.

The required size of the samples will vary according to the intended analysis/testing to be carried out.

4.3 BACKFILLING

The test pits or trenches should be backfilled immediately upon completion of the hole. Prior to backfilling, pits and test trenches should be inspected to make sure it is safe to approach the excavation with the backfill and equipment. Poorly compacted backfill will cause settlement at the ground surface and hence the spoil should be recompacted in several thin layers using the excavator bucket and any surplus material placed over the top of the pit.

If a sealing layer has been penetrated during excavation, resulting in a groundwater connection between contaminated and previously uncontaminated zones, the backfill material must represent the original conditions or be impermeable. Backfill material could comprise a soil-bentonite mix or a cement-bentonite grout.

4.4 DECONTAMINATION

The purpose of decontamination and cleaning procedures during sampling tasks is to prevent foreign contamination of the samples and cross contamination between sites. All sampling and excavation equipment must be decontaminated before use.

5.0 REFERENCES

Scientific and Technical Standards for Hazardous Waste Sites, Book 1, Volume 1, Site Characterization, August 1990.

Tomlinson, M.J., 1986. *Foundation Design and Construction*, 5th Edition.

Test Pit ID: ______________

FIELD SAMPLE DATA SHEET (FSDS)
TEST PIT LOGGING

Sheet NO.: TP- ____________

GENERAL LOCATION: ____________ DATE: ______________ NORTHING: ____________

PIT TREND: __________________ FIELD ENGINEER: ____________ EASTING: ____________

PIT FACE LOGGED: __________________

TEST PIT LOG

LEGEND

- – – – – SOIL HORIZON
- –·–·–·– HORIZON CONTRACT
- ▽ GROUNDWATER LEVEL
- ⊠ SAMPLE

SAMPLE No.	DEPTH	TIME	TYPE

Pit Width: ______________

Pit Length: ______________

Pit Depth: ______________

GW Depth: ______________

USCS SYMBOL	SOIL UNIT	SOIL DESCRIPTION AND EXCAVATION NOTES

SPECIAL NOTES:

Corresponding GT FSDS Sheet No.: GT- ________________