Skyline AUM Waste Pile Site Removal Assessment Report, Navajo Nation, San Juan County, Utah

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List of Abbreviations and Acronyms

µR/hr	micro Roentgens per hour
AUM	Abandoned Uranium Mine
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DCGL	Derived Concentration Guideline Level
E & E	Ecology and Environment Inc.
ERS	Emergency Response Section
ERRS	Emergency and Rapid Response Service
EQM	Environmental Quality Management
FOSC	Federal On-Scene Coordinator
GIS	Geographic Information System
GPS	Global Positioning System
IDW	Investigation Derived Waste
IETF	Indoor Exposure Time Fraction
kcpm	kilo-counts per minute
mg	milligrams
mrem	millirem
NaI	Sodium Iodide
NNEPA	Navajo Nation Environmental Protection Agency
NPL	National Priorities List
NRC	United States Nuclear Regulatory Commission
NTUA	Navajo Tribal Utility Authority
OETF	Outdoor Exposure Time Fraction
OSWER	Office of Solid Waste and Emergency Response
pCi/g	picocuries per gram
PRG	Preliminary Remediation Goal
PST	Pacific Strike Team
QA/QC	Quality Assurance-Quality Control

List of Abbreviations and Acronyms (cont.)

QASP	Quality Assurance and Sampling Plan
Ra-226	Radium-226
RAT	Rapid Assessment Tool
rem	Roentgen Equivalent Man
RPD	relative percent difference
SMWP	Skyline AUM Waste Pile
SRM	Skyline Road Mine
SSL	Soil Screening level
START	Superfund Technical Assessment and Response Team
TLDA	Transloading Decision Area
TSDA	Talus Slope Decision Area
U.S. EPA	United States Environmental Protection Agency
USCG	United States Coast Guard

1 Introduction

During the period between July 2009 and March 2010, the United States Environmental Protection Agency (U.S. EPA) Federal On-Scene Coordinator (FOSC) Jason Musante tasked the Superfund Technical Assessment and Response Team (START) to provide additional assistance with an on-going assessment of an area impacted by historic releases of radioactive uranium ore and associated daughter products from the former Skyline Abandoned Uranium Mine (AUM). The Skyline AUM, the Skyline Mine Waste Pile (SMWP) site, and surrounding properties are part of the Oljato Chapter of the Navajo Nation (Navajo). The location of the Skyline Mine is shown on Figure 1. Site features are depicted on Figure 2.

Nearby residents have expressed concern to the Navajo Nation Environmental Protection Agency (NNEPA) regarding the potential for wind-blown and water-borne radioactive particles to migrate from the site and impact their livestock and/or properties. The SMWP site at the base of Oljato Mesa (the mesa) is used as grazing land for livestock owned by the local residents. During a site inspection performed by the NNEPA in July 2005, gamma radiation activity (gamma activity) counts greater than two times the background level were detected in approximately 80 locations at the SMWP site. The NNEPA requested assistance from the U.S. EPA in performing an investigation of the SMWP site and surrounding area to determine the nature and extent of the contamination and to mitigate any potential impacts to human health and/or the environment.

The purpose of this document is to summarize removal assessment work performed at the former Skyline AUM and SMWP sites between July 2009 and March 2010. The purpose of the assessment work was to define the lateral and vertical extent of elevated radioactivity attributable to past mining practices at the site and to determine if unacceptable health risks to nearby residents and/or the environment are present.

2 Site Information

2.1 Site Location

The former Skyline AUM is located on top of the mesa, approximately 1.5 miles northwest of Gouldings in Monument Valley, San Juan County, Utah. The Skyline AUM Waste Pile (SMWP) site is located approximately 700 feet below the former mine at the eastern base of the mesa and consists of residual mine waste (Latitude: 37° 01’ 13.99” N, Longitude: 110° 13’ 50.97” W).

2.2 Site Description

The area of concern with regard to this report is the Skyline AUM, the SMWP site, and associated residential and pastoral areas east and downgradient from the foot of the mesa. Site features are depicted on Figure 2. Photographs of the Skyline AUM, the SMWP site, and related START assessment activities are included in Appendix A.

Approximately five homesites with residential structures are located between 1,490 feet and 1,800 feet east and northeast of the SMWP site. These residential properties are cross gradient to the waste piles and runoff from the portions of the SMWP site that are impacted by mine waste does not flow though them. Land use in the project area is characterized by a low density of single-family residences surrounded by open grazing land. Areas near the foot of the mesa are characterized by talus slopes covered with waste rock and/or waste ore that was pushed over, or fell from, the top of the mesa where the operating mine was located. Portions of the cliff directly below the mine are visibly stained a grey-green color from this activity. As part of regular mining operations, a gondola was used to transport ore from the Skyline AUM to the foot of the mesa where it was loaded into trucks for transport to the mill. Portions of the gondola, including steel cables, remain at the foot of the mesa. One area of documented elevated gamma activity is located approximately 500 feet southeast of the base of the stained areas. This area may have been the transloading area where ore was transferred from ore cars to trucks for transport to a uranium mill.

According to NNEPA personnel, the top of the mesa and the SMWP area are used seasonally during the spring, summer, and fall by local residents as pastureland for grazing sheep and cattle and gathering traditional herbs and plants. The road to the top of the mesa is in extremely poor condition and therefore access to the top of the mesa is limited to 4-wheel drive vehicles, all-terrain vehicles, or foot traffic. Other than several former uranium mine sites, there is no known permanent infrastructure on the top of the mesa.

2.3 Site Background

Portions of the Navajo Nation are on geologic formations rich in radioactive uranium ores. Beginning in the 1940s, widespread mining and milling of uranium ore for national defense and energy purposes on Navajo tribal lands led to a legacy of abandoned uranium mines. The Skyline AUM is one of approximately 520 AUMs located on the Navajo Nation. During the late 1990’s, portions of the Skyline AUM on top of the mesa were closed by the Navajo Nation Abandoned Mine Land (NNAML) program. This work focused on removing immediate physical hazards including sealing the mine portals, consolidating loose accessible mine waste, and capping it with uncontaminated fill material. However, due to the steep terrain, residual mine waste at the eastern edge of the mesa and the bottom of the mesa were not removed during mine closure activities.

2.4 Previous Investigations

In 2001, the Region 9 Emergency Response Section (ERS) of the U.S. EPA demolished one structure constructed of radioactive stone and located in the residential area east of the SMWP site (E&E 2001).

Between November 10 and 13, 2008, START collected 28 surface soil samples from two areas within the SMWP site and performed surface gamma activity scans at the SMWP site and nearby residences using the Rapid Assessment Tool (RAT) developed by the U.S. EPA. Each RAT unit was equipped with a Ludlum Model 2241 Digital Survey Ratemeter (Ludlum 2241) with a Ludlum Model 44-10 2-inch diameter sodium iodide (NaI) gamma scintillation detector (2x2), a Panasonic Toughbook® laptop computer, and a Trimble® Model GeoXT™ Global Positioning System (GPS) unit. The RAT software developed by the U.S. EPA allows the user to simultaneously collect and record gamma activity counts and their associated GPS locations and display this information in real time on the laptop computer. As part of the removal assessment performed at the site in November 2008, a background area with similar geology and no known or suspected impacts from mining was selected. Surface soil samples and gamma activity scan data were collected at 14 locations within the background area to allow for a comparison of radium 226 (Ra-226) concentrations and gamma activity counts in soils from the Skyline AUM. A summary of the soil sampling data for the background area from November 2008 is shown on Table 1. The average background area Ra-226 soil concentration for the 14 samples was 0.16 picocuries per gram (pCi/g). The removal assessment documented the presence of mine waste that contains Ra-226 above background concentrations at two locations within the SMWP site. (E&E 2009a). These locations were the suspected former transloading area, designated the transloading decision area (TLDA), and the top of the talus slope immediately below the mine, designated the talus slope decision area (TSDA). To establish a derived concentration guideline level (DCGL) for residential soils, the average background area Ra-226 soil concentration of 0.16 pCi/g was added to the established baseline U.S. EPA Preliminary Remediation Goal (PRG) for Ra-226 of 1.24 pCi/g to produce a DCGL of 1.41 pCi/g. Based on data correlation studies performed by the U.S. EPA and the START, the removal assessment did not identify any elevated gamma activity readings within approximately 500 feet of the nearest home site that correlated to an activity level greater than the established DCGL.

3 Summary of START Activities July 2009 Through March 2010

The following sections describe field activities performed by the U.S. EPA and the START between July 2009 and March 2010. During the period, four mobilizations occurred as follows:

July 2009- The START, the U.S. EPA, and the NNEPA traveled to the Skyline AUM and several other former AUMs on the top of Oljato Mesa. The assessment team performed visual inspections and used a Ludlum 2241 meter with a 2x2 detector to and a micro-R meter to estimate gamma radiation activity and exposure rates at and near the former mine entrances. The purpose of the work was to evaluate whether additional radioactive materials associated with former mining activity were potentially present in surface soils at or near those sites. Additional gamma radiation activity rate scans were performed at and north of the SMWP site to evaluate whether the site boundary needed to be expanded northward.

August 2009-The START and the U.S. EPA traveled to the SMWP site and collected surface and subsurface soil samples and performed additional gamma activity scans to further define the lateral and vertical extent of radioactive materials.

October 2009- The START and the U.S. EPA performed additional gamma activity scans on surface and subsurface soils in the arroyo at the SMWP site to define the lateral and vertical extent of elevated gamma radiation activity.

March 2010- The START and the U.S. EPA performed additional gamma activity scans at the SMWP site and at the three home sites located immediately northeast of the site to further evaluate the lateral extent of radioactive materials in surface soils.

April 2010- The START, the U.S. EPA, and Environmental Quality Management (EQM) mobilized to the SMWP site to install fencing and apply a soil stabilizer at the two locations within the SMWP site with the highest observed gamma radiation activity.

Prior to mobilizing each time, the START updated the site-specific health and safety plan as needed.

During the November 2008, August 2009, October 2009, and March 2010 removal assessments, the START used the RAT to perform surface gamma activity measurements at the SMWP site. Existing RAT data from these four assessments are depicted on Figure 2. Except for measurements from the March 2010 assessment which utilized a Ludlum 2221 meter with a 2x2 detector, all gamma activity measurements were made with Ludlum Model 2241 meters with Ludlum Model 44-10 2x2 detectors.

3.1 July 2009 START Activities

Prior to field work on July 24, 2009, START and U.S. EPA met with NNEPA representatives E. Esplain and S. Edison and traveled to the Oljato Chapter House of the Navajo Nation to inform the Chapter Administration of the U.S. EPA and NNEPA's intent to visit the Skyline AUM site, and to explain the nature of the project assessment work.

After visiting the Chapter House, START, the U.S. EPA, and NNEPA representatives traveled to the top of Oljato Mesa to the former Skyline AUM Site and used a Ludlum 2x2 detector and micro-R meter to measure gamma activity and exposure rates. Gamma activity readings ranged from approximately 20 kilo counts per minute (kcpm) to greater than 999 kcpm. Photos of the mine portals and the impacted areas are included in Appendix A. Approximate average readings of 15 to 30 kcpm were observed in areas that did not appear to be impacted by mine waste. Gamma activity counts in areas with visible mine waste or ore varied greatly. For example, surface scans of soil used to cap mine waste ranged from approximately 20 to 50 kcpm. Readings in areas with lighter colored mine waste visible on the surface generally averaged 200 to 300 kcpm. Gama activity counts in some areas near the two sealed mine portals were above 999 kcpm. No attempt was made to evaluate the effects of source geometry. However, it should be noted that activity rates were generally highest when standing within 3 to 5 feet of a vertical rock formation.

An area immediately southeast and down gradient from the mine portals displayed a surface material that was lighter in color than surrounding soils and appeared to be mine waste. As discussed above, gamma activity counts in these areas were noticeably higher than in areas away from the mine site. The area of lighter colored visible mine waste was approximately 250 feet wide at the top of the slope near the mine, and tapered to approximately 75 feet wide at the base of the slope. The length of the visibly impacted area was approximately 300 feet. A more exact area and depth of the material could not be directly determined due to the steep inaccessible terrain. However, at least some debris lay in an intermittent layer from approximately 6 to 12 inches thick on top of the undisturbed sandstone rock. At least one rock overhang was visible in the debris field. The debris field ended at the point that the slope steepened to vertical. At that point, the terrain dropped almost straight down (i.e., the side of Oljato Mesa) for approximately 400 feet to the top of the talus slopes at the foot of Oljato Mesa. Mine waste on the steep slope in this area is generally inaccessible to humans and livestock and is not considered an immediate threat to human health or the environment. However, debris on the steep slope could be deposited at the foot of the mesa by erosion and gravitational forces. START also performed photo documentation using a digital camera and geo-located selected locations in a geographic information system (GIS) database using a Trimble Model GeoXT GPS unit (Trimble).

After leaving the Skyline AUM site, the START, U.S. EPA, and NNEPA assessment team then traveled to four other mines on the top of the mesa and within approximately ¾-mile of Skyline Mine. These included U.S. EPA Atlas Project Mine Numbers 18 through 21: the Skyline Road Mine, Tom Holliday Mine, and two other mines both designated Mitten No. 1. Only one mine, the Skyline Road Mine (SRM), had visibly stained surface soils that appeared to be mine waste. Gamma activity counts as high as 365 kcpm were observed in the debris field on the slope below the sealed portal of the SRM (Figure 1). No readings greater than approximately 10 kcpm were observed at any of the other mine sites.

The following day the same group traveled to the TLDA at the SMWP site and used a hand auger to evaluate soil conditions for the purpose of planning future sub-surface soil sampling activities. The group then walked to the top of the TSDA and used a hand auger to evaluate soil conditions and the feasibility of using heavy equipment to potentially remediate mine waste located there. U.S. EPA Region 8 FOSC Merritt, NNPEA representative Edison, and START member Milton then traveled approximately ½-mile northwest of the SMWP site to the western side of the promontory that trends outward in a northern direction from Skyline AUM and Oljato Mesa (Figure 2). The purpose of the reconnaissance was to assess the nature and surface extent of higher-than-background gamma activity observed in an ephemeral drainage during a surface scan of the area performed by the START in November 2008 (Figure 2). This ephemeral drainage transports runoff from the northwestern side of the promontory. A Ludlum 2241 meter with a 2x2 detector was used to measure gamma activity of surface soils. Special attention was paid to drainages near the mesa, which were dry at the time the work was performed. Upon entering the drainage where elevated gamma activity had previously been observed, activity counts increased from 9 to 12 kcpm to 20 to 26 kcpm. Activity counts generally increased as the drainage was traced back to its origin at the foot of the mesa, and reached a maximum average reading of about 40 kcpm within about 25 feet of the base of the mesa. The maximum individual reading in this area, approximately 55 kcpm, occurred approximately 25 feet east of the drainage and near the top of a talus slope adjacent to the mesa. Due to local topography, the exact geographic coordinates of the highest activity rate could not be determined using available GPS technology. There were no visible indications of mining activity or mine waste in this area. The elevated readings observed in the drainage appeared to be due to the erosion of uranium-bearing ore located at the top of Oljato Mesa and did not appear to be related to past mining activities.

3.2 August 2009 START Activities

Specific actions performed by the START as part of removal assessment work conducted from August 24 through 28, 2009 included:

1. Collecting 14 subsurface soil samples, GPS coordinates, and associated 1-minute gamma activity counts in the previously established background area located approximately ½-mile southeast of the site (Figure 1).
2. Performing 1-minute gamma activity counts associated with 18 subsurface soil samples and four surface soil samples from the TLDA near the foot of Oljato Mesa (Figure 3).
3. Performing additional surface gamma scans using the U.S. EPA’s RAT software package, a Trimble GPS unit, and a Ludlum 2241 meter with a 2x2 detector.

All gamma activity scans and soil sampling were performed in accordance with the *Time Critical Quality Assurance Sampling Plan For Skyline AUM Radiation Removal Assessment and Sampling*, dated August 18, 2009 (August-QASP). A copy of the August-QASP is included in Appendix B. In a change from the procedures stated in the August-QASP and in concurrence with FOSC Musante, the hand auger used in subsurface soil sampling during the August 2009 assessment work was decontaminated between boreholes using disposable wipes. Wipes were used to avoid generating potentially contaminated investigation derived waste (IDW) that could not be properly secured prior to leaving the site, and, therefore; equipment rinsate blanks were not collected. Prior to their disposal as municipal wastes, wipes and used personal protective equipment (i.e. disposable nitrile gloves, booties, and tyvek suits) were scanned using a pancake probe to ensure radioactivity was within the range of background concentrations.

Immediately prior to collecting the surface soil samples, the START used the Ludlum 2x2 to perform 1-minute gamma activity scans at each surface soil location. The probe was held 6-inches above the soil surface during the measurement. The sample location's latitude and longitude were recorded using GPS technology. For subsurface samples, a hand auger with a 3-inch bit was used to bore to 1-foot bgs, the 2x2 detector was lowered to within 1-inch of the bottom of the hole and a 1-minute gamma activity count was performed. After recording the activity count, the soil sample was collected and the borehole was filled in with the excavated material.

Soil samples were collected into 9-ounce (oz.) soil-jars. The jars were immediately labeled with the sample ID, date, time, and sampler's initials. The same information was recorded on the chain-of-custody form. All samples were placed in a cooler until they were shipped to GEL Laboratories LLC (GEL), Charleston, South Carolina, for analysis for radium 226-gamma spectroscopy with ingrowth, by method HASL 300,4.5.2.3. All soil sampling data were validated in accordance with the, *Quality Assurance/Quality Control Guidance for Removal Activities, Sampling QA/QA Plan and Data Validation Procedures* (EPA/540/G-90/004, OSWER Directive 9360.4-01), dated April 1990. Copies of the data validation reports, including summarized lab reports, are included in Appendix C. The data were considered valid, definitive, and acceptable for use without qualification, and all parameters evaluated were within acceptable quality assurance and quality control (QA/QC) limits established in the U.S. EPA-approved August-QASP.

As part of the August 2009 removal assessment work, the START attempted to collect subsurface soil samples from the TSDA in order to delineate the vertical extent of Ra-226 in soil in this area at concentrations above approximately 2 pC/g. The TSDA is located at the top of a steep talus slope and is inaccessible to mechanized drilling equipment and/or vehicles, therefore, a hand auger was used to attempt the borings. However, boulders and cobbles in surface soils prevented the auger from advancing deeper than about 6-inches and START was unable to collect subsurface samples from this area.

3.3 October 2009 START Activities

Specific actions performed by the START as part of removal assessment work conducted from October 27 through 31, 2009 included:

1. Performing additional surface gamma scans using the U.S. EPA's RAT software package, a Trimble GPS unit, and a Ludlum 2241 meter with a 2x2 detector.
2. Performing surface and subsurface 1-minute gamma activity counts at ten test pits excavated to a maximum depth of 3.5 feet below ground surface (bgs) in selected

locations along an approximately 1,825-foot reach of the unnamed arroyo that carries runoff from the Skyline AUM and SMWP sites, including impacted areas at the base of the mesa.

All gamma activity scans were performed in accordance with the *Time Critical Quality Assurance Sampling Plan For Skyline AUM Radiation Removal Assessment and Sampling, October, 2009* (E& E 2009c, October-QASP). A copy of the October-QASP is included in Appendix C.

3.4 March 2010 START Activities

As part of removal assessment work conducted from March 9 through 11, 2010, the START performed additional surface gamma scans using the U.S. EPA's RAT software package, a Trimble GPS unit, and a Ludlum 2221 meter with a 2x2 detector in the background area, the arroyo, and three residential home sites adjacent to the SMWP site. All gamma activity scans were performed in accordance with the August-QASP and the October-QASP.

Gamma activity scans at the residential home sites (designated as HS-01, HS-02, and HS-03) were conducted in accordance with the U.S. EPA's Navajo Nation Residential Structures Assessment Program. In general, gamma activity scans were performed in an approximately ½-acre area around the primary residence and other habitable structures at each home site. Prior to conducting the residential scans and in accordance with the method, a minimum of 180 individual gamma activity measurements are collected in the associated background area. The investigation level (IL) for residential home sites is determined by adding 10 times the standard deviation of the background area data set to the average background activity count (U.S. EPA 2008).

3.5 April 2010 START Activities

During the period from April 20 through 23, 2010, START, U.S. EPA, and EQM, the Emergency and Rapid Response Contractor (ERRS) mobilized to the SMWP site to install fencing and apply a soil stabilizer in the areas with the highest observed gamma radiation activity.

Approximately 650 linear feet of 4-foot high orange safety fence was installed around the perimeter of the TLDA and approximately 300 linear feet of the same type of fence was installed around three sides of the TSDA. The purpose of the fencing was to prevent grazing animals and the public from contacting soils contaminated with radionuclides.

To limit fugitive dust emissions, Soiltac® soil stabilizer mixed with water at a 10:1 ratio was applied to surface soils in the TSDA and TLDA. It is anticipated that the stabilizer will limit or prevent fugitive dust emissions until it biodegrades in 12 to 24 months.

4 Discussion of Analytical Results and Gamma Activity Scan Data

The specific instruments used varied for the three removal assessments conducted in November 2008, August 2009, and October 2010. However, studies between the November 2008, August 2009, and October 2010 data sets suggest gamma activity measurement made with different instruments are strongly correlated for areas where Ra-226 concentrations and gamma activity counts are above background levels. For example, surface gamma activity counts conducted in November 2008 and August 2009 at TLDA locations 15 through 28 were compared using intrinsic linear regression analysis. The correlation coefficient (R^2) between gamma activity counts taken in 2008 and those taken in the same locations in 2009 was greater than 0.97. A graph of these data is shown on Figure 3. The average activity count was 26.2 kcpm in November 2008 and 23.4 in August 2009. The relative percent difference (RPD) between the averages is 11 percent, which is within the normal tolerance.

4.1 Background Area Subsurface Soil Assessment

On August 27, 2009, the START performed 1-minute gamma activity counts and collected soil samples from 1-foot bgs at the same 14 background area locations where surface soil samples were collected in November 2008. A summary of the Ra-226 concentrations in surface soil and associated surface gamma activities from the November 2008 assessment work are shown on Table 1. Background area subsurface soil concentrations and gamma activity counts from August 2009 are summarized in Table 2.

Ra-226 concentrations in background area subsurface soil samples ranged from 0.209 pCi/g in sample BG-5-1' to 0.372 pCi/g in sample BG-9-1'. The average concentration was 0.260 pCi/g. This compares with an average Ra-226 concentration of 0.16 pCi/g in surface soil samples collected from those same locations in November 2008. It should be noted that laboratory data for three data points (samples BG-5-1', BG-6-1', and BG-8-1') were flagged as “UI” indicating the data were rejected due to a low abundance of Ra-226 (i.e., detected concentrations were below the practical quantifiable limits for these samples).

Gamma activity counts in background subsurface soils ranged from 6.1 to 8.0 kcpm and averaged 7.2 kcpm. In general, Ra-226 concentrations in subsurface soil samples correlated poorly with measured gamma activity counts at the background subsurface sampling locations. A linear regression analysis comparing the soil data to the subsurface gamma activity count returned an R^2 value of 0.67. This relatively poor correlation was also observed when the Ra-226 concentrations in surface soil samples were compared with their respective surface gamma activity counts as part of the November 2008 removal assessment work. The R^2 value between surface gamma activity counts taken in 2008 and those taken in the same locations in 2009 was 0.70. The poor correlation is likely due to the relatively low Ra-226 soil concentrations and gamma activity counts in the background area. At relatively low activity counts, natural variation in the measurements due to surface topography, instrument geometry, instrument drift (noise), and sampling error (e.g., small variations in distance from the detector to ground surface) have a greater relative impact on the activity count in comparison to locations where elevated activity counts and Ra-226 concentrations are present.

4.2 TLDA Surface and Subsurface Soil Sampling and Gamma Activity Measurements

On August 28, 2009, the START collected surface and subsurface soil samples from the TLDA located at the foot of the mesa. Soil sample locations for surface and subsurface soil samples collected from the TLDA in November 2008 and August 2009 are shown on Figure 4. A summary of the analytical data for surface soil samples collected from the TLDA is included on Table 3.

4.2.1 Surface Soil Sampling and Gamma Activity Measurements

Surface soil samples DA1-29-S and DA1-30-S were collected in an attempt to laterally define soil concentrations above approximately 2 pCi/g on the eastern side of the decision area. Samples DA1-31-S and DA1-32-S were collected in an attempt to laterally define soil concentrations above approximately 2 pCi/g on the western side of the decision area. Soil samples were collected into 9-oz. soil-jars labeled with the sample ID, date, time, and sampler's initials. The same information was recorded on the chain-of-custody form. The samples were placed in a cooler until they were shipped to GEL for analysis for Ra-226.

Radium-226 concentrations in surface samples collected in the TLDA during November 2008 (Locations 15 through 28 on Figure 4) ranged from 0.56 pCi/g to 28.1 pCi/g. The average concentration for the sample set was 7.15 pCi/g. Surface 1-minute gamma activity counts at these 14 soil sample locations ranged from 10.4 kcpm to 87.3 kcpm, with an average of 26.2 kcpm. During the August 2009 removal assessment, detected Ra-226 concentrations ranged from 0.832 pCi/g in sample DA1-29-S, to 2.05 pCi/g in sample DA1-31-S. These results indicate that, with the possible exception of areas west of Location 31 (Figure 4), the lateral extent of Ra-226 in TLDA surface soil at concentrations above 2 pCi/g is defined.

Surface gamma activity counts and Ra-226 concentrations in co-located soil samples as measured in November 2008 and August 2009 were compared to evaluate the relationship between the two. Using linear regression analysis, the R^2 value between TLDA gamma activity counts taken in 2008 and 2009 and Ra-226 concentrations in corresponding samples collected from the same locations in 2008 and 2009 was greater than 0.92. A graph of these data is shown on Figure 5.

Laboratory analytical reports and data validation reports for soil samples collected in August 2009 are included in Appendix E. No data were qualified and no problems or exceptions were noted. All data were considered suitable for use for the purposes stated in the August-QASP.

4.2.2 Subsurface Soil Sampling and Gamma Activity Measurements

After collecting surface soil samples at TLDA locations 29-32 and 1-minute surface gamma activity measurements at locations 15-32, the START and members of the U.S. Coast Guard's Pacific Strike Team (PST) augered holes to 1-foot bgs at each location (15-32). The 2x2 probe was lowered to within 1-inch of the bottom of the hole and a 1-minute gamma activity scan was performed. Immediately after completing the scan at each location, the START collected subsurface soil samples at TLDA locations 15-32 (Figure 4). Duplicate soil samples were collected from locations 20 (Sample DA1-89-1'), 28 (DA1-90-1'), 29 (DA1-29-1'-dup), and 30 (DA1-30-1'-dup). A summary of the analytical data for subsurface soil samples collected in August 2009 is shown on Table 4.

Detected Ra-226 concentrations in subsurface soils ranged from less than the detection limit (<0.208 pCi/g) in sample DA1-29-1' to 6.87 pCi/g in sample DA1-21-1'. Concentrations were greater than 4.0 pCi/g in samples collected at locations 21-23. Except for these locations, detected concentrations were less than 1.63 pCi/g for all subsurface soil samples. The lack of highly impacted soils at depth strongly suggests surface deposition of mine waste is the source of radioactivity and indicates that, except at locations 21-23, the vertical extent of Ra-226 above 2.0 pCi/g in the TLDA is defined.

Subsurface 1-minute gamma activity counts ranged from 7.9 kcpm at location 31, to 19.6 kcpm at location 21. Similar to the procedure used for surface soil data, linear regression analysis was used to compare Ra-226 concentrations in subsurface soil samples and their associated 1-minute gamma activity counts. The R^2 value between Ra-226 concentrations in subsurface soil samples DA1-15-1' through DA1-32-1' (including duplicate samples) and gamma activity counts performed at those locations was 0.95. A graph of these data is shown on Figure 6.

The data were reviewed by a qualified chemist as part of the data validation process. All data met data quality objectives and were considered to be acceptable for use as stated in the August-QASP. No qualifications were noted in the data validation reports. Laboratory analytical reports and data validation reports are included in Appendix E.

4.3 TSDA Surface Soil Sampling and Gamma Activity Measurements

As part of the removal assessment work at the SMWP site, surface soil samples Mine Soil 1_111208 through Mine Soil 14_111208 were collected from a sample grid established at the TSDA. Prior to collecting each soil sample during the November 2008 assessment work, 1-minute surface gamma activity counts were performed at the 14 TSDA soil sample locations. In addition to the 1-minute gamma activity counts, START used the RAT equipment to perform surface gamma activity scans in this area during the November 2008 and August 2009 removal assessments. Soil sample locations and RAT data from November 2008 and August 2009 are depicted on Figure 7. However, due to local topography GPS satellite coverage was not available in this area and, therefore, some locations were estimated and may not be accurate to within 10 meters. A summary of the surface soil data and associated gamma activity counts from November 2008 is shown on Table 5.

Detected Ra-226 concentrations in the November 2008 soil samples ranged from 0.22 pCi/g in sample Mine Soil 9_111208 to 49.1 pCi/g in sample Mine Soil 5_111208. Concentrations for 6 of the 14 samples collected from the TSDA were greater than 2 pCi/g and the average concentration was 8.03 pCi/g. One-minute gamma activity counts ranged from 9.4 kcpm to 139.1

kcpm, with an average of 38.7 kcpm. Detected Ra-226 concentrations correlated well with activity counts. The calculated R^2 value between the gamma activity counts and Ra-226 concentrations in soil samples was 0.97. A graph of soil concentrations and gamma activity counts in the TSDA is shown on Figure 8.

4.4 Unnamed Arroyo RAT Surface Gamma Activity Scans

During the November 2008 soil assessment work, RAT gamma activity scans of portions of an unnamed arroyo (arroyo) that receives runoff from the Skyline AUM and the north side of the TSDA documented elevated gamma scan readings. At one location, approximately 1,100 feet north-northeast of the beginning of the channel, surface gamma activity counts increased from approximately 11 kcpm on the banks of the arroyo, to an average of 28.3 kcpm in bottom sediments. These data indicated that impacted sediments related to former mining activities may be migrating in runoff from the Skyline AUM and/or the TSDA and may pose a risk to downstream users and/or groundwater. To laterally define the extent of surface contamination, START used the RAT to perform surface gamma scans in the arroyo as part of the removal assessment work performed in August and October 2009. As shown on Figure 9, surface gamma counts generally decreased as the distance from the mesa increased, and elevated gamma activity counts were laterally confined within the banks of the arroyo. Concentrations generally decreased to less than 20 kcpm at 1,300 feet from the beginning of the channel. In general, surface scan data collected during the August and October 2009 assessment work agreed closely with previous RAT data.

4.5 Unnamed Arroyo Test Pit Gamma Activity Scans

To define the vertical extent of contamination in the arroyo, the START and the U.S. EPA excavated 10 test pits spaced approximately 150 feet apart in the channel bottom of the arroyo. The test pits were excavated to a maximum depth of 3.5 feet bgs. Prior to excavating each test pit, a 1-minute surface gamma activity scan was performed at each location. An additional 1-minute scan was performed approximately every 1-foot of depth. In an attempt to evaluate the effects of surface geometry on the Ludlum 44-10 2x2 probe, some subsurface soil samples were scanned in-situ, then collected into the excavator bucket and dumped on the surface of the ground. The samples were then roughly leveled prior to performing an additional 1-minute gamma activity scan. Scan depths and their associated measurements are included in the table shown on Figure 9.

One-minute surface gamma activity scans generally exhibited higher gamma activity levels at test pits closer to the TSDA and Skyline AUM. Test Pits 1 and 2 had the highest surface gamma activity at 31.0 kcpm and 36.4 kcpm respectively. Surface activity counts decreased to less than 20 kcpm between Test Pits 5 and 6, and were less than 15 kcpm at Test Pits 7-10.

With the exception of Test Pit 2, measured gamma activity counts generally decreased with depth and were less than 20 kcpm within 2.5 feet bgs. Gamma scan results for Test Pit 2 varied with depth. Scans performed on subsurface soils from Test Pits 6 through 10, did not yield any activity levels above 20 kcpm, suggesting contaminant migration occurs through surface sediment transport and is limited to the upper 2 to 4 feet of the first 1,500 linear feet of the arroyo.

4.6 SMWP Site Residential Homes

The average of 209 gamma activity count measurements taken in the background area on March 17, 2010 was 1.77 kcpm and standard deviation of the data set was 171 cpm. Based on these data the established IL for the three home sites (HS-01, HS-02 and HS-03) evaluated on that day was 3.483 kcpm. Figures 10 through 12 show the areas scanned and the results of the gamma activity measurements at each home site. Gamma activity count rates above the IL were not detected at home sites HS-01 and HS-02. At HS-03, ten of the approximately 4,520 measurements were above the IL. The maximum gamma activity count was 4.44 kcpm. Elevated gamma activity was measured in three areas as shown on Figure 12.

5 Modeling

The START used Resrad-Offsite 2.5 (Resrad) software and the on-line version of the U.S. EPA's Soil Screening Guidance for Radionuclides-Preliminary Remediation Goal (PRG) Calculator to estimate site-specific radiological dose and associated risk to human health for residents living near the Skyline Mine and the associated TLDA and TSDA. The programs were also used to estimate a soil screening level (SSL) that would be implemented during remedial activities (such as soil removal) at the site.

Since it allows the user to consider the distance of the receptor from the source, the Resrad model is considered the most appropriate for use at sites where residences are not located directly on impacted soils, such as at the SMWP site. The PRG Calculator is designed for use at sites where the residences are built on top of or directly adjacent to contaminated materials. Therefore, SSLs derived by using the PRG Calculator are only considered appropriate for use in the residential area located east and northeast of the Skyline AUM and SMWP sites.

5.1 Evaluation of Potential Exposure Pathways

A diagram showing the observed range of gamma activity counts and potential exposure pathways for each area of concern (e.g., the SMWP site arroyo, TSDA, TLDA, and adjacent home sites and the Skyline AUM) is shown on Figure 16.

5.1.1 SMWP Site Residential Home Sites Pathways

Based on observed gamma activity scans at home sites HS-01, HS-02, and HS-03 it is likely that soils at these locations do not contain Ra-226 above the existing DCGL of 1.41 pCi/g. Therefore, there is no potential exposure for residents to consume plants or animal products grown in, or grazing in, contaminated soil in this area. Water is supplied to theses residences by NTUA and no wells were observed during the recent assessment work, therefore consumption of groundwater is not an exposure pathway for residents at these home sites. The nearest soil concentrations above the DCGL are in the TLDA, more than 600 feet from the home sites, indicating that direct exposure to surface radiation is not a potential threat. Residents are potentially exposed to fugitive dust emissions from the SMWP and Skyline AUM sites, either through direct exposure to radioactive dust, or inhalation of Ra-226 and daughter products such as radon.

5.1.2 SMWP Site-TLDA Pathways

Potential exposure pathways at the SMWP site-TLDA site include: consumption of plants; consumption of meat and dairy products from sheep or cattle grazed in the area; direct exposure to those recreating (e.g., ATV riding, camping, or hiking), foraging for plants, or tending livestock in the area; fugitive dust emissions, and downstream impacts to groundwater. Because the TLDA is relatively easy to access (it is the only impacted area potentially accessible to highway vehicles), persons in this area are expected to have the highest potential for exposure to fugitive dust emissions and direct exposure to radioisotopes. However, the area does not appear to be heavily used for grazing, foraging, or recreation. The recent work to stabilize the soil surface in the TLDA should reduce the potential for exposure to fugitive dust emissions for persons entering or living near the TLDA. Additionally, the new fence around the area should limit the potential for direct exposure to radioactive soils. Potential impacts to groundwater are cannot be fully evaluated because no wells are known to exist within 1 mile of the area. However, the potential for groundwater to be impacted is considered low because contamination from radioisotopes is generally limited to the upper 1-foot of soil in the TLDA and the area receives an average of only 6-8 inches of rain per year. Furthermore, the potential for exposure to impacted groundwater is minimal because nearby residents do not have wells or use well water.

5.1.3 SMWP Site-TSDA

Potential exposure pathways at the SMWP site-TSDA include: consumption of plants; consumption of meat and dairy products from sheep or cattle grazed in the area; direct exposure to those recreating (camping or hiking), foraging for plants, or tending livestock in the area; fugitive dust emissions, and downstream impacts to groundwater. The site is located at the top of a long, steep, sandy slope and is not accessible to anything except foot traffic. Because the area is small in size, sparsely vegetated, and difficult to access, the potential for long term exposure to direct radiation and fugitive dust for grazing animals, or foraging or recreating persons is low. The TSDA does not appear to be used for grazing, foraging, or recreation and recent work to stabilize the soil surface and fence the area should further limit potential exposure to fugitive dust and direct radiation, respectively. Potential impacts to groundwater are cannot be fully evaluated because no wells are known to exist within 1 mile of the area. However, the potential for groundwater to be impacted is considered low because contamination from radioisotopes is likely limited to the upper 1-foot of soil in the TSDA and because the area receives an average of only 6-8 inches of rain per year. Furthermore, the potential for exposure to impacted groundwater is minimal because nearby residents do not have wells or use well water.

5.1.4 SMWP Site-Arroyo

Potential exposure pathways at the SMWP site-Arroyo site include: consumption of plants; consumption of meat and dairy products from sheep or cattle grazed in the area; direct exposure to those recreating (camping or hiking), foraging for plants, or tending livestock in the area; fugitive dust emissions, and downstream impacts to groundwater. The arroyo is generally not accessible to highway vehicles and the most impacted portions are not accessible to any motorized vehicle. Due to its relative inaccessibility, the potential for long term exposure to direct radiation and or fugitive dust for grazing animals or foraging or recreating persons is low. Because it is a drainage, it has the highest potential to impact groundwater. Potential impacts to groundwater are cannot be fully evaluated because no wells are known to exist within 1 mile of the area. However, the potential for groundwater to be impacted is considered low because contamination from radioisotopes appears to be limited to the upper 4-feet of soil in the TSDA and because the area receives an average of only 6-8 inches of precipitation per year, and much of this occurs as snow, which is less likely (than rain) to produce runoff or infiltration. Furthermore, the potential for exposure to impacted groundwater is minimal because nearby residents do not have wells or use well water.

5.1.5 Skyline AUM

Potential exposure pathways at the Skyline AUM site are limited due to its remote nature. However, exposure pathways could potentially include: consumption of plants; consumption of meat and dairy products from sheep or cattle grazed in the area; direct exposure to those recreating (camping or hiking), foraging for plants, or tending livestock in the area; fugitive dust emissions, and downstream impacts to groundwater. Potential impacts to groundwater are expected to be limited because no wells are known to exist within 1 mile of the Skyline AUM.

5.2 Resrad 2.5 Offsite

The START used Resrad software version 2.5, released October 30, 2009, to estimate site-specific radiological dose and associated risk to human health for residents living near the Skyline AUM and the associated SMWP site. Resrad was developed by the Environmental Science Division of the Argonne National Laboratory under sponsorship from the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission (NRC).

5.2.1 Resrad 2.5 Model Inputs

The model requires that the user input known environmental data such as: observed soil concentrations for contaminants of concern (COCs); distance of the potentially affected residence from the source; land use (e.g., information on drinking water wells, grazing, and crop production); hydrogeologic information (soil porosity, hydraulic conductivity, depth to groundwater); structural information (type, floor thickness); and, dietary information (e.g. percentage of crops milk, meat, etc., ingested from impacted area). The parameters used in the model and their associated assumptions and model output files are included as Appendix G.

In general, the START used default model parameters when site-specific information was not available. However, in order to be more protective of the health of the nearby residents, several input parameters were deliberately skewed toward a more conservative risk scenario. For example, the time of exposure was increased from the normal 30 year period to a 50 year period. The location of the residence was moved to within 100 feet of the hypothetical contaminated area, whereas gamma activity data indicate the closest residence is more than 600 feet from the nearest impacted area. The fraction of overall time spent indoors in the off-site dwelling was assumed to be 95 percent and the remaining 5 percent of the total time was assumed to be spent either outdoors at the dwelling, or in the impacted area. Livestock consumed by the residents were assumed to be grazing in the impacted area a portion of the time and drinking groundwater from the area. Although there are no known dairy cattle grazing at or near the project area, the nearby residents were assumed to be drinking milk from dairy cattle pastured within the SMWP site. The model inputs assumed an initial Ra-226 concentration of 49 pCi/g. This is the highest concentration detected in any soil sample collected during the removal assessment work. The Basic Radiation Dose Limit (Dose Limit) was set to 5 milli Roentgen Equivalent Man (mrem) units. Although NRC rule sets an allowable cleanup level of 25 mrem per year effective dose equivalent as the primary risk standard, with exemptions allowing a cleanup levels of up to 100 mrem per year (mrem/yr), the U.S. EPA has determined that the NRC limit will generally not provide a protective basis for establishing SSLs under current Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) regulation (U.S. EPA, 1997). Therefore, the more protective U.S. EPA limit of 5 mrem/yr was used in the model.

5.2.2 Resrad 2.5 Model Results

Using the conservative input parameters discussed above and without a removal effort at the Skyline AUM and SMWP sites, the predicted maximum dose rate to nearby residents (i.e. those living at home sites HS-01, HS-02, and HS-03) was approximately 23.6 mrem/yr and reached the maximum dose rate after about 70 years. This corresponded with a maximum excess cancer risk of 2.7 x 10^{-4}. Most of the dose and associated excess cancer risks would be due to consumption of plants impacted by direct and airborne radiation, or direct radiation from the contaminated areas and airborne radioactive particles. It should be noted that the assumptions regarding the consumption of plants and animal products from impacted areas and the proximity of the residence to the impacted area were overestimated and therefore, the calculated excess cancer risk of 2.7 x 10^{-4} is likely and overestimate of the true current risk to residents of the area.

To limit the excess cancer risks and reduce the estimated dose to less than 5 mrem/yr, the Resrad software calculated a SSL of 10.36 pCi/g. This concentration is the cleanup level that, if implemented, would limit the annual dose to nearby residents to less than 5 mrem/yr. Graphs depicting the estimated dose, excess cancer risk, and soil guidelines versus time are included in Appendix G.

5.3 U.S. EPA Soil Screening Guidance for Radionuclides-Preliminary Remediation Goal (PRG) Calculator

5.3.1 PRG Calculator Model

The Soil Screening Guidance for Radionuclides PRG Calculator (PRG Calculator) is an internet-based tool developed and maintained by the U.S. EPA to help standardize and accelerate the evaluation and cleanup of soils contaminated with radioactive materials at sites on the National Priorities List (NPL) with anticipated future residential land use scenarios. This guidance provides a methodology for calculating risk-based, site-specific SSLs, (also referred to as PRGs), for radioactive contaminants in soil. The START used the PRG Calculator to estimate a site-specific SSL for Ra-226 in soil based a user-specified cancer risk level. U.S. EPA guidance documents indicate acceptable risk levels range from 10^{-4} to 10^{-6} (U.S. EPA 2000B).

It should be noted that SSLs alone do not trigger the need for response actions or define "unacceptable" levels of radionuclides in soil. "Screening," for the purposes of the guidance, refers to the process of identifying and defining areas, radionuclides, and conditions at a particular site that do not warrant further attention. Generally, at sites where radionuclide concentrations fall below SSLs, no further action or study is warranted under the CERCLA. Where radionuclide concentrations equal or exceed the SSLs, further study or investigation, but not necessarily cleanup, is warranted.

Unless otherwise specified by the user, radionuclide SSLs are based on an excess cancer target risk of one-in-a-million (10^{-6}). The SSLs, in activity concentration units of pCi/g, are derived from equations combining exposure information assumptions with EPA radiotoxicity data. The PRG Calculator provides a framework for screening soils contaminated with radionuclides that encompasses both simple and more detailed approaches for calculating site-specific SSLs, and generic SSLs for use where site-specific data are limited. The U.S. EPA's guidance (U.S. EPA, 2000A) focuses on the application of the simple site-specific approach by providing a step-by-step methodology to calculate site-specific SSLs and plan the sampling necessary to apply them. The associated technical background document (U.S. EPA, 2000B) describes the development and technical basis of the methodology presented in the User's Guide. It includes detailed modeling approaches for developing screening levels that can take into account more complex site conditions than the simple site-specific methodology emphasized in the User's Guide. It also provides generic SSLs for the most common contaminants found at NPL sites.

The purpose of the process is to develop and apply simple, site-specific SSLs. This approach is likely to be most useful where it is difficult to determine whether areas of soil are contaminated to an extent that warrants further investigation or response (e.g., whether areas of soil at a site require further investigation under CERCLA). The screening levels have been developed assuming future residential land use assumptions and related exposure scenarios. Although some of the models and methods presented in the PRG calculator could be modified to address exposures under other land uses, the U.S. EPA has not yet standardized assumptions for those other uses. Therefore, as previously discussed, using the PRG Calculator for sites where residential land use assumptions do not apply (e.g., the SMWP and Skyline AUM sites) results in overly conservative screening levels. However, the U.S. EPA recognizes that some parties responsible for sites with non-residential land use might still benefit from using SSLs as a tool to conduct conservative initial screening.

SSLs can be used as cleanup goals provided appropriate conditions are met (i.e., conditions found at a specific site are similar to conditions assumed in developing the SSLs). The concept of calculating risk-based SSLs for use as remedial goals (or "draft" cleanup levels) was introduced in the *Risk Assessment Guidance for Superfund* (RAGS), *Volume I, Human Health Evaluation Manual* (HHEM), *Part B* (U.S. EPA, 1991b). SSLs are risk-based values that provide a reference point for establishing site-specific cleanup levels.

5.3.2 PRG Calculator Model Inputs

At the Skyline AUM site Ra-226 and daughter products were selected as the primary contaminants of concern. The PRG Calculator incorporates readily obtainable site data into simple, standardized equations to derive a site-specific SSL for Ra-226 based on various exposure pathways. A hyperlink to the internet version of the PRG Calculator is: http://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search

The potential pathways of exposure to radionuclides in soil at Skyline AUM that were considered in the calculations were as follows:

- Direct ingestion of soil
- Inhalation of fugitive dusts
- External radiation exposure from photon-emitting radionuclides in soil
- Ingestion of homegrown produce that has been contaminated via plant uptake

For some radionuclides, the ingestion of contaminated produce and drinking water constitute the most likely exposure pathways if these items are obtained from on-site sources. However, groundwater pathways were not considered because the nearby home sites are supplied with domestic water service by the Navajo Tribal Utility Authority (NTUA). Because of the arid climate, large gardens and fruit trees are uncommon in the Oljato chapter of the Navajo Nation, and none were observed within the SMWP site or at any of the nearby residences. Based on conversations with NNEPA personnel, residents are restricted from using domestic water supplied by the NTUA for agricultural purposes, but residents may occasionally forage for native plants traditionally used as food or medicine. Therefore, rates for ingestion of homegrown fruits and vegetables were each set at a relatively low 0.5 kilograms (1.1 pounds) per adult per year and 0.2 kilograms per child per year. Soil ingestion rates for adults were reduced from the default value of 100 mg/day to 50 mg/day and from 200 mg/day to 100 mg/day for children.

The exposure pathways listed above represent the most likely exposure mechanisms for individuals residing near Skyline AUM. The external radiation exposure pathway is, for most radionuclides, the dominant mode of exposure and typically represents the most significant risk. The inhalation of fugitive dust pathway is included in the analysis; however, it is of significance for only a very few radionuclides.

For each pathway, radiotoxicity criteria are used to define an acceptable level of radionuclides in soil, based on an individual excess lifetime cancer risk range of 10^{-4} to 10^{-6}. The potential for additive effects has not been "built in" to the PRG Calculator. While the pathways included in the analysis are considered to represent expected pathways for the SMWP site, SSLs are not calculated for a specific scenario (i.e., SSLs are not summed over a set of pathways). According to U. S. EPA guidance, setting a 10^{-6} risk level for individual radionuclides and pathways will generally lead to cumulative risks within the acceptable range of 10^{-4} to 10^{-6} for the combinations of radionuclides typically found at Superfund sites (U.S. EPA, 2000B).

In calculating particulate emissions factors, the model uses climate data based on nine regional U. S. climatic zones. Climatic Zone 3, which includes the Skyline AUM location, was selected for use in the model. Based on an assumed size of 30,000 ft^2 (0.69 acres) for the impacted area (TLDA) nearest the residences, an impacted area of 1 acre was selected in the model. One acre was selected because the model only allows discrete inputs of 0.5 or 1 acre in this size range. Based on observed vegetation at the site, an input value of 10 percent vegetative cover was selected.

Default values were used in all other cases. This included standard assumptions of a 30 year total exposure duration (6 years for children and 24 for adults), an Indoor Exposure Time Fraction (IETF) of 0.683 (i.e., 68.3 percent), and an Outdoor Exposure Time Fraction (OETF) of 7.3 percent. The IETF and OETF are the estimated portions of time a resident spends indoors or outdoors in the contaminated area, respectively.

5.3.3 PRG Calculator Model Results

A copy of the input values, model results, and a description of the model calculations are included as Appendix H. Based on the aforementioned input values and using a target excess cancer risk of 10^{-4}, the model calculated a SSL for the Skyline AUM site of 1.31 pCi/g.

6 Conclusions and Recommendations

The following conclusions and recommendations were made based on START's review of the existing data and on START's knowledge of existing site conditions.

Soils with elevated concentrations of Ra-226 are present at the Skyline AUM, and at the foot of the mesa in the SMWP site's TLDA, TSDA, and arroyo. Based on discussions with NNEPA personnel, the top of the mesa is used seasonally during the spring, summer, and fall by local residents as pastureland for grazing sheep and cattle. The road to the top of the mesa is in extremely poor condition and therefore access to the top of it is limited to 4-wheel drive vehicles, all-terrain vehicles, or foot traffic. Other than the former uranium mine sites, there is no known permanent infrastructure on the top of the mesa. Based on these observations, the current risk of long-term exposure to radionuclides from contaminated soils on top of the mesa (i.e. the Skyline AUM site) is low.

Detected surface soil concentrations in the TSDA and TLDA and the upper reaches of the unnamed arroyo were above the SSL of 10.36 pCi/g recommended by the Resrad 2.5 software program. Because the Resrad 2.5 model accounts for the existing distance between the residences and the impacted area, the Resrad 2.5 SSL of 10.36 is most appropriate for the SMWP site and Skyline AUM. START recommends applying the current DCGL for the site of 1.41 pCi/g only to the immediate one-acre area around each home site. Based on current gamma activity scan data and an SSL of 1.41 pCi/g, it is anticipated that soil will not need to be removed from any of the three residential home sites. However, soil sampling is recommended to confirm this in the locations at HS-03 where elevated gamma activity was detected.

Based on an SSL of 10.36 pCi/g, START estimates the impacted area in the TLDA is approximately 6,704 square feet (ft^2), with an estimated average depth of 0.5 feet. It should be noted that this is the approximate extent of soil with gamma activity counts above 35 kcpm. Based on observed correlations between gamma activity and Ra-226 concentrations in soil in the TLDA and TSDA, 35 kcpm equates to approximately 10.3 pCi/g. The estimated volume of soil that will need to be removed from the TLDA is approximately 143 cubic yards (yd^3). The estimated extent of the removal area is depicted on Figure 13. Estimates of the contaminated areas and removal volumes are included on Table 6.

Based on correlated laboratory soil sampling data and gamma activity scan results for the TSDA, the RAT scans delineated an impacted area above 10.3 pCi/g of approximately 6,629 ft^2. Using an assumed depth of impact of 0.5 feet in this area, the estimated volume of soil in the TSDA requiring removal is 141 yd^3. The estimated extent of the removal area is depicted on Figure 14.

Based on an SSL of 10.3 pCi/g and an assumed average depth of 0.5 foot, the estimated removal volume in the unnamed arroyo is 504 yd^3. It is unclear whether this SSL is sufficiently protective of groundwater resources. Information regarding the use of groundwater in downgradient areas was not available for this report. Further soil sampling performed in conjunction with gamma activity scanning is recommended in this area to more accurately define the lateral and vertical extent of Ra-226 activity concentrations above the SSL. The estimated extent of the removal area is depicted on Figure 15.

If a further reduction in risks to human health and the environment is desirable, a more conservative remedial goal for Ra-226 in surface soil could be applied at the SMWP site. Reducing the SSL increases the amount of soil requiring excavation and thus increases project costs. The estimated change in removal area and the corresponding soil volumes at SSLs of 5 pCi/g and 2.5 pCi/g are included in Table 6. The estimated changes in removal areas for the various SSLs in each decision area are depicted on Figures 13, 14, and 15 respectively. Based on correlation studies between soil sampling data and gamma activity scan data, the lateral extents of Ra-226 concentrations above 2.5 pCi/g in surface soils at the SMWP site are defined.

START recommends an evaluation of feasible disposal alternatives to determine the most efficacious method of disposing of impacted soils. The feasibility study should include evaluating the use of existing mines, contaminated areas, and/or soil repositories such as: the SMWP site; the former Moonlight Mine near Oljato Utah; and, the U.S. Department of Energy's existing Mexican Hat Disposal Cell located near Mexican Hat, Utah. The evaluation should include input from NNEPA personnel and local residents who might be impacted by the presence of a new or modified existing soil repository. The area at the SMWP site that was identified as a potential repository is shown on Figure 16.

7 References

E & E, April 2001. “Navajo Radioactive Hogans Site – Removal Report”, U.S. EPA Region 9 TDD File No. 09-01-02-0008

E & E, May 18, 2009a. “Skyline AUM Waste Pile Assessment Report, San Juan County, Utah”, U.S. EPA Region 9 TDD File Number 09-08-11-0001

E & E, August 18, 2009b (August-QASP). “Time Critical Quality Assurance Sampling Plan For Skyline AUM Radiation Removal Assessment and Sampling”, U.S. EPA Region 9 TDD File Number 09-08-11-0001

E & E October 14, 2009c (October-QASP). “Time Critical Quality Assurance Sampling Plan For Skyline AUM Radiation Removal Assessment and Sampling”, U.S. EPA Region 9 TDD File Number 09-08-11-0001

TerraSpectra Geomatics**,** December 2000. “Abandoned Uranium Mines Project, Arizona, new Mexico, Utah – Navajo Lands, 1994-2000, Project Atlas, TerraSpectra Geomatics” (Prepared for the U.S. Army Corps of Engineers Contract No. DACW-09-00-M-0045)

U.S. EPA, 1991. “Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual (HHEM), Part B”

U.S. EPA, August 27, 1997. “Memorandum Regarding Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination”, U.S. EPA Office of Emergency and Remedial Response and U.S. EPA Office of Indoor Air and Radiation, OSWER No. 9200.4-18

U.S. EPA, October 2000a. “Soil Screening Guidance for Radionuclides: User’s Guide”, U.S. EPA Office of Indoor Air and Radiation, (EPA/540-R-00-007)

U.S. EPA, October 2000b-“Soil Screening Guidance for Radionuclides: Technical Background Document”, U.S. EPA Office of Indoor Air and Radiation, (EPA/540-R-00-006)

U.S. EPA 2008**. “**Structures & Homesite Yard Trigger Level Determination Paper”,
Prepared by: H. Allen (2-2063) & R. Terry, W. Duncan

FIGURES

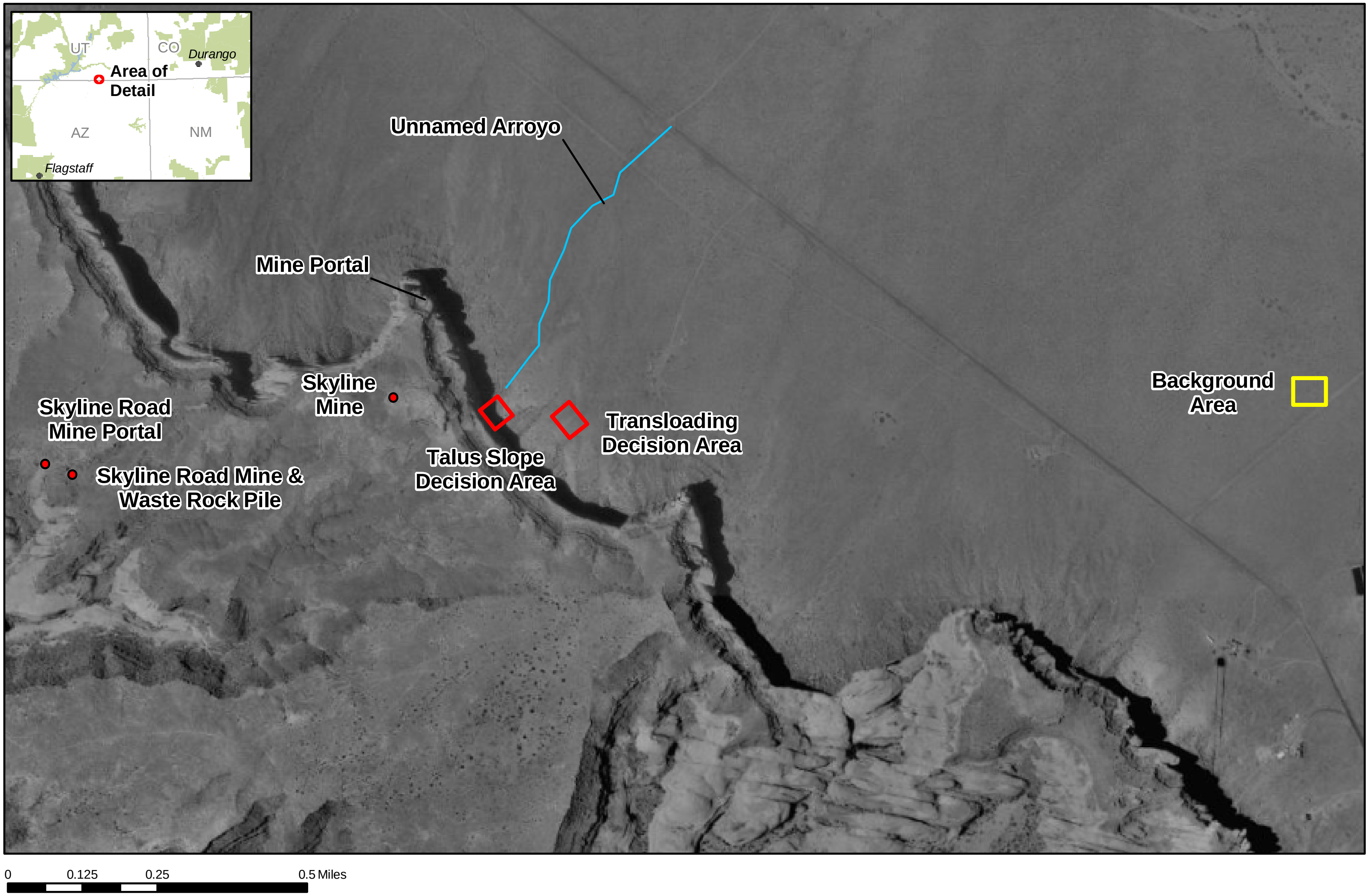

Figure 1
Location Map
Skyline AUM Waste Pile Assessment

San Juan County, Utah
START 3 - Region IX

Field Data
Ephemeral Drainage
Decision Area
Background Area

N

Source:

Aerial Photography - Microsoft Virtual Earth Overview - ESRI

Date: JANUARY 13 2010

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TDD# 09-08-11-0001
PAN# 2693.2019.01RA

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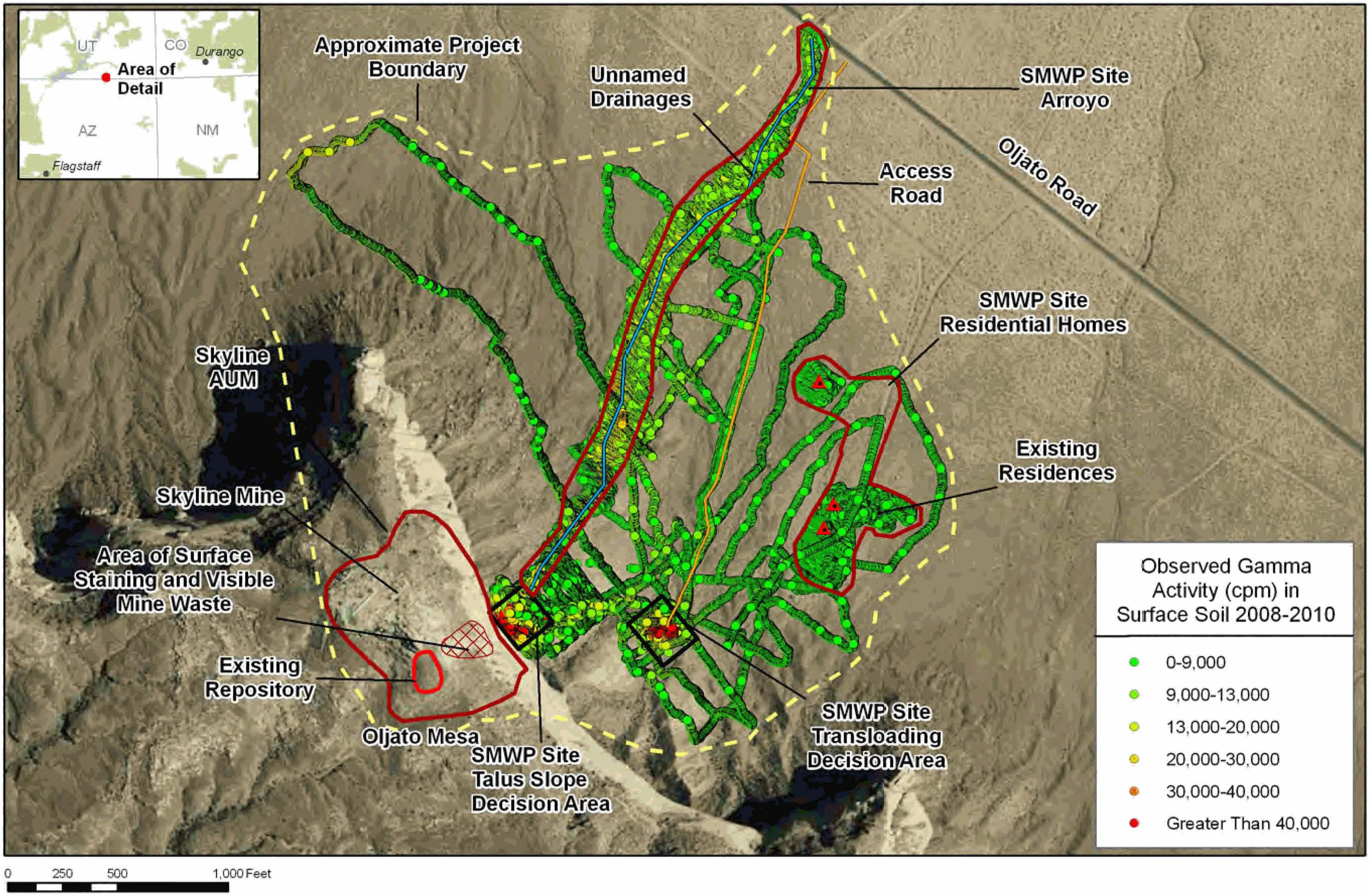

Figure 2
Site Features
Skyline AUM Waste Pile Assessment

San Juan County, Utah
START 3 - Region IX

Homesite
Ephemeral Drainage
Access Road
Approximate Decision Area Boundary
Approximate Project Boundary

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Source:
Aerial Photography - Digital Globe Image date 07/14/2006
Overview - ESRI

Date: APRIL 23 2010

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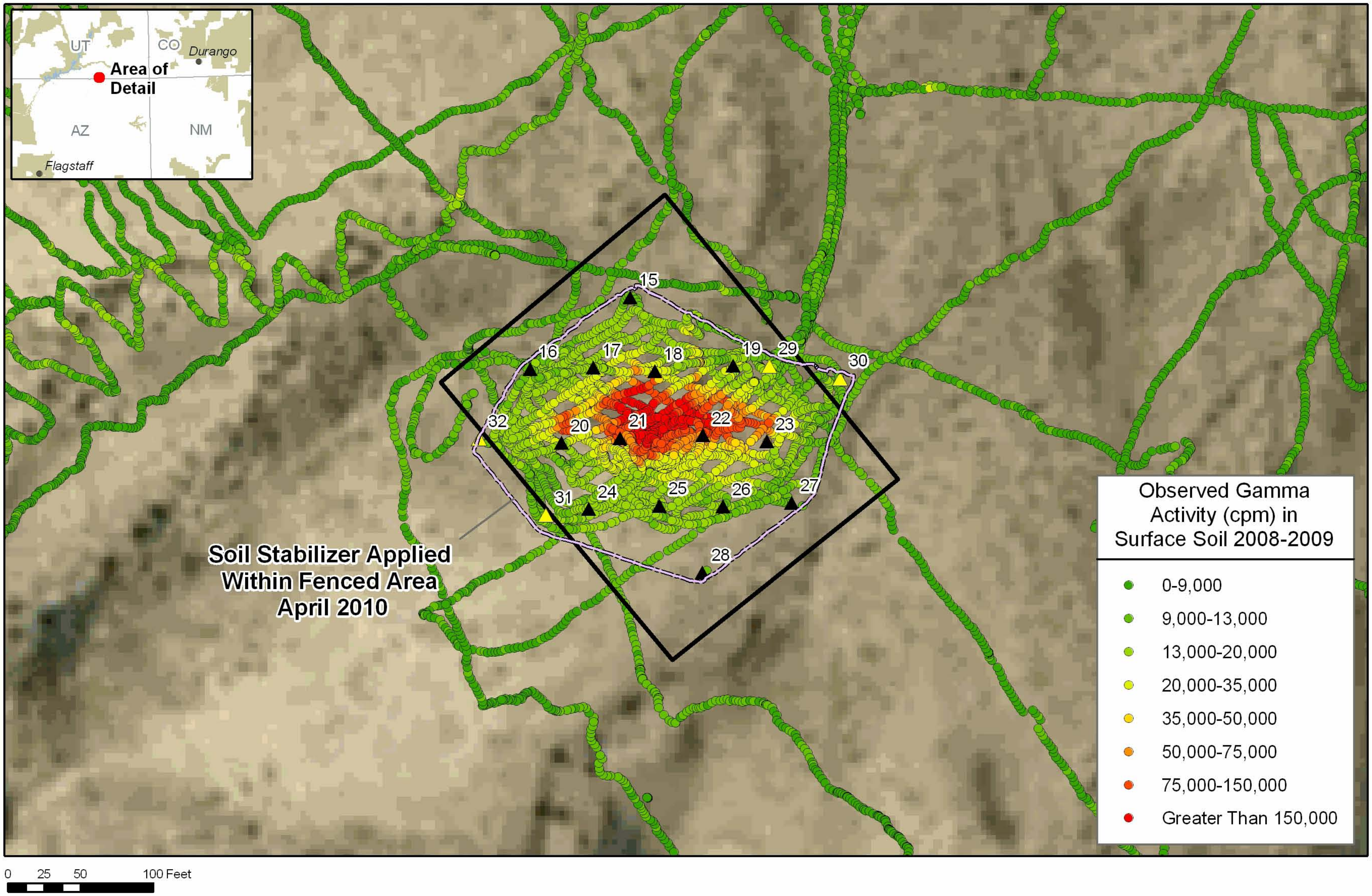

Figure 4
Transloading Decision Area
Skyline AUM Waste Pile Assessment

San Juan County, Utah
START 3 - Region IX

Soil Sample

- Surface and Subsurface Soil Sample, August 2009
- Surface Soil Sample November 2008, Subsurface August 2009
- Fenced Area, Soil Stabilizer, April 2010
- Decision Area Boundary

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Source:

Aerial Photography - ESRI
Overview - ESRI

Date:

APRIL 27 2010

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TDD# 09-08-11-0001
PAN# 2693.2019.01RA

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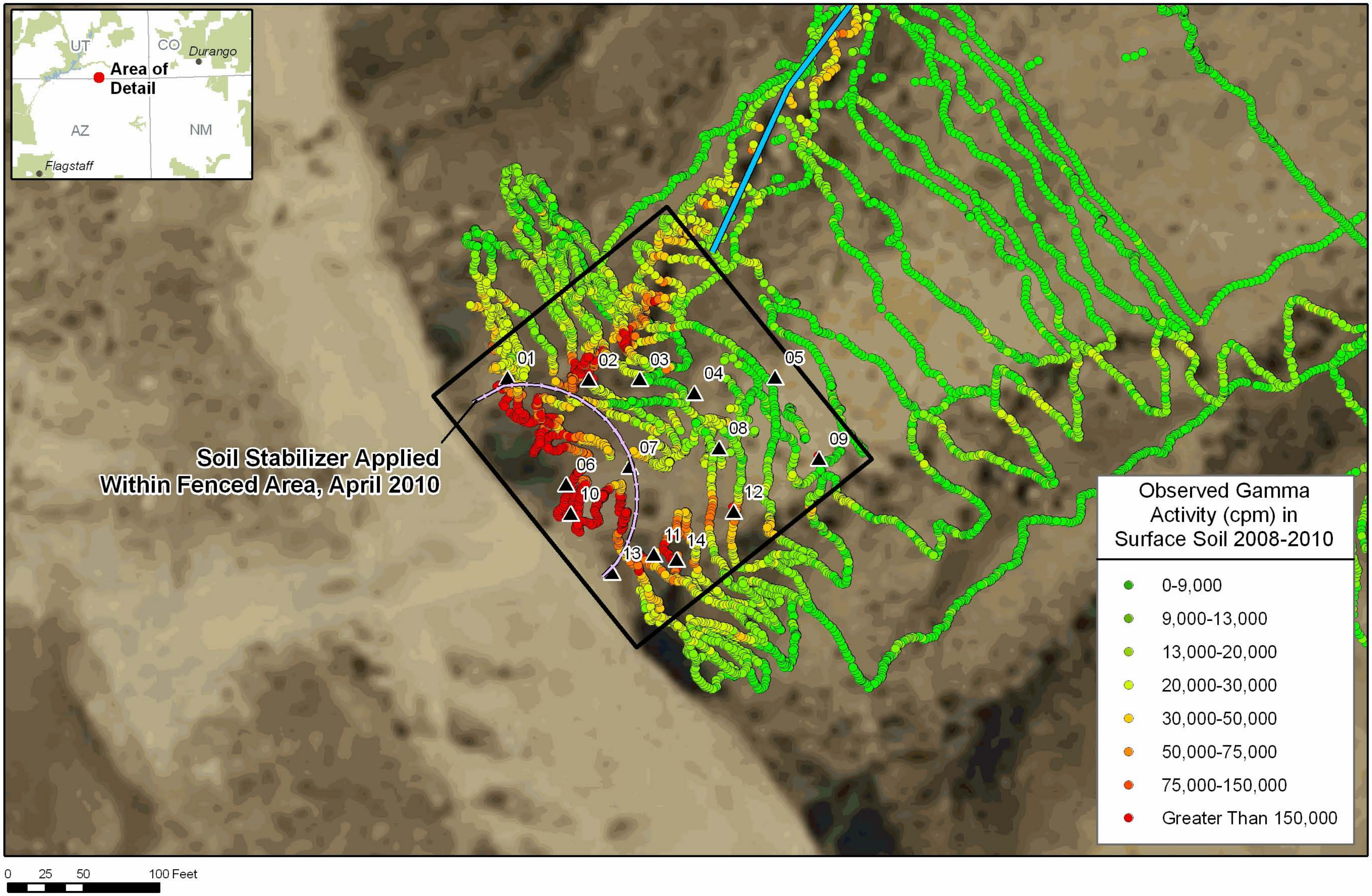

Figure 7
Talus Slope Decision Area
Skyline AUM Waste Pile Assessment

San Juan County, Utah
START 3 - Region IX

Soil Sample - November 2008
Ephemeral Drainage
Decision Area Boundary
Approximate extent of safety fencing + soil stabilizer, April 2010

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Source:
Aerial Photography - ESRI
Overview - ESRI

Date: APRIL 27 2010

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talus_slope_decision_area.mxd - GIS
TDD# 09-08-11-0001
PAN# 2693.2019.01RA

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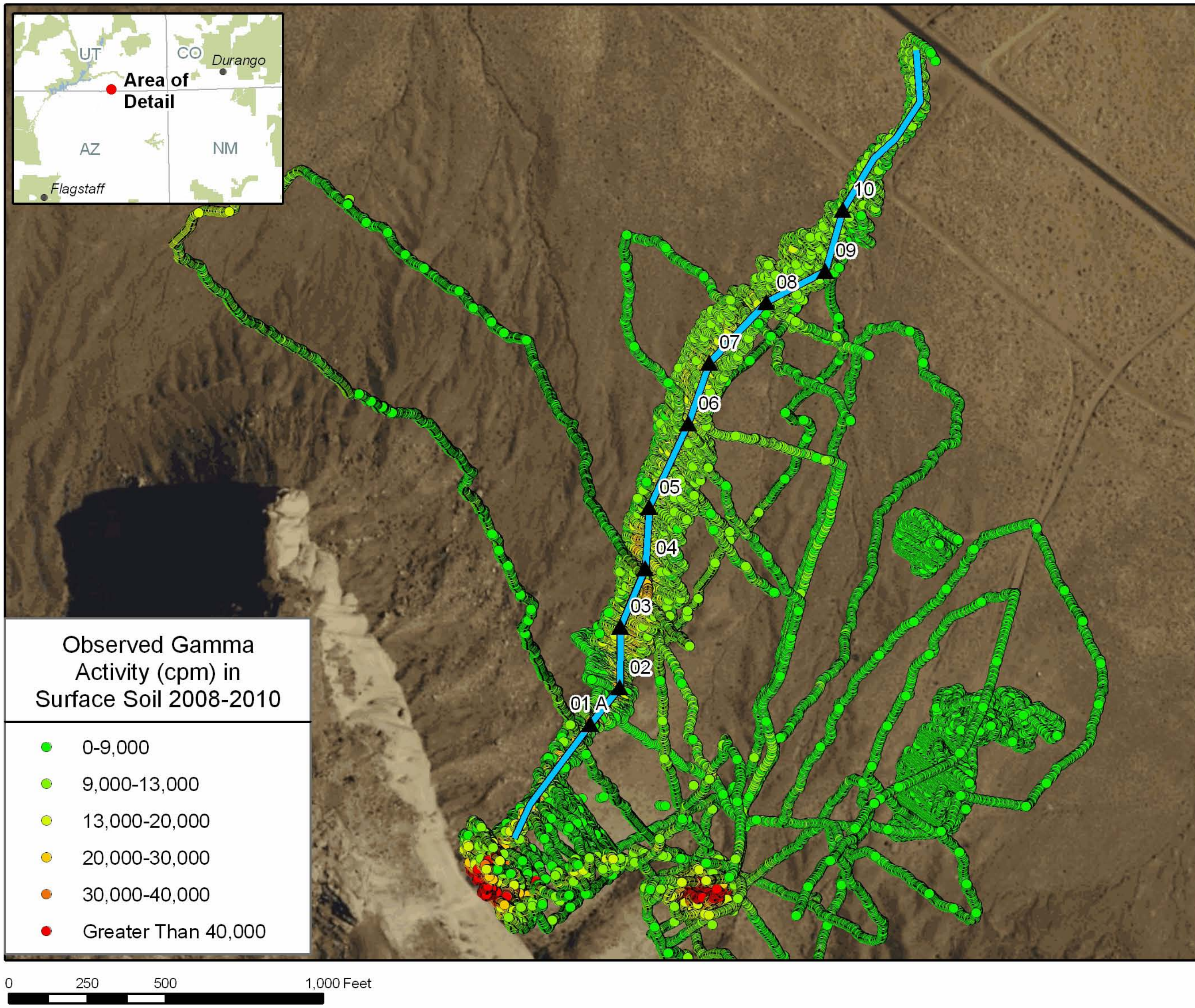

Location	Depth of Gamma Scan	One-Minute Gamma Activity Count (cpm)
Test Pit 1	0 feet	31005
	16 inches	23061
	2 feet	24461
	2.5 feet	21349
	2.5 feet-S	17036
Test Pit 2	0 feet	36303
	1 foot	41159
	2 feet	37639
	3 feet-S	32050
	3 feet	21636
	3.5 feet	30811
	3.5 feet-S	20592
Test Pit 3	0 feet	25604
	1 foot	18741
	2 feet	14379
Test Pit 4	0 feet	30377
	1 foot	22322
	2 feet	18046
Test Pit 5	0 feet	24068
	1 foot	20328
	2 feet	18344
	2 feet-S	16126
Test Pit 6	0 feet	17612
	1 foot	16287
	2 feet	14986
Test Pit 7	0 feet	14675
	1 foot	14580
	2 feet	16758
	2 feet-S	11072
Test Pit 8	0 feet	14346
	1 foot	13017
	2 feet	13043
	2 feet-S	10081
Test Pit 9	0 feet	14109
	1.5 feet	12983
	2 feet	12079
	2 feet-S	11642
Test Pit 10	0 feet	12205
	1 foot	12941
	2 feet	11772
	2 feet-S	8263

Figure 9

Unnamed Arroyo Gamma Activity
Skyline AUM Waste Pile Assessment

San Juan County, Utah
START 3 - Region IX

▲ Test Pit - October 2009

Ephemeral Drainage

Notes:
cpm = counts per minute

"X-feet-S" - Indicates a sample was obtained from this depth and spread out on the ground surface before performing the one minute gamma activity count. Unless otherwise stated sub-surface gamma activity scans were perfomed with the probe approximatley 1-inch above the soil surface.

N

Source:

Aerial Photography - Microsoft Virtual Earth
Overview - ESRI

Date: APRIL 26 2010

M:\Oakland\SkylineMine\Maps\MXD\Jan_2010\arroyo.mxd - GIS
TDD# 09-08-11-0001
PAN# 2693.2019.01RA

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ATTACHMENT B:
TABLE

Table 1 - Summary of Soil Sample Results for Radium 226 and Associated Gamma Activity Counts, Skyline Mine Waste Pile Assessment, San Juan County, Utah

E & E Project No. 002693.2019.01RA — TDD No. TO2-09-08-11-0001

Sample ID	Radium 226 (pCi/g)	Method Detection Limit (pCi/g)	Associated Gamma Activity Count (1-minute count)	Sample ID	Radium 226 (pCi/g)	Method Detection Limit (pCi/g)	Associated Gamma Activity Count (1-minute count)	Sample ID	Radium 226 (pCi/g)	Method Detection Limit (pCi/g)	Associated Gamma Activity Count (1-minute count)
Mine Soil 01_111308	7.63	0.191	41,590	Mine Soil 15_111208	0.562	0.109	10,363	BGK 1 Skyline	0.182	0.061	5161
Mine Soil 02_111208	5.90	0.189	33,276	Mine Soil 16_111208	1.05	0.0934	12,098	BGK 2 Skyline	0.235	0.092	4604
Mine Soil 03_111208	1.03	0.115	19,235	Mine Soil 17_111208	2.19	0.118	18,211	BKG 3 Skyline	0.150	0.102	4483
Mine Soil 04_111208	0.56	0.104	11,959	Mine Soil 18_111208	8.56	0.174	24,562	BGK 4 Skyline	0.191	0.087	4951
Mine Soil 05_111208	49.1	0.322	139,125	Mine Soil 19_111208	3.43	0.148	17,635	BGK 5 Skyline	0.214	0.096	4479
Mine Soil 06_111208	6.81	0.186	42,895	Mine Soil 20_111208	2.67	0.118	15,881	BKG 6 Skyline	0.240	0.12	4962
Mine Soil 07_111208	1.28	0.173	15,585	Mine Soil 21_111208	21.0	0.278	87,342	BGK 7 Skyline	0.159	0.068	4414
Mine Soil 08_111208	0.82	0.103	15,183	Mine Soil 22_111208	24.8	0.331	60,212	BGK 8 Skyline	0.151	0.086	4362
Mine Soil 09_111208	0.215	0.107	9,402	Mine Soil 23_111208	28.1	0.339	59,611	BKG 9 Skyline	0.18	0.093	4723
Mine Soil 10_111208	29.6	0.305	86,737	Mine Soil 24_111208	2.66	0.116	13,111	BGK 10 Skyline	0.0657 U	0.103	4837
Mine Soil 11_111208	1.14	0.104	28,172	Mine Soil 25_111208	1.60	0.128	13,328	BGK 11 Skyline	0.112	0.087	4543
Mine Soil 12_111208	1.93	0.126	48,623	Mine Soil 26_111208	1.70	0.166	12,798	BKG 12 Skyline	0.127 U	0.129	4949
Mine Soil 13_111208	0.408	0.113	12,864	Mine Soil 27_111208	0.782	0.111	11,053	BGK 13 Skyline	0.105	0.091	4586
Mine Soil 14_111208	5.93	0.132	36,631	Mine Soil 28_111208	0.974	0.115	10,602	BGK 14 Skyline	0.167	0.08	4486
MINIMUM	0.215		9,402	MINIMUM	0.562		10,363	MINIMUM	0.105		4362
MAXIMUM	49.1		139,125	MAXIMUM	28.1		87,342	MAXIMUM	0.24		5161
AVERAGE	8.03		38,663	AVERAGE	7.15	pCi/g	26,201	AVERAGE*	0.174	pCi/g	4681
STANDARD DEVIATION	14.1		35,484	STANDARD DEVIATION	9.78	pCi/g	24,332	STANDARD DEVIATION*	0.058	pCi/g	249
CORRELATION COEFFICIENTS			**0.967**				**0.921**				**-0.01**

DCGL = BACKGROUND AVERAGE* + PRG = (0.174 + 1.24) pCi/g = **1.41 pCi/g**

Radium 226 concentrations by EML HASL 300, 4.5.2.3

Gamma activity counts by Ludlum Measurements Inc. Model 2241 Ratemeter and Detector Model 44-10 2"x2" NaI Gamma Scintillator

Notes: * Indicates this statistic was calculated using 1/2 of the method detection limit for samples listed as non-detect (U-flagged).

DCGL-Derived Concentration Guideline Level